KNS Autumn Meeting 2016

Temporary Management of Spent Nuclear Fuel during Decommissioning of an NPP

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INTRODUCTION

Background

➢ Transshipment

Transshipment is the transportation of spent fuel from one NPP to another.

From the reactor site, spent fuel is transported by road to neighboring plant when:

- There is insufficient storage space
- Emptying for decommissioning of the NPP.

The principal assurance of safety in the transshipment of nuclear materials is the design of the packaging, which must allow for foreseeable accidents.

➢ Spent Fuel Pool Island

The SFPI is a modification of the existing spent fuel pool, isolating it from the remainder of the plant "nuclear island"

This approach allows decommissioning to begin on the remainder of the plant while the fuel is safely maintained.

This places the plant into "cold and dark" condition, where all liquid containing systems have been drained, and electrical power to components has been removed.

Systems Engineering Requirements Analysis

Primary Requirements	Secondary Requirements	Tertiary Requirements
Temporary Management of Spent nuclear Fuel during Decommissioning	Review of Regulations	Review of U.S.A regulations for transporting spent nuclear fuel
		Review of U.S.A regulations for spent fuel pool island implementation
		Review of Korean regulations for transporting spent nuclear fuel
		Review of Korean regulations for spent fuel pool island implementation
	Requirements Analysis	Perform a requirements analysis for spent nuclear fuel transportation
		Perform a requirements analysis for SFPI
	Transshipment of Spent Nuclear Fuel Concept Application	Investigate current inventory of spent fuel of Kori unit 1
		Establish a procedure for the Transshipment of spent nuclear fuel from Kori unit 1 to neighboring plants
		Produce a transshipment schedule
		Perform a costs analysis
		Establish Risk management methodology and assessment
		Investigate public acceptance and political issues related to Transshipment of spent nuclear fuel
	Spent Fuel Pool Island Concept Application	Investigate current inventory of spent fuel of Kori unit 1
		Establish a procedure to apply the SFPI in Kori unit 1
		Produce a SFPI schedule
		Perform a costs analysis
		Establish Risk management methodology and assessment
		Investigate public acceptance and political issues related to SFPI application at Kori unit 1
	Systems Engineering	Employ systems engineering tools for decision making between SFPI and Transshipment of spent nuclear fuel
	Recommendations	Make recommendations as to which Temporary management of spent nuclear fuel method is optimal for Kori unit 1 between Transshipment and SFPI

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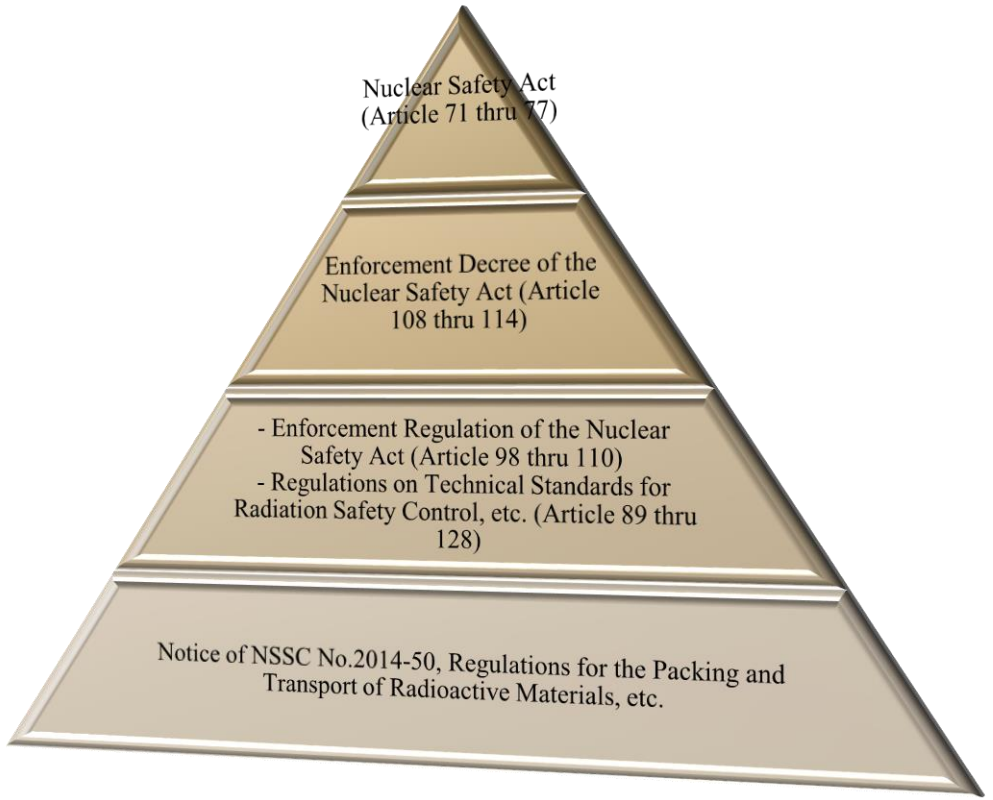
TRANSSHIPMENT

