KAIST

NQe
DEPARTMENT OF NUCLEAR & QUANTUM ENGINEERING

사용후핵연료 분야 주요 이슈

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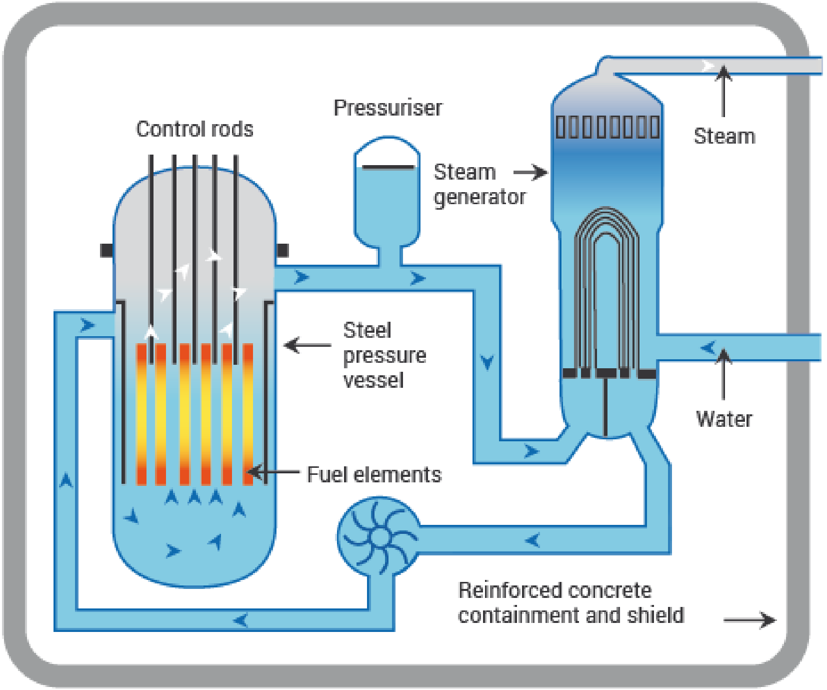
" 안전한 사용후핵연료 관리를 위한 과학기술인 워크숍 "

