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Transportation of Spent Nuclear Fuel in the US – What Will It Take?

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SCALE, UNCERTAINTIES, AND GOALS

SNF Inventory

- Total inventory by 2055 - 140,000 MTU (two repositories of the size authorized by NWPA)
- 9 old shutdown sites 2,813 MTU, 248 dry storage casks.
- 5 new shutdown sites 3,600 MTU, 260 dry storage casks.
- 99 operating reactors 133,586 MTU (>10,500

Uncertainties

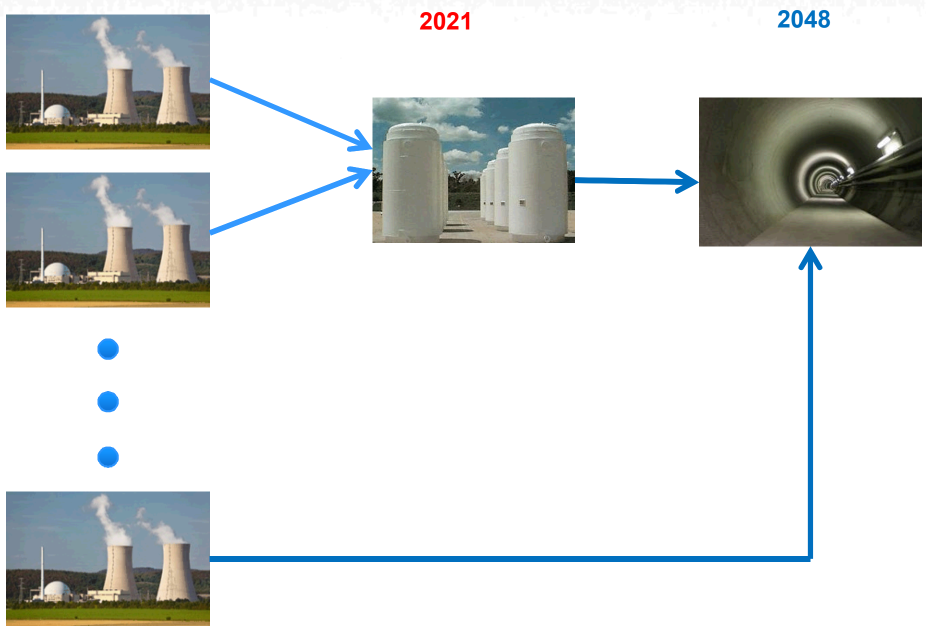
- Future SNF management practices.
- Location of Interim Storage Facility (ISF).
- Location of repository.
- Transportation routes.

Transportation Analysis Objectives

- ❑ Rough order of magnitude (ROM) transportation costs.
- ❑ Spending profile.
- ❑ Transportation fleet requirements.
- ❑ Unloading strategy (consist size).
- ❑ Distance traveled with loaded casks.
- ❑ Age and burnup of fuel and cask heat output during transportation.