Regulatory framework

➢ US Transshipment regulations

	Regulatory Framework	Comment
Technical Standard	• 10 CFR Part 71-Packaging and transportation of radioactive material • 10 CFR Part 73- Physical protection of plants and materials •	Regulation
Detail Criteria	• U.S. NRC Regulation Guideline • U.S. DOT shipment of hazardous and radioactive material regulations • NUREG SRP for Transportation packages • Regulatory Guideline division 7-Transportation • Industrial Code, Shipping Requirements, Package Certification	Guideline

➢ ROK Transshipment Regulations

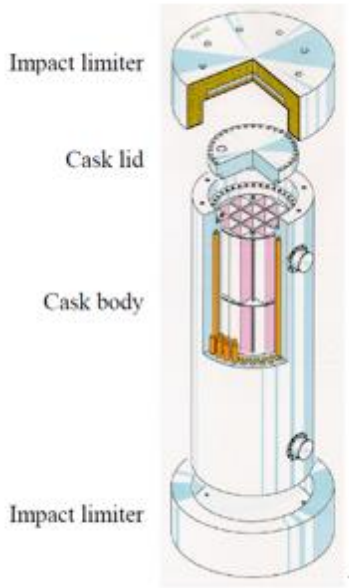


Transshipment current status in Korea

➢ Transport containers

Model	Organization	Transport Capacity (FA)	Maximum burnup (MWD/MTU)	Maximum enrichment (wt%)	Cooling period (years)	Maximum decay heat (kW)	Quantity	Type	Use
KSC-1	KAERI	1 PWR	45,000	3.5	1	7.2	1	Transport only	NPP-KAERI
KSC-4	KAERI	4 PWR	38,000	3.2	3	7	2	Transport only	Kori on-site
KN-12	KHNP	12 PWR	50,000	5	7	12.6	5	Transport only	WH fuel on-site
KN-18	KHNP	18 PWR	55,000/7years 60,000/9years	5	7~9	19.1	4	Transport only	CE fuel on-site
HI-STAR 63	KHNP	120 CANDU	78,000	0.711	6	0.0063(per assembly)	2	Transport only	CANDU fuel on-site

➢ KN-12 Cask & loaded cask



Transshipment current status in Korea

➢ Kori site inventory

Site		Capacity (Assembly)	Current storing (Assembly)	Expected saturation year	
				Before HDR*	After HDR*
Kori	Kori 1	562	328	2016	2024
	Kori 2	920	684		
	Kori 3	2,260	1,987		
	Kori 4	2,262	1,940		
	Shin Kori 1	700	426		
	Shin Kori 2	1,450	312		
	sum	8,154	5,677	Storing 82.0 % of capacity	

*HDR- high density rack

➢ Key assumptions

There are 18 assemblies of damaged fuel in the Kori Unit 1 SFP.