Highest Priority in Nuclear Energy Industry

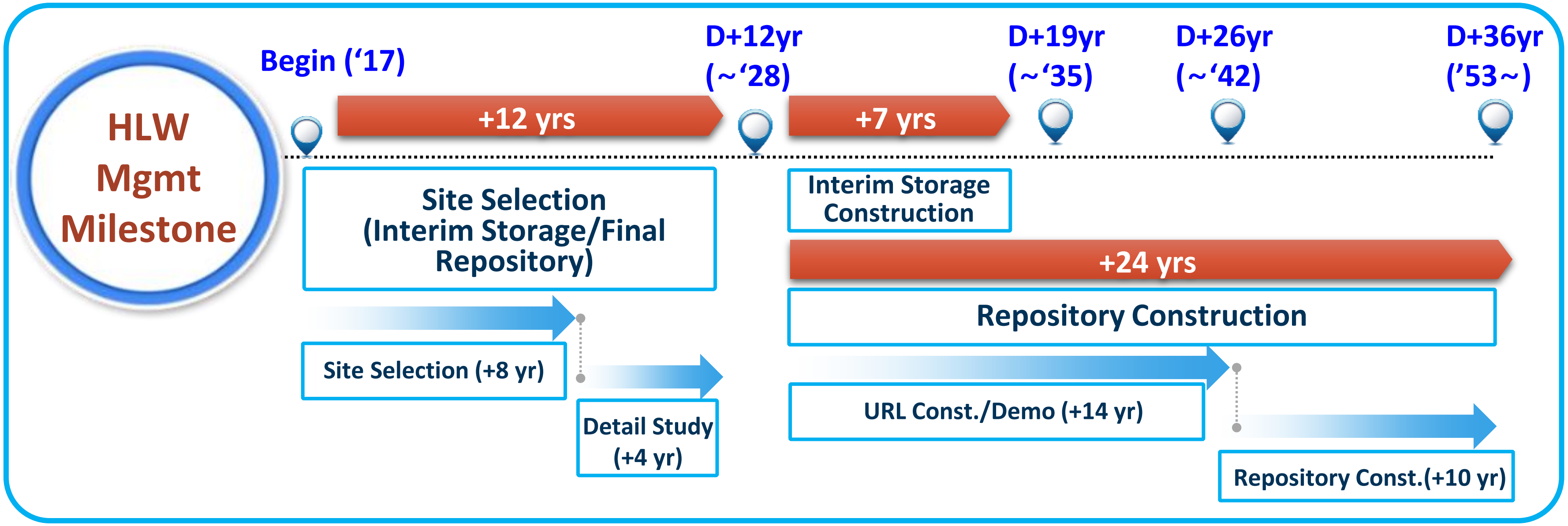
SAFETY

Nuclear Reactor



Spent Fuel

National Policy on HLW Management



AEC: Atomic Energy Commission of the Republic of Korea (July 25, 2016)

Changeable saturation point in Gori due to transshipment ('24-'34)

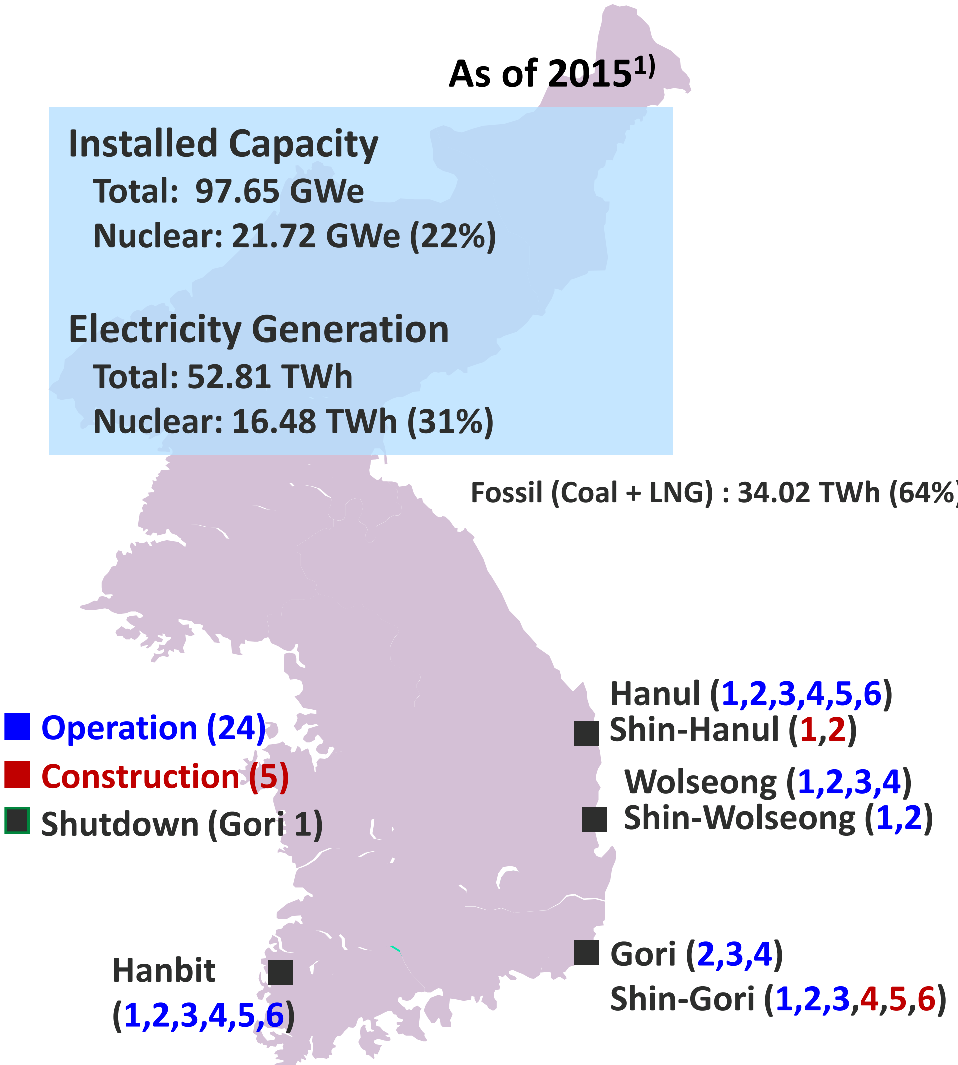
Current Status: Nuclear Energy and SF Inventory