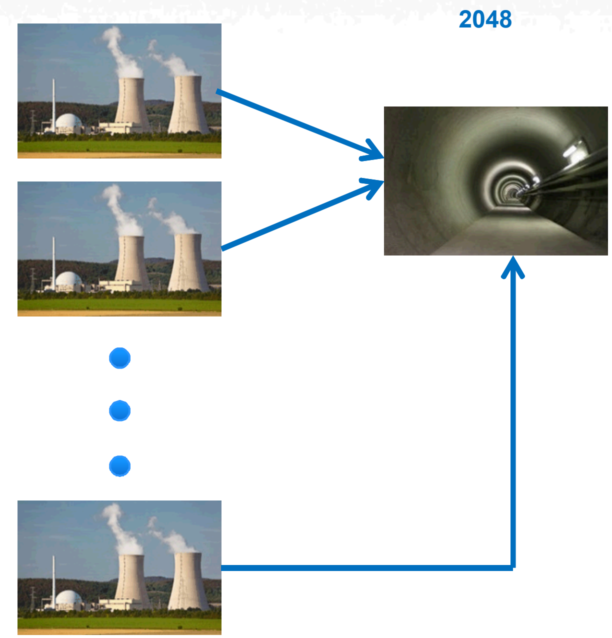
TRANSPORTATION SIMULATION SETUP

Scenarios with ISF



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

Scenarios without ISF



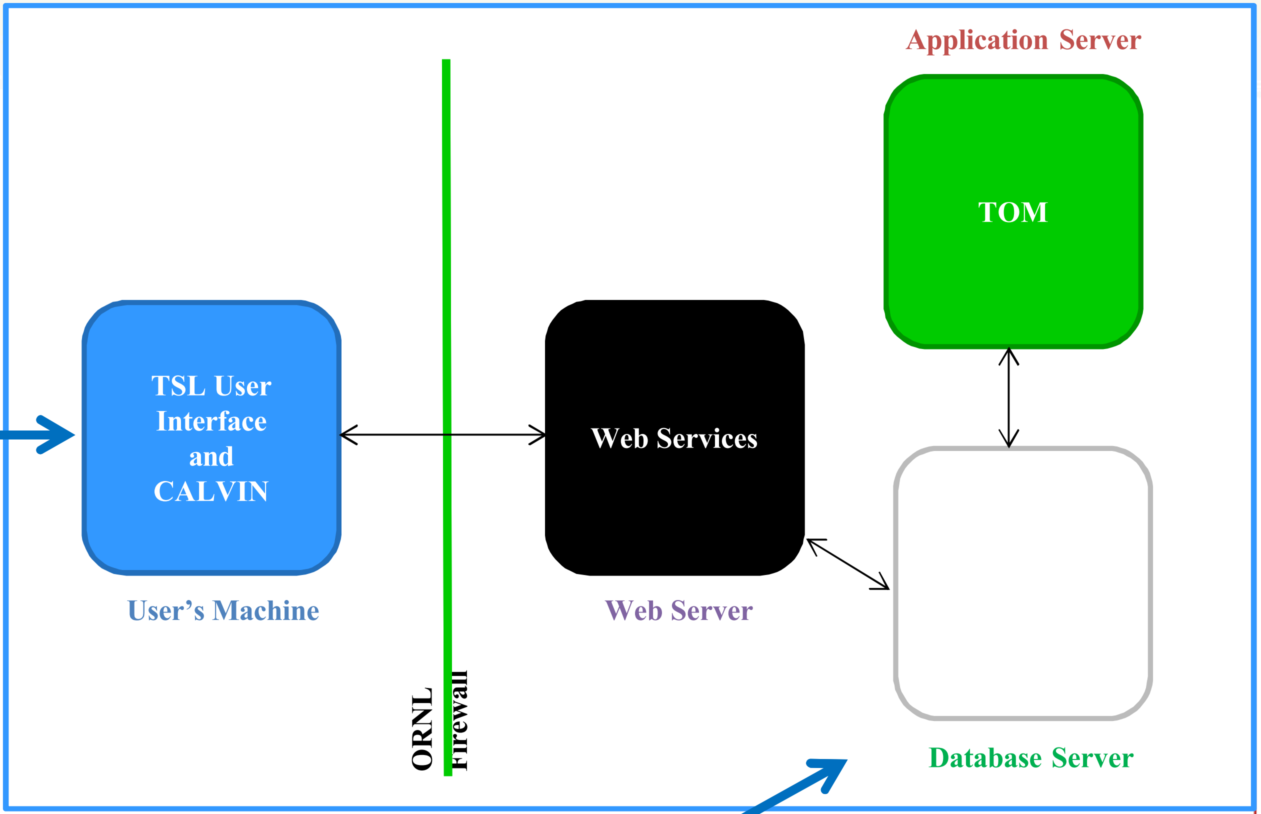
SNF is transported directly to a repository starting in 2048.

TRANSPORTATION SIMULATION ASSUMPTIONS

- The shutdown reactors are unloaded first.
- The ISF and repository waste acceptance rate is 3,000 MTU/yr.
- The ISF is operational from 2021 until the last SNF is transported from the ISF to the repository.
- The repository is operational from 2048 until the last SNF from the ISF and the reactors sites is transported to the repository.
- The initial site allocation (MTU/yr) is based on the older fuel first rule.
- The actual SNF amount transported off site (MTU/yr) is limited by the availability of SNF meeting the transportation requirements.
- The repository is in SW region of US.
- The current dry storage practice assumes that the reactors continue to load the existing dry storage canisters (DPCs).
- The "hypothetical" dry storage practice assumes that at some future time the reactors will switch to Multiple Purpose Canisters (MPCs), 12 (PWR)/32 (BWR).
- A transportation overpack will be designed to transport one MPC.

TRANSPORTATION ANALYSIS TOOLS

TSL-TOM - Transportation Operations Model:
- Models transportation operations.
- Calculates transportation fleet.
- Calculates transportation costs.



TSL – Calvin (Logistics Model)
- Generates pickup schedule.
- Calculates all costs, except transportation costs.
- Includes database with the SNF projection, reactor site information, and dry storage canisters/casks information.

TOM Database:
- Transportation routes.
- Cask data.
- Processing times.
- Costs (casks, transportation, security, maintenance and other).

TRANSPORTATION ANALYSIS METHOD SUMMARY

TOM Calculates:

- ❑ Resources (casks and vehicles) required for meeting the specified pickup schedule.
- ❑ Timing of each trip (its transportation cycle).
- ❑ All associated costs.

Transportation Cycle:

- ❑ Traveling to the pickup site.
- ❑ Loading SNF into casks and onto the transportation asset.
- ❑ Traveling to the storage facility (repository).
- ❑ 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.

Maximum Consist Size:

TOM builds as many of the largest-sized consists (maximum consist size defined by the user) as possible, and then adds another less-than-maximum-sized consist to move the remaining casks.