One unit of KSC-1 and 2 units of KN-12 casks will be used for transportation of spent fuel.

For non-damaged spent fuel assemblies, two KN-12 casks are used, each cask placed on a separate truck.

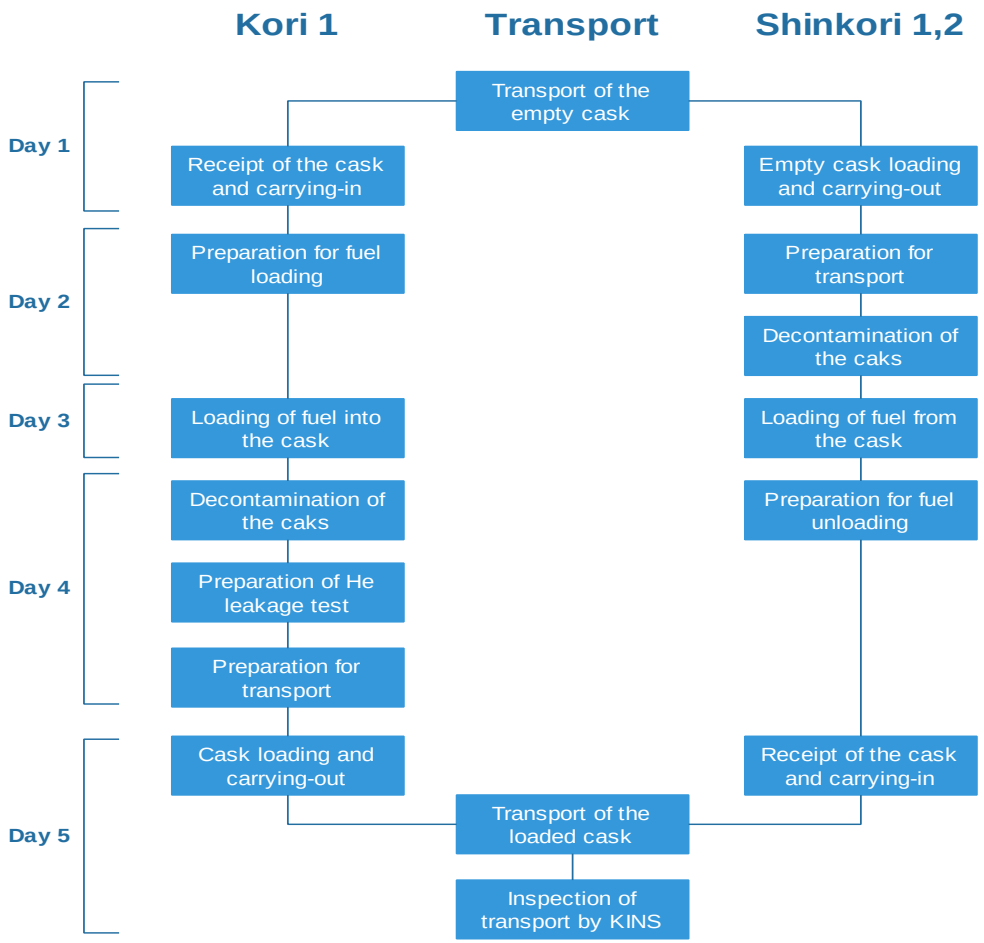
One KCS-1 cask will be used for damaged spent fuel assemblies.

At least 7 years cooling time of fuel in the SFP is required for transportation of spent fuel with KN-12 cask.

Spent nuclear fuel is shipped by truck.

Distance from Kori Unit 1 to neighboring NPPs is assumed as approximately 5 km.