As of 2015[1)]

Installed Capacity
Total: 97.65 GWe
Nuclear: 21.72 GWe (22%)

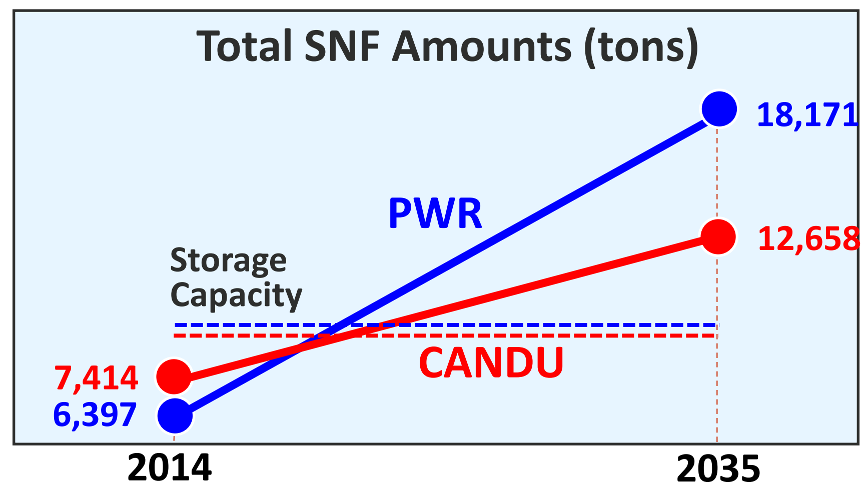
Electricity Generation
Total: 52.81 TWh
Nuclear: 16.48 TWh (31%)

Fossil (Coal + LNG) : 34.02 TWh (64%)



As of 2014[2)]