Total Transportation Cost

Capital Costs

- ▪Purchase buffer railcar
- ▪Purchase cask
- ▪Purchase cask railcar
- ▪Purchase escort railcar

Operational costs

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

Maintenance Costs

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

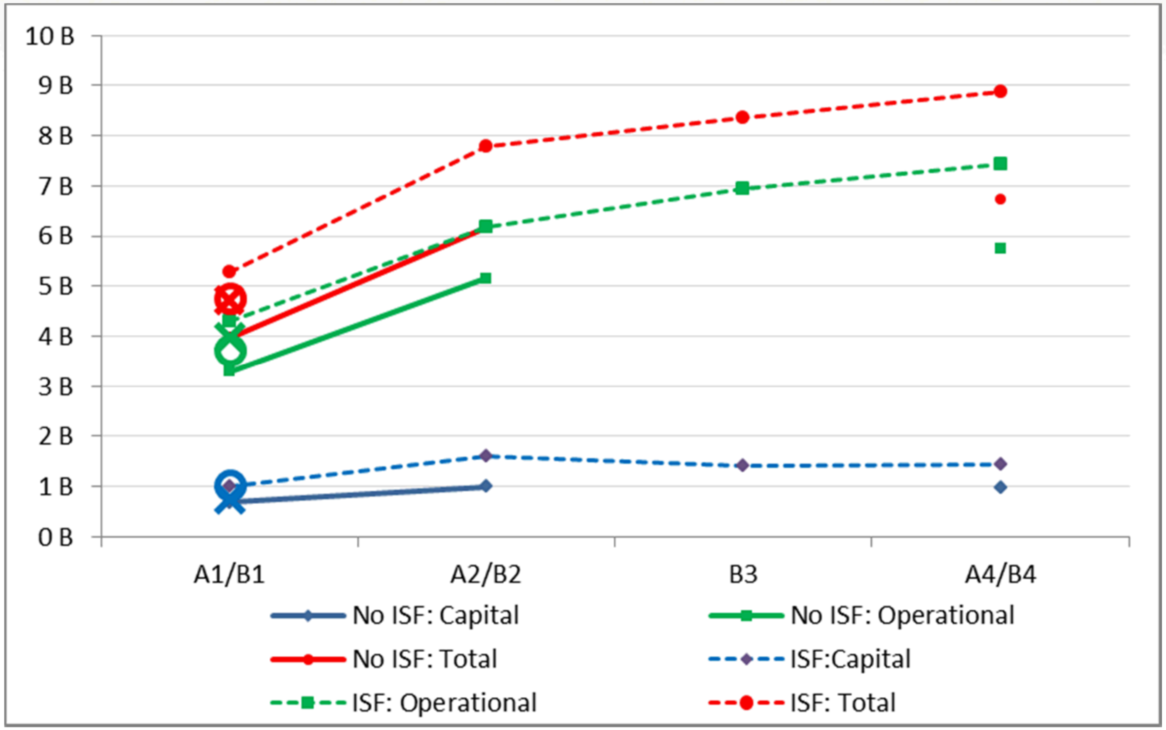
TRANSPORTATION SIMULATION VARIABLES

- At-reactor SNF management:
  1) Reactors continue loading DPCs.
  2) Reactors switch to MPCs.
- Year to switch to MPCs: (1) 2025; (2) 2030; and (3) 2036
- Maximum consist size:
  (1) 2-car consist; (2) 3-car consist;
  (3) 4-car consist; and (4) 5-car consist.
- Processing time (loading/unloading):
  (1) from TOM database (original) and (2) two times longer (x2)
- Train speed on the mainline rail: (1) 55 mph and (2) 35 mph
- ISF Location:
  (1) SE of US; (2) NW of US; and (3) co-located with the repository.