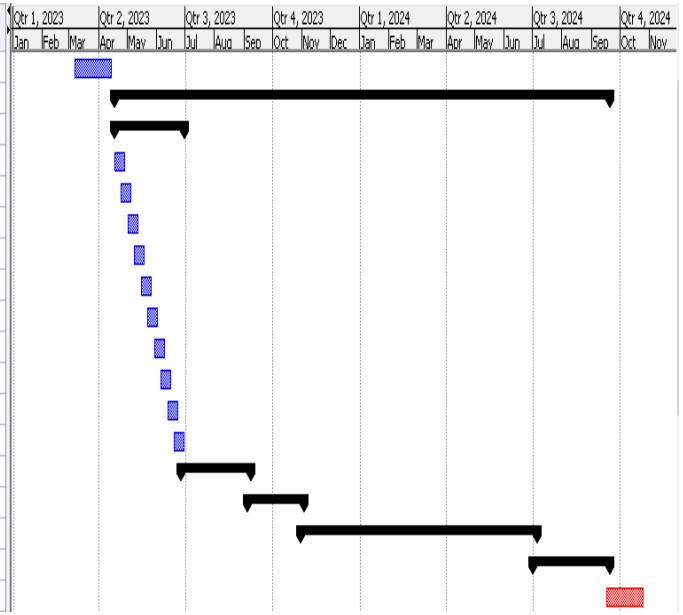
Transshipment Application



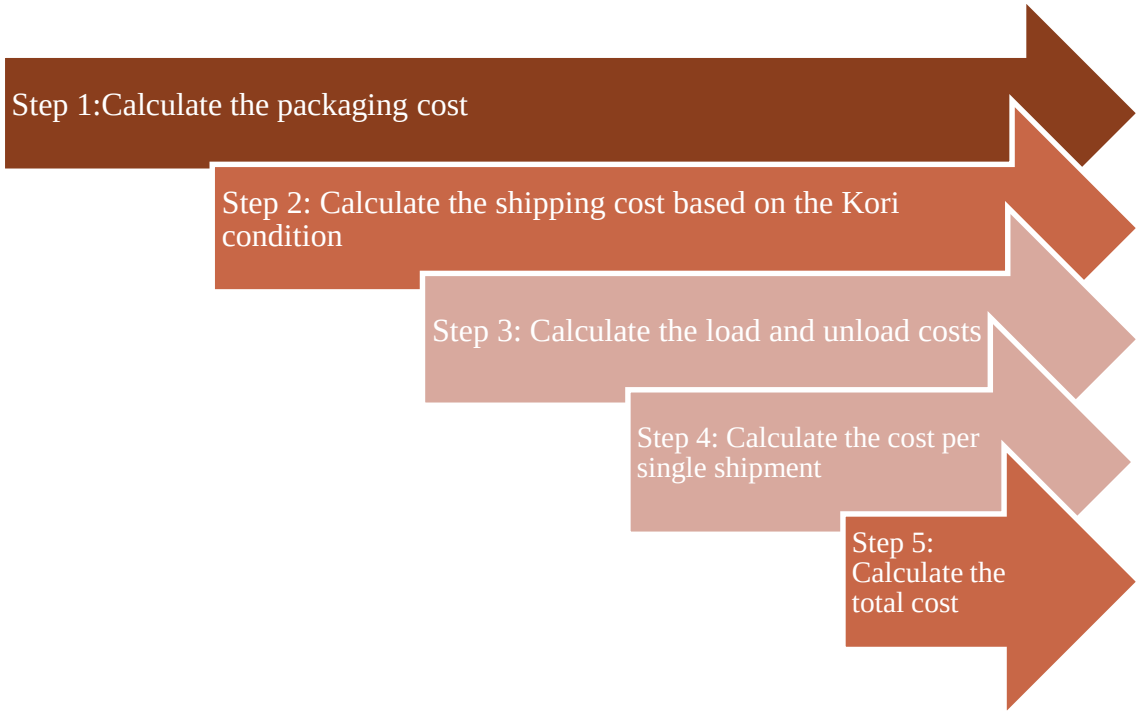
- **Transshipment Procedure**

- **Project Schedule:** starts in March 2023, the expected finish date September 2024