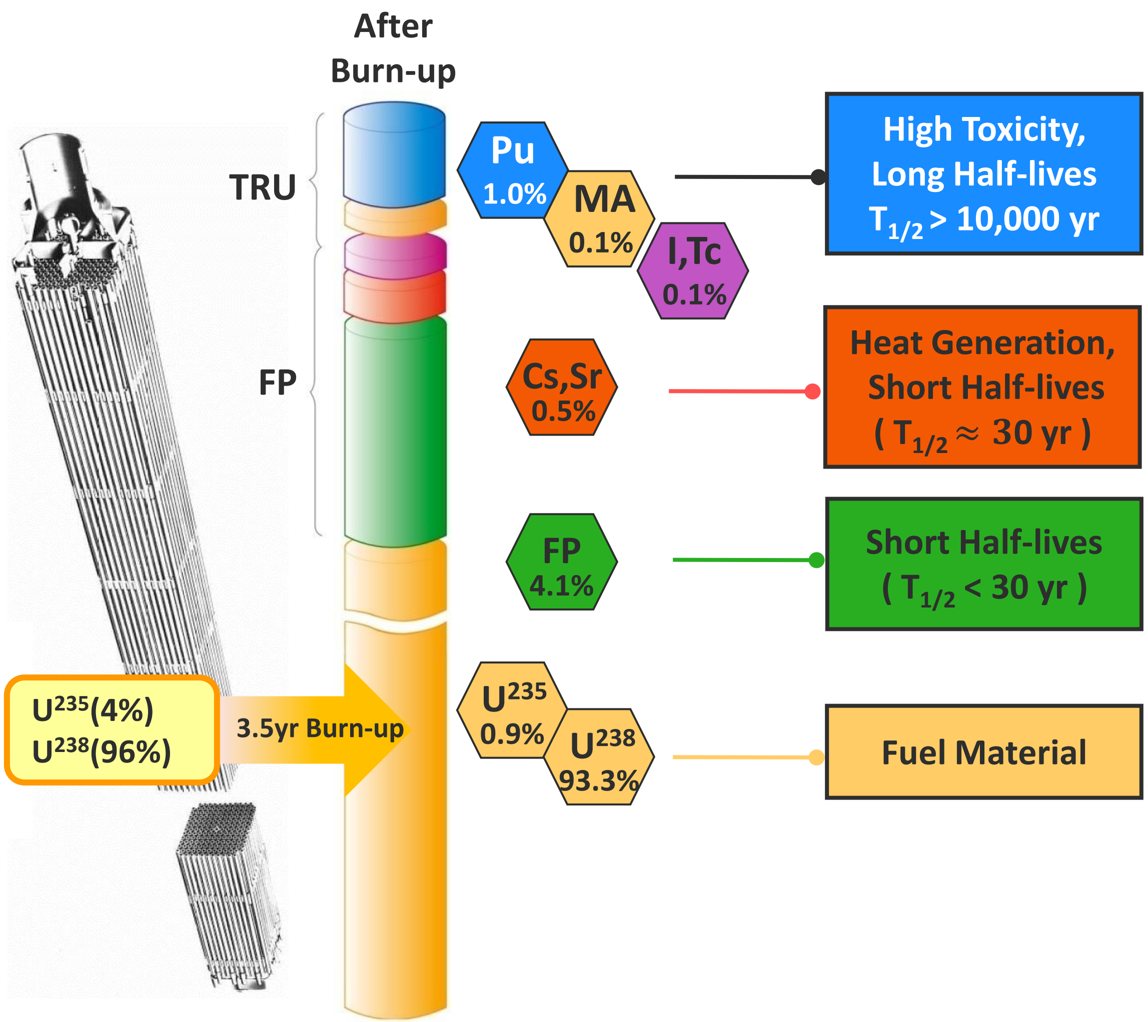
SNF		Storage	Saturation (yr): Re-rack	Saturation (yr): Trans.
PWR (Water Pools)	GR	2153 t	2016	2028
	HB	2258 t	2019	2024
	HU	1959 t	2021	2026
	WS	27 t	2022	2038
CANDU (Dry Storage Cask)	WS	7414 t	2019	



1) EPSIS
2) PECOS

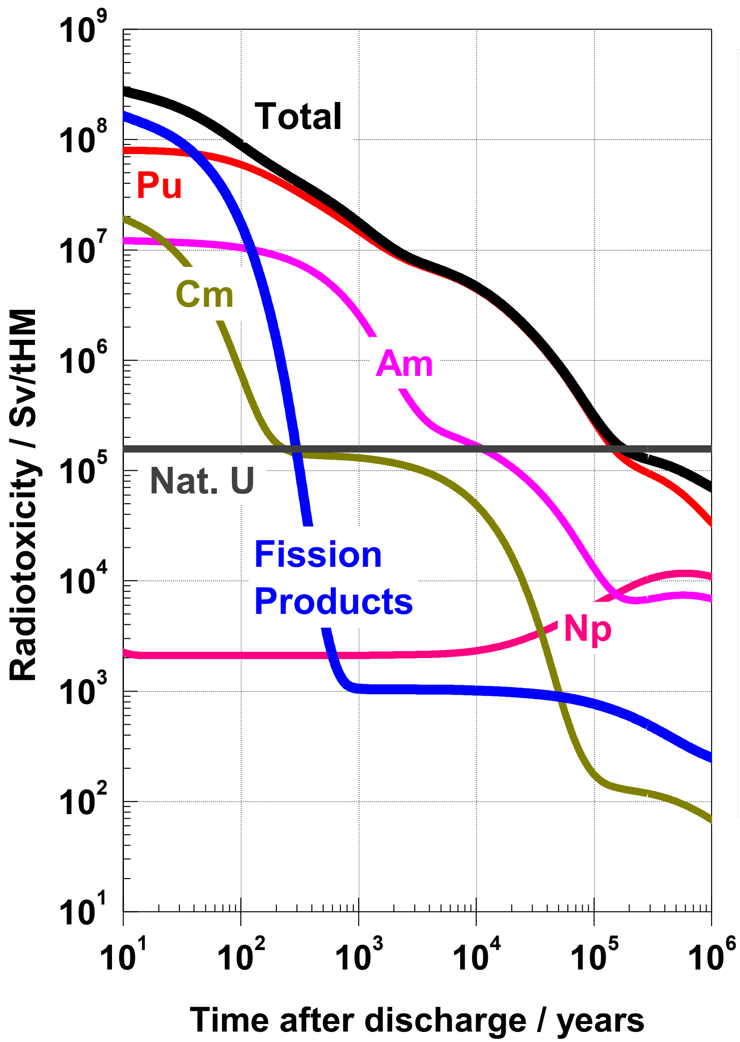
As of 2016: ca. 15,000 tons
Energy Transition Policy: Total ~40,000 tons (PWR ~27,000 + CANDU ~13,000)