TRANSPORTATION SCENARIOS

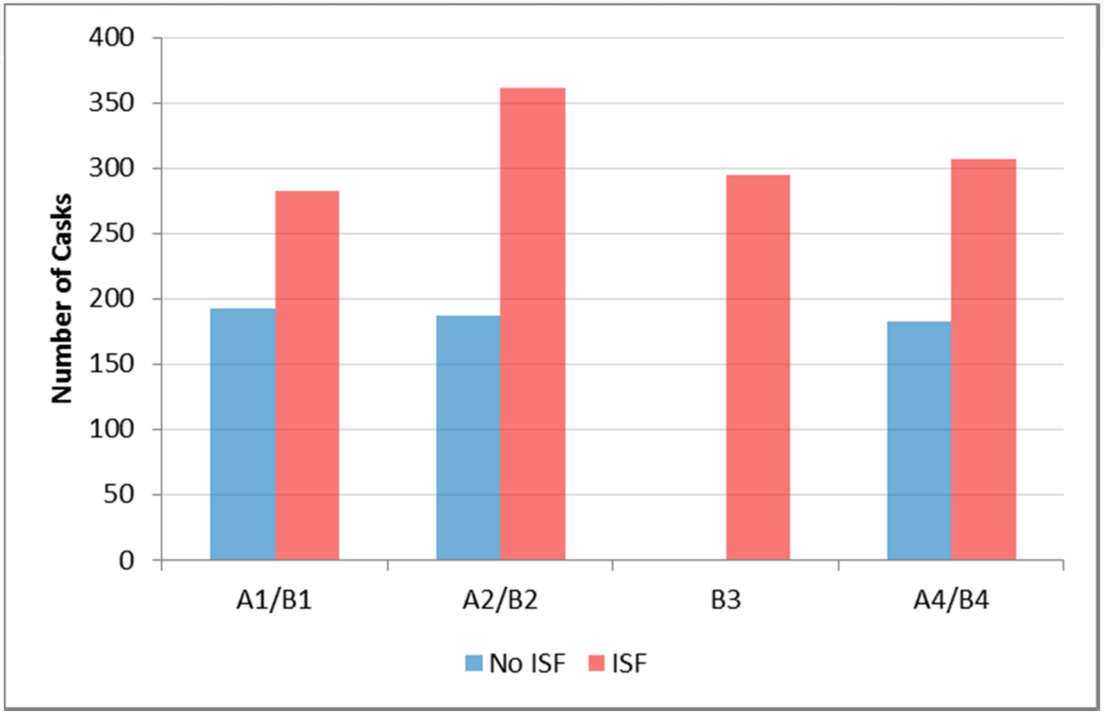
Scenario ID	Scenario Variables				
	Consist Size	Processing Time	Rail Speed (mph)	Switch to MPCs	ISF Location
A1	3	original	55		
A1-a	2	original	55		
A1-a	2	original	55		
A1-c	5	original	55		
A1-d	3	x2	55		
A1-e	3	x2	35		
A2	3	original	55	2036	
A3	3	original	55		Colocated
A4	3	original	55	2025	
B1	3	original	55		SE
B1-a	2	original	55		SE
B1-b	4	original	55		SE
B1-c	5	original	55		SE
B1-d	3	x2	55		SE
B1-e	3	x2	35		SE
B2	3	original	55	2036	SE
B3	3	original	55	2030	SE
B4	3	original	55	2025	SE
B5	3	original	55		NW

TRANSPORTATION COSTS FOR DIFFERENT AT-REACTOR MANAGEMENT PRACTICES



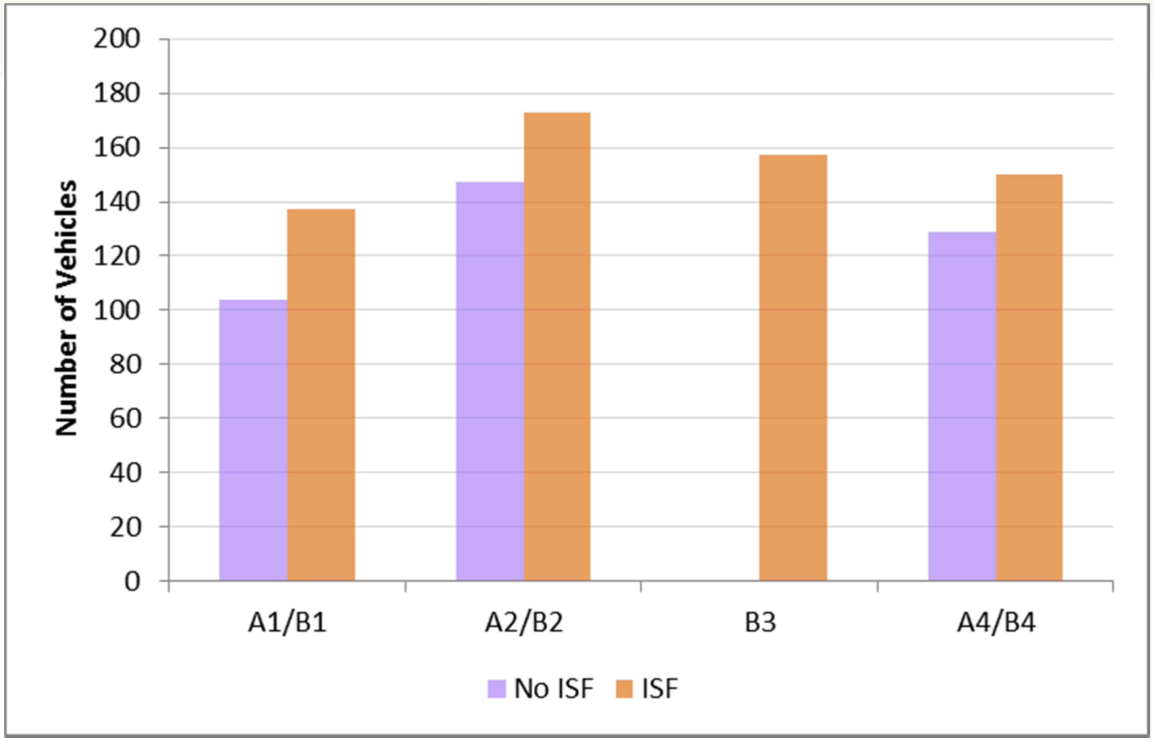
A1/B1	**DPCs**
A2/B2	**Switching to MPCs in 2036**
B3	**Switching to MPCs in 2030**
A4/B4	**Switching to MPCs in 2025**