	Name	Duration	Start	Finish
1	Preparation of transportaion	30 days	3/6/23 8:00 AM	4/14/23 5:00 PM
2	⊟Transportaion of spent fuel	375 days?	4/17/23 8:00 AM	9/20/24 5:00 PM
3	⊟1-10th transportaion	55 days?	4/17/23 8:00 AM	6/30/23 5:00 PM
4	1st Transportation	10 days	4/17/23 8:00 AM	4/28/23 5:00 PM
5	2nd Transportation	10 days	4/24/23 8:00 AM	5/5/23 5:00 PM
6	3rd Transportaion	10 days	5/1/23 8:00 AM	5/12/23 5:00 PM
7	4th Transprotation	10 days	5/8/23 8:00 AM	5/19/23 5:00 PM
8	5th Transprotation	10 days	5/15/23 8:00 AM	5/26/23 5:00 PM
9	6th Transprotation	10 days	5/22/23 8:00 AM	6/2/23 5:00 PM
10	7th Transprotation	10 days	5/29/23 8:00 AM	6/9/23 5:00 PM
11	8th Transprotation	10 days	6/5/23 8:00 AM	6/16/23 5:00 PM
12	9th Transprotation	10 days	6/12/23 8:00 AM	6/23/23 5:00 PM
13	10th Transprotation	10 days?	6/19/23 8:00 AM	6/30/23 5:00 PM
14	⊞11-20th transportaion	55 days	6/26/23 8:00 AM	9/8/23 5:00 PM
25	⊞21-28th transportaion	45 days	9/4/23 8:00 AM	11/3/23 5:00 PM
34	⊞1-18th Damaged transportation	180 days	10/30/23 8:00 AM	7/5/24 5:00 PM
53	⊞29-39th Transportaion of Intact	60 days	7/1/24 8:00 AM	9/20/24 5:00 PM
65	Follow-up measures	30 days	9/16/24 8:00 AM	10/25/24 5:00 PM



Transshipment Application



➢ **Costs Analysis Procedure**

- Step 1: packaging(cask purchase) cost - $0
- Step 2: Shipping cost - $ 63,083 /shipment
- Step 3: Load and unload costs – $2,485 & $2,485 /shipment
- Step 4: cost per single shipment - $0 + $63,083 + $2,485 + $2,485 = $68,052
- Step 5: total cost for 57 transshipments - $68,052 x 57 = $3,878,953

Transshipment Application

➢ Risk management

Adequate risk management

Plans to ensure safety of people

Safeguards & Security

Assessment of spent fuel transportation and risk mitigation

Emergency response plans: personnel training

Transportation logistics.

➢ Public acceptance

Transshipment will occur in NPPs within the same county. For transportation of spent fuel..

No requirement for public hearing.

Unless transshipment occurs across counties.

03

SFPI

Overview

To attain independent storage of SF during NPP D&D

➢ Advantages

- Simpler, smaller, and more localized to the SFP area

- Significantly reduces the required plant maintenance and monitoring program

➢ Framework: No SFPI regulation criteria in ROK upon time of study

	U.S.	Korea
General Criteria	10 CFR 50	• Classified as an NPP related facility • Follow the same regulations with safety related facilities
Design Criteria	• US NRC Reg. Guide 1.13 • Appendix A of 10 CFR 50	
Activities	In accordance with the existing operation license	Based on Article 34 (Application for Change Permit)

Case Study

- Self-contained (i) fuel pool cooling (ii) cleanup systems (iii) monitoring, controls, electrical power
- Effectively isolate the spent fuel pool from the remainder of the plant

	YNPS*	SONGS 2&3 NPP	Trojan NPP	MAINE YANKEE NPP
Reactor type	PWR (185 MWe)	PWR (1,127 MWe)	PWR (1,130MWe)	PWR (860MWe)
NPP Operation duration	1961-1991	Unit 2: 1983-2013 Unit 3: 1984-2013	1976-1993	1972-1996
Decommissioning Strategy	DECON	DECON		DECON
SFPI Operation duration	Until ISFSI became available	During the transition period		Until the DOE fulfilled its obligations