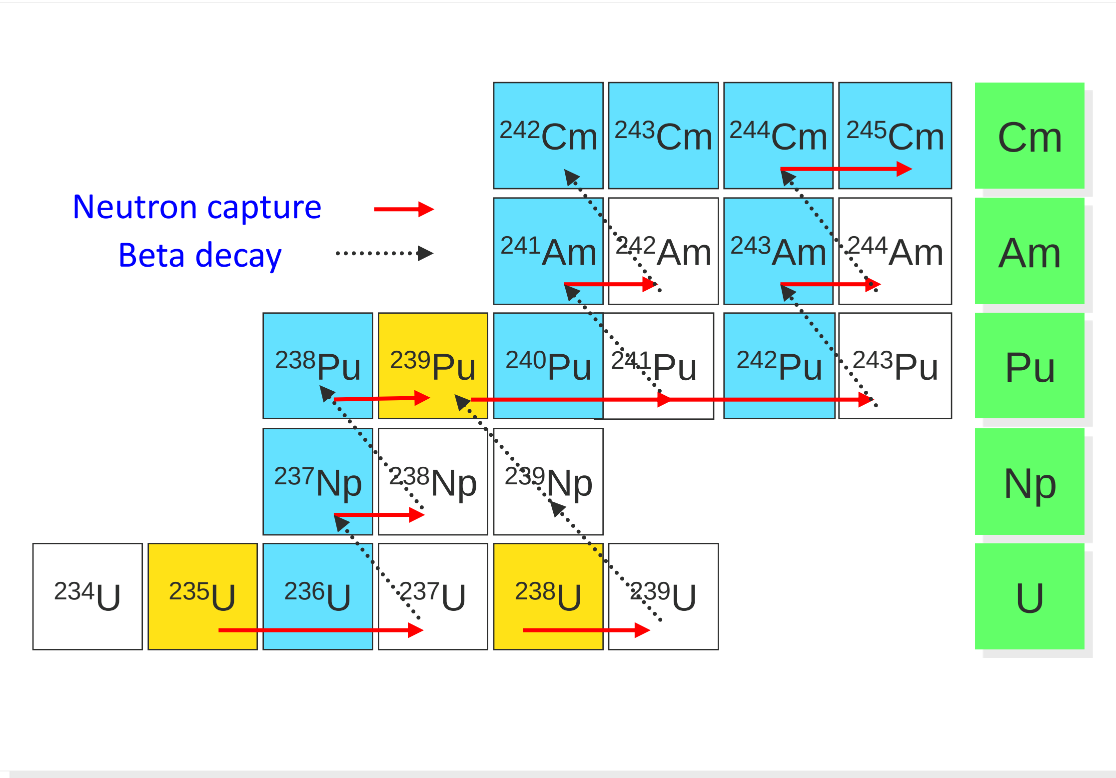
Composition in Spent Fuel



MA: Minor Actinides (Np, Am, Cm)
FP: Fission Products

Radiotoxicity (Enrichment: 4.2% U-235, Burn-up: 50 GWd/tHM)