CASK ACQUISITION FOR DIFFERENT AT-REACTOR MANAGEMENT PRACTICES



A1/B1	**DPCs**
A2/B2	**Switching to MPCs in 2036**
B3	**Switching to MPCs in 2030**
A4/B4	**Switching to MPCs in 2025**

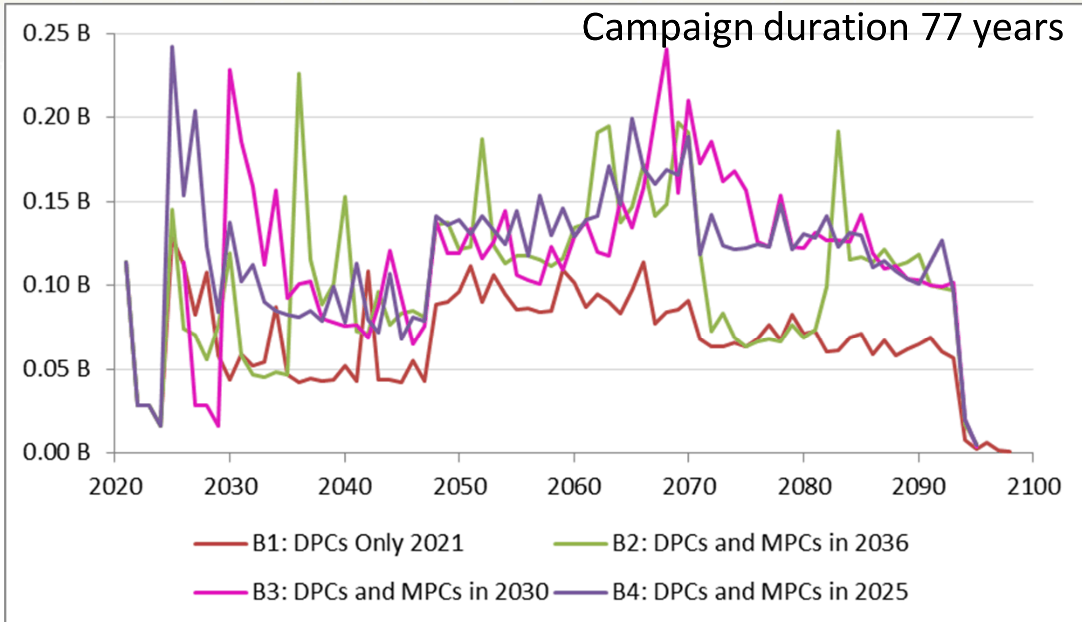
VEHICLE ACQUISITION FOR DIFFERENT AT-REACTOR MANAGEMENT PRACTICES



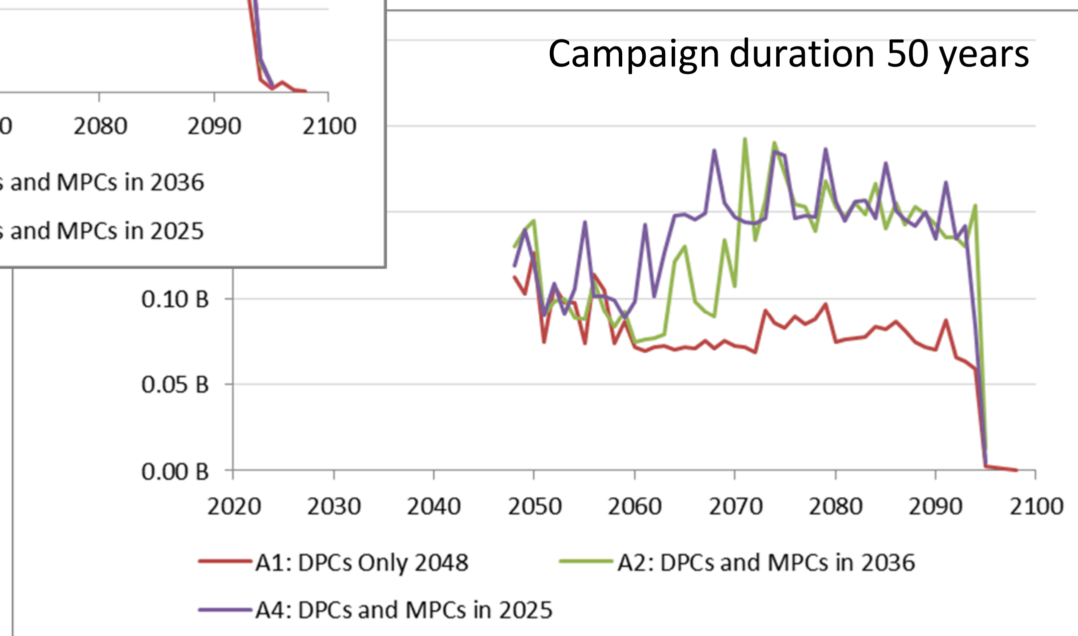
A1/B1	**DPCs**
A2/B2	**Switching to MPCs in 2036**
B3	**Switching to MPCs in 2030**
A4/B4	**Switching to MPCs in 2025**