* The Yankee Nuclear Power Station

SFPI APPLICATION

➢ Design modification

Cooling and Cleanup System	Ventilation System
Cooling System	Electrical System
Purification and Make-Up Systems	Instrumentation and Controls System

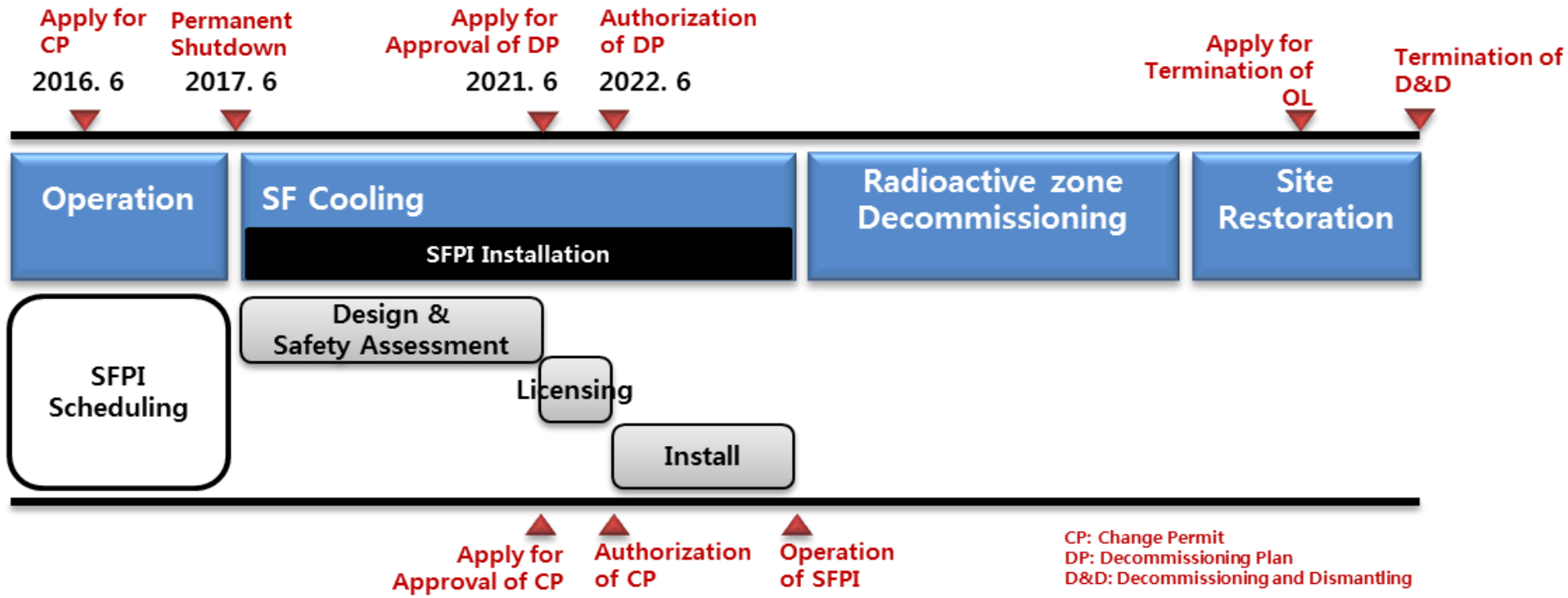
➢ Risk Management

- Quantitative assessment: Frequency, Consequence
- Risk Management Plan: Defense-in-depth fundamentals

Type of Risk	Risk Management Plan
– Seismic event – Loss of off-site power – Internal fire – Loss of pool cooling – Aircraft impact	– System redundancy, independence, and diversity – The robust structural design – An offsite resource – Readouts and alarms in the control room – An offsite restoration plan