Transuranium Elements in SF

- Plutonium ～ 1 %
- Minor Actinides (Np, Am, Cm) ～ 0.1 %

SF Management Pathway

SF

Reactor Pool

Interim Storage

Wet

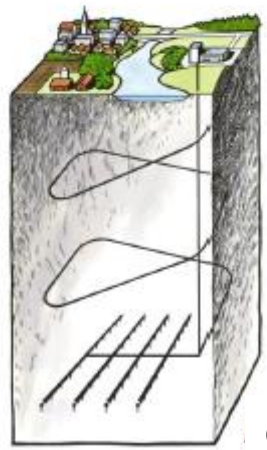
Dry

Final Repository

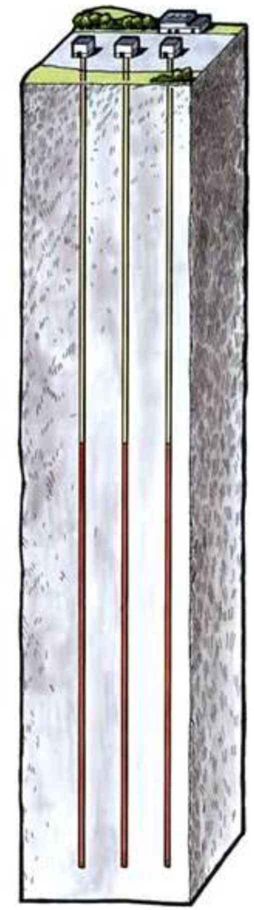
Technical Options: Reprocessing/Recycling of SF (Pyro + SFR in ROK)

SF Management Alternative Methods

Monitored Storage



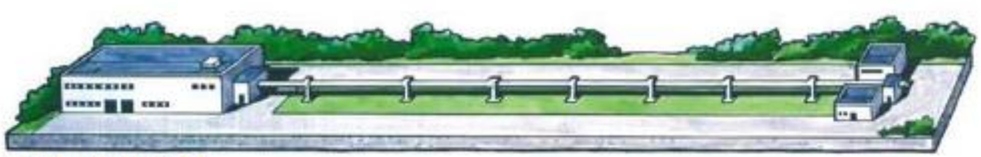
Geological Disposal
(0.5 – 1 km)



Deep Bohrhole Disposal
(~ 5 km)