TRANSPORTATION CAMPAIGN SPENDING PROFILES

Scenarios with ISF



Scenarios without ISF



NNSA National Nuclear Security Administration

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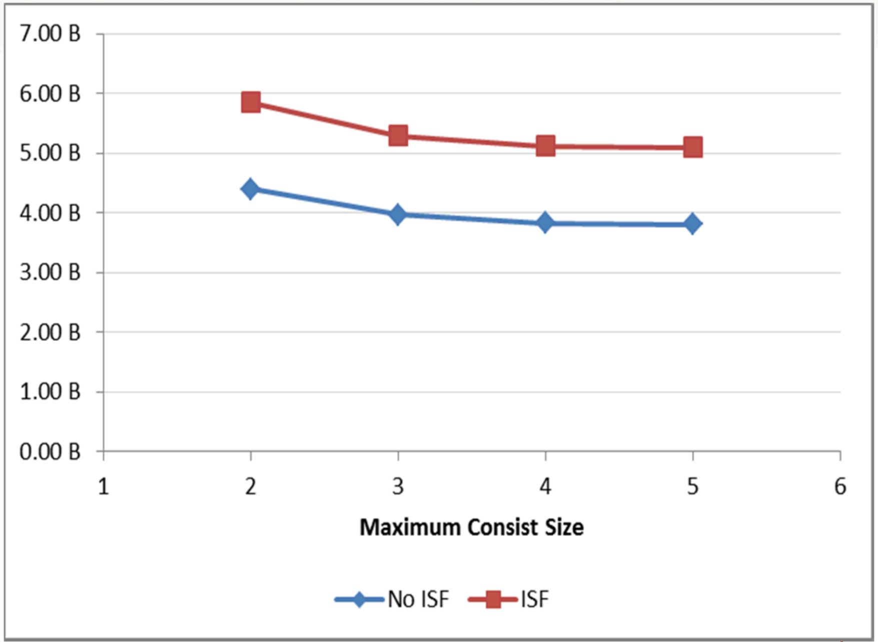
TOTAL COST AS A FUNCTION OF MAXIMUM CONSIST SIZE

A1 and B1 **DPCs only**

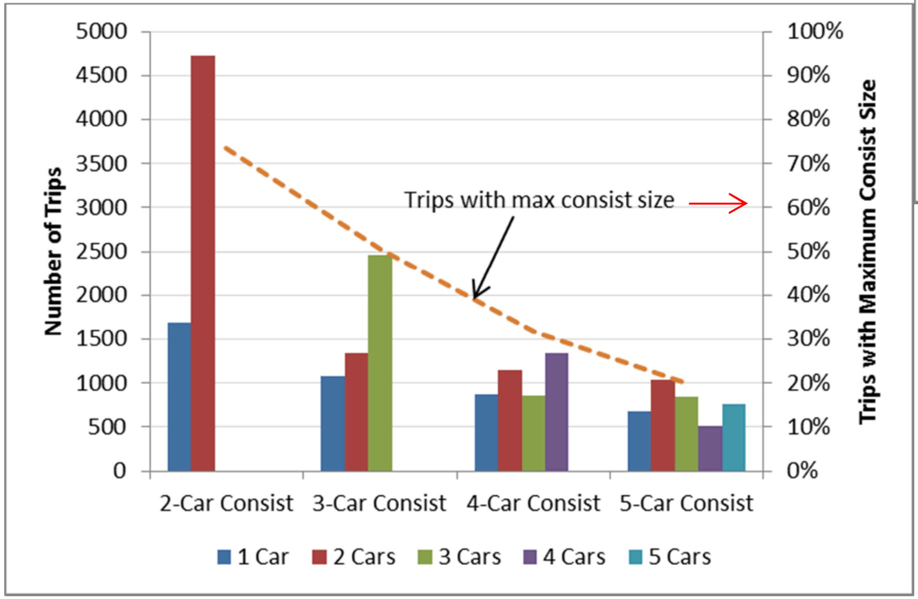
Scenario ID	Max Consist Size	Total Cost $B	Million Miles	Cask Miles to Consist Miles Ratio
A1-a	2	4.40	34	1.7
A1	3	3.97	25	2.3
A1-b	4	3.83	22	2.6
A1-c	5	3.80	20	2.9
B1-a	2	5.52	55	1.8
B1	3	5.29	41	2.4
B1-b	4	5.12	35	2.8
B1-c	5	5.09	31	3.1