SFPI APPLICATION

➢ **Schedule**



➢ **Cost Analysis**

- $11,157,000 (half of SONGS Units 2&3)

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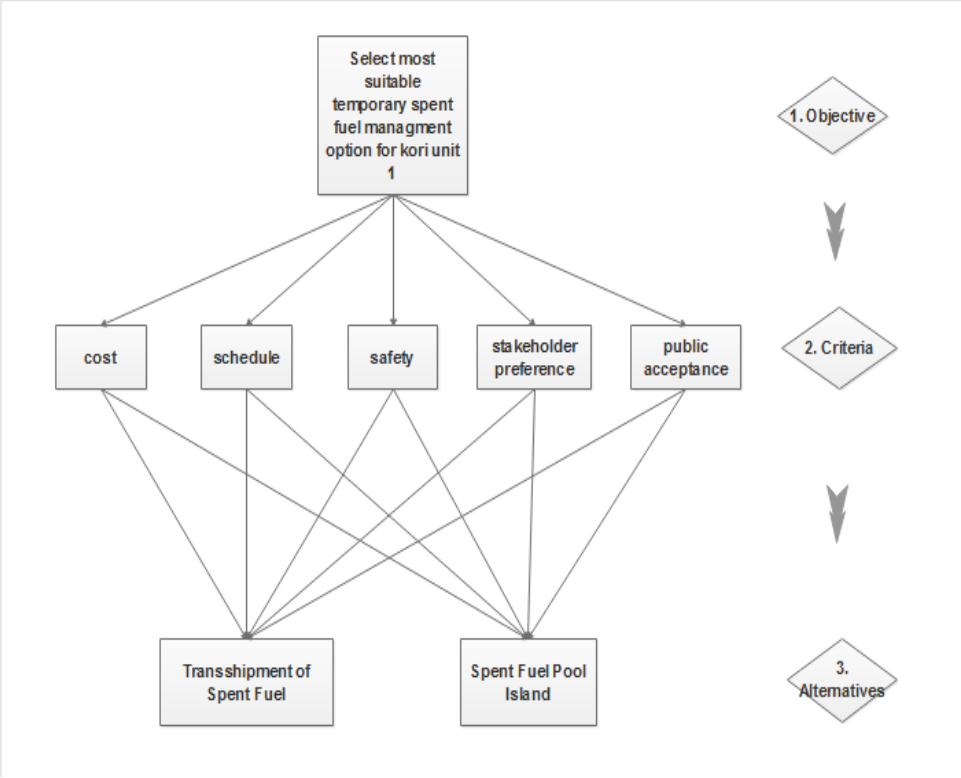
DECISION MAKING

DECISION MAKING: Analytical Hierarchical Process

➢ Decision making process



➢ Pairwise comparisons in terms of importance of criterion

➢ Intensity of importance scale

Intensity of importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

DECISION MAKING: Analytical Hierarchical Process

➢ **Pairwise comparison for the alternatives based on criterion**

Comparisons wrt "Schedule" node in "3Alternatives" cluster
Transship is strongly more important than Spent Fuel Pool Island

1. Spent Fuel Pool~ | >=9.5 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >=9.5 | No comp. | Transship

Comparisons wrt "Safety" node in "3Alternatives" cluster
Spent Fuel Pool Island is equally as important as Transship

1. Spent Fuel Pool~ | >=9.5 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >=9.5 | No comp. | Transship

Comparisons wrt "Stakeholder preference" node in "3Alternatives" cluster
Transship is strongly more important than Spent Fuel Pool Island

1. Spent Fuel Pool~ | >=9.5 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >=9.5 | No comp. | Transship

Comparisons wrt "Public Acceptance" node in "3Alternatives" cluster
Spent Fuel Pool Island is very strongly more important than Transship