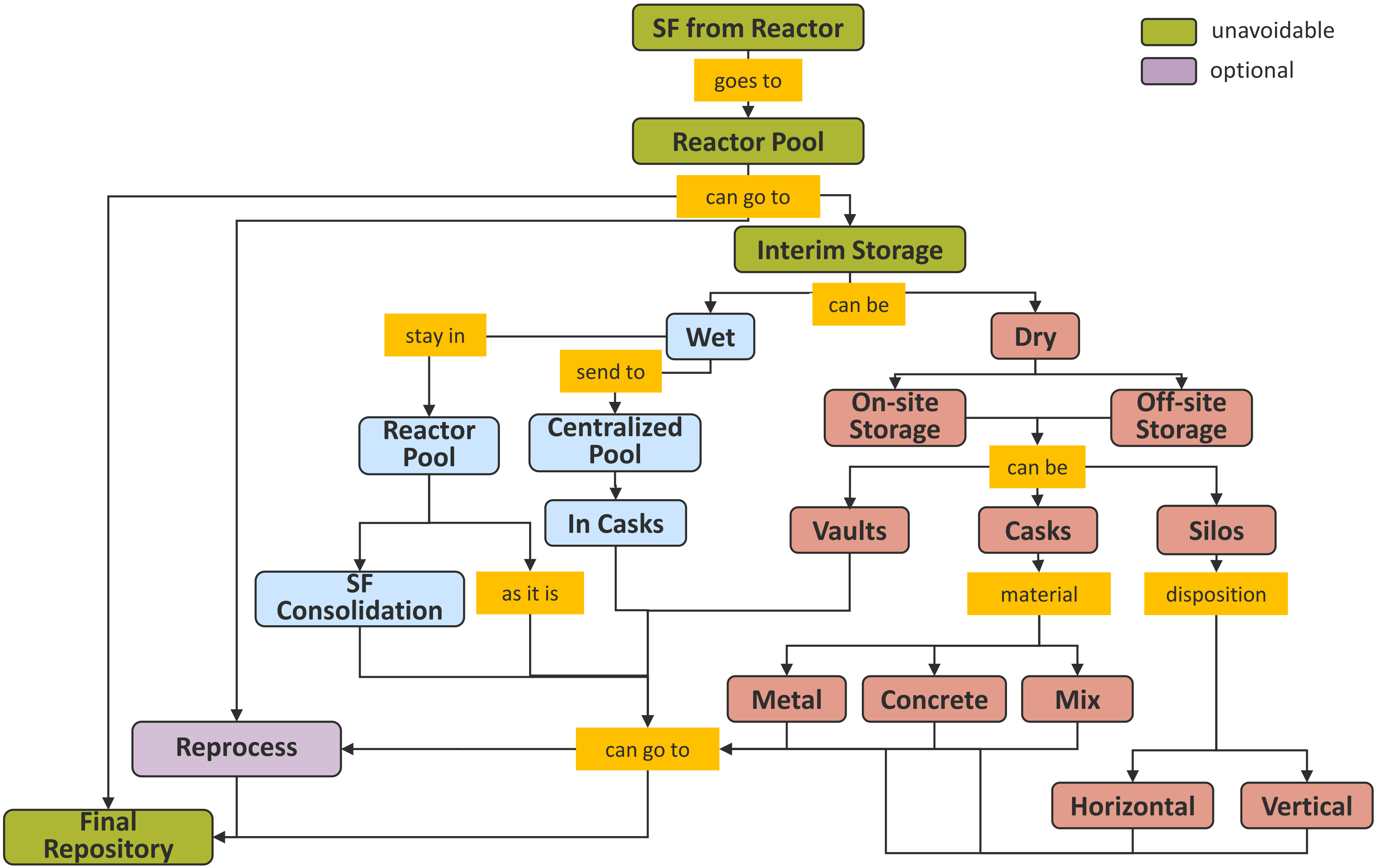
Launch into Space

Reprocessing/Recycling



Transmutation (Gen-IV, ADS etc.)

SF Management Concept (Interim Storage)



Modified from INAC 2011 by L. S. Romanato

Wet Storage vs. Dry Storage

	Dry Storage	Wet Storage
Mobility/Expansion	Possible	No
Cooling	Passive	Forced
Purification	No	Necessary
Leakage	Easy to repair	Hard to repair
Inventory at accident	Only SF in cask	All SF at pool
Waste	None	Large amount of liquid waste

Types of Packaging for Transport

Type A packaging must withstand four tests simulating normal transport conditions.