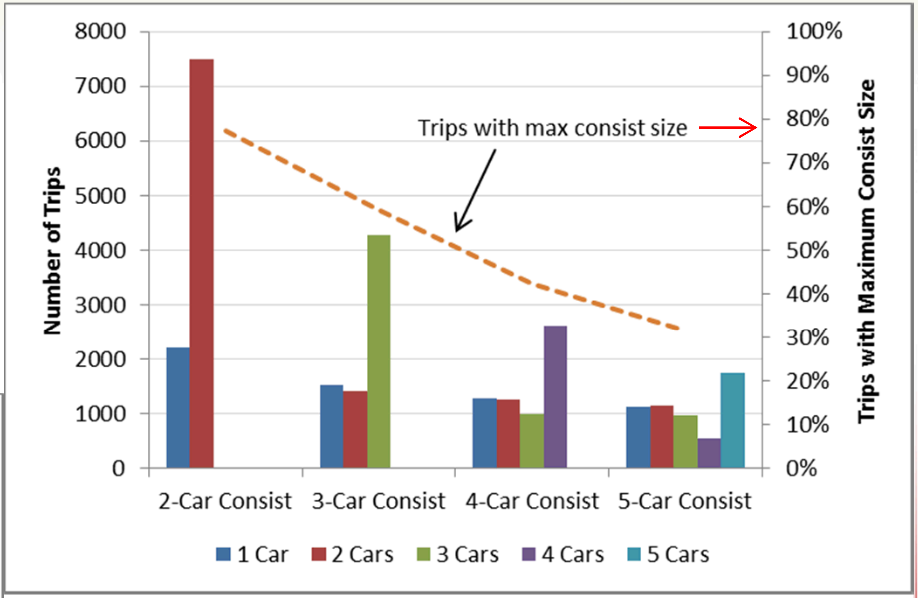


CNF Transportation Statistics	Past 40 years	Projected (80 year campaign)	
		DPCs	DPCs and MPCs
NN of shipments	~3,000	8,000	12,200
Million mi	~1.7	55	69