1. Spent Fuel Pool~ | >=9.5 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >=9.5 | No comp. | Transship

Comparisons wrt "Cost" node in "3Alternatives" cluster
Transship is strongly more important than Spent Fuel Pool Island

1. Spent Fuel Pool~ | >=9.5 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | >=9.5 | No comp. | Transship

➢ **Pairwise comparison for the alternatives based on criterion**

Normal | Hybrid

Inconsistency: 0.11262

Cost		0.07822
Public Ac~		0.02876
Safety		0.57109
Schedule		0.07822
Stakehold~		0.24370

➢ **Result**

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: Spent Fuel PI vs. Transship.sdmod

Name	Graphic	Ideals	Normals	Raw
Spent Fuel Pool Island		0.606174	0.377403	0.188701
Transshipment of spent fuel		1.000000	0.622597	0.311299

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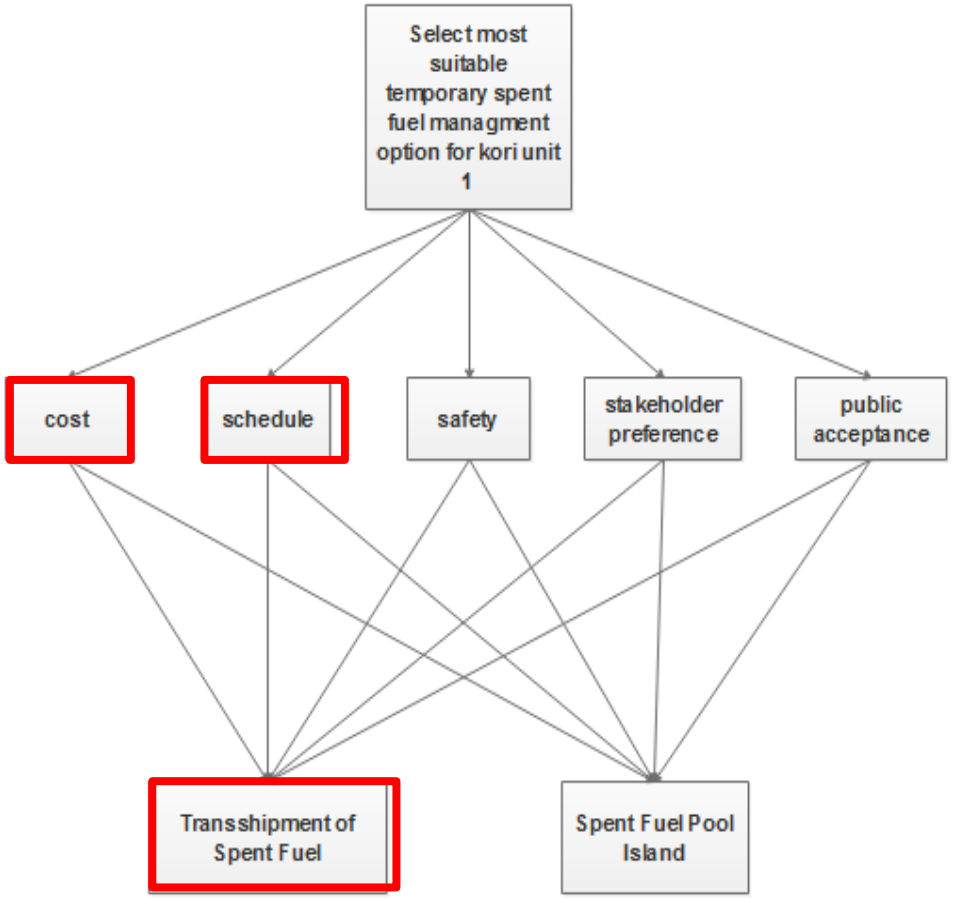
CONCLUSION

Conclusion

- **Option study for temporary storage of SF**
  - SFPI vs Transshipment
- **Decision making: AHP**
  - Transshipment is a more preferred option
  - Especially in regard to cost and schedule



THE END

Thank you for your attention