NUMBER OF TRIPS WITH DIFFERENT CONSIST SIZES

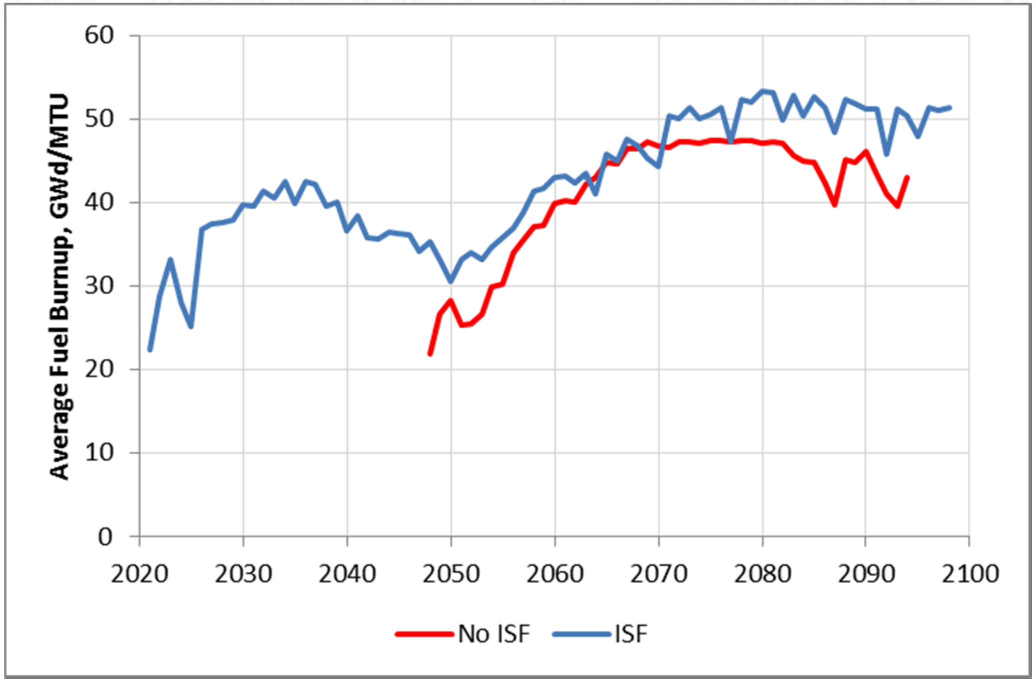
Scenarios without ISF





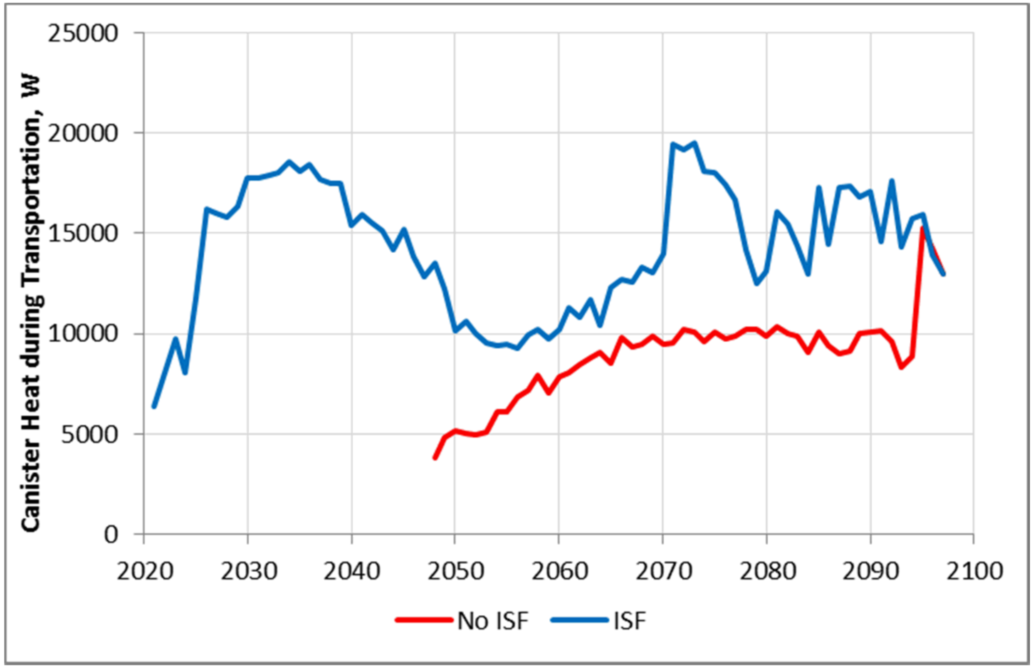
Scenarios with ISF

AVERAGE SNF BURNUP DURING TRANSPORTATION

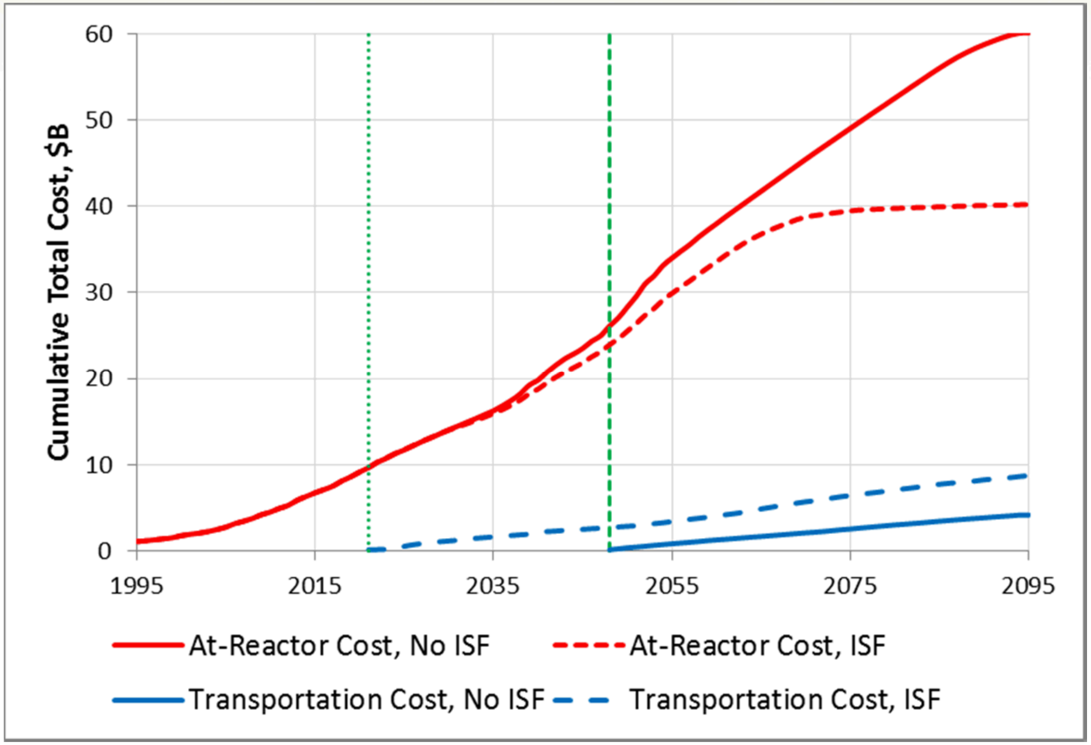


AVERAGE SNF AGE DURING TRANSPORTATION

AVERAGE CANISTER HEAT OUTPUT DURING TRANSPORTATION



TRANSPORTATION COST VERSUS AT-REACTOR COSTS



SUMMARY AND CONCLUSIONS

- The total cost of the transportation is driven by the operational costs.
- The scenarios with the higher total cost (more trips) are the ones:
  (1) with the small canisters (MPCs) used at the reactor sites.
  (2) with the interim storage facility (ISF).
- Using MPCs have greater impacts on the total cost than including ISF.
- The ROM total transportation cost ranged from $4B to $9B.
- The hardware acquisitions are less affected by the scenario parameters.
- Acquisition: 183 to 361 casks and 104 to 173 vehicles.
- Capital costs: $0.7B to $1.6B.
- The differences in the spending profiles is driven by the differences in the operational costs.
- ISF location, maximum consist size, train speed, and processing time have small impacts on the transportation costs.
- The pickup schedule cannot be realized without using 1- and 2-car consists.
- Average fuel age is 20 to 40 years the first 20 years of campaign, 50 years old the last 20 years; and 30 to 60 years old in between. The younger fuel has higher burnup and higher canister heat output.