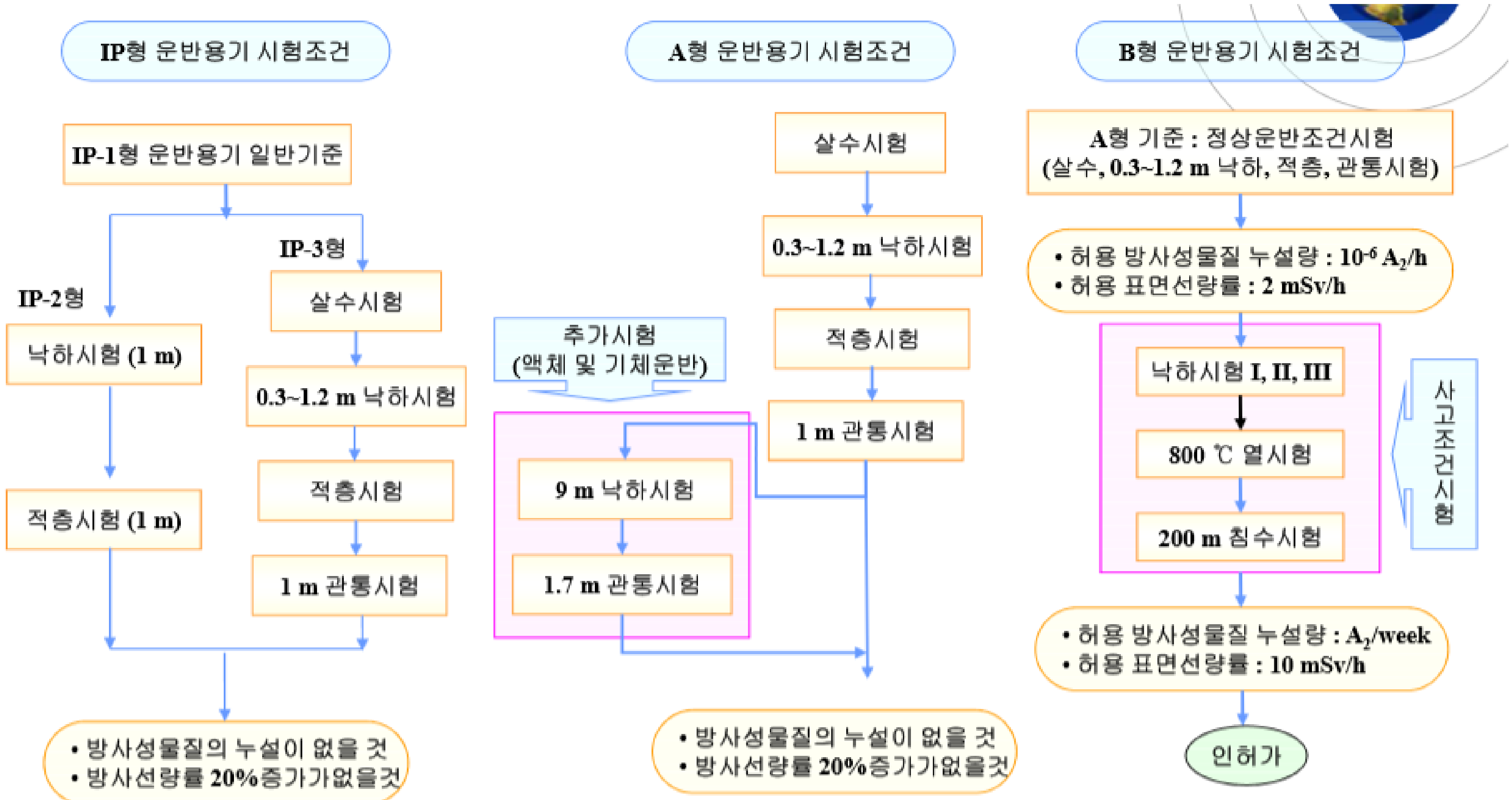
- Water spray for 1 hr to simulate rainfall of 50 mm/hr
- Free fall drop test onto a hard flat surface
- Compression of at least 5 times the weight of the package
- Penetration test by dropping a 6 kg (13 lb.), 3 cm (1.25 in.) diameter bar vertically onto the package from a height of 1 m (3.3 ft.)

Type B packaging must withstand Type A packaging testing criteria as well as four additional tests.

- A 9 m (30 ft.) drop onto a flat, unyielding surface so that the package's weakest point is struck
- A 1 m (40 in.) free drop onto a 15 cm (6 in.) diameter steel rod at least 20 cm (8 in.) long, striking the package at its most vulnerable spot
- Exposure of the entire package to 800 ^{o}C (1475 ^{o}F) for 30 min
- Immersion of the package under 4.6 m (15 ft.) of water for at least 8 hr

10 CFR part 71
IAEA SSS-6

Acceptance Criteria for Transport Cask



관련근거 : 과기부고시2008-69, NUREG-1617

Packaging for Transport

Radioactive – White I: 0.5 mrem/hr on the package surface

Radioactive – Yellow II: 50 mrem/hr on the package surface
1 mrem/hr at 1m from the package

Radioactive – Yellow III: 200 mrem/hr on the package surface
10 mrem/hr at 1 m from the package

10 CFR part 71
IAEA SSS-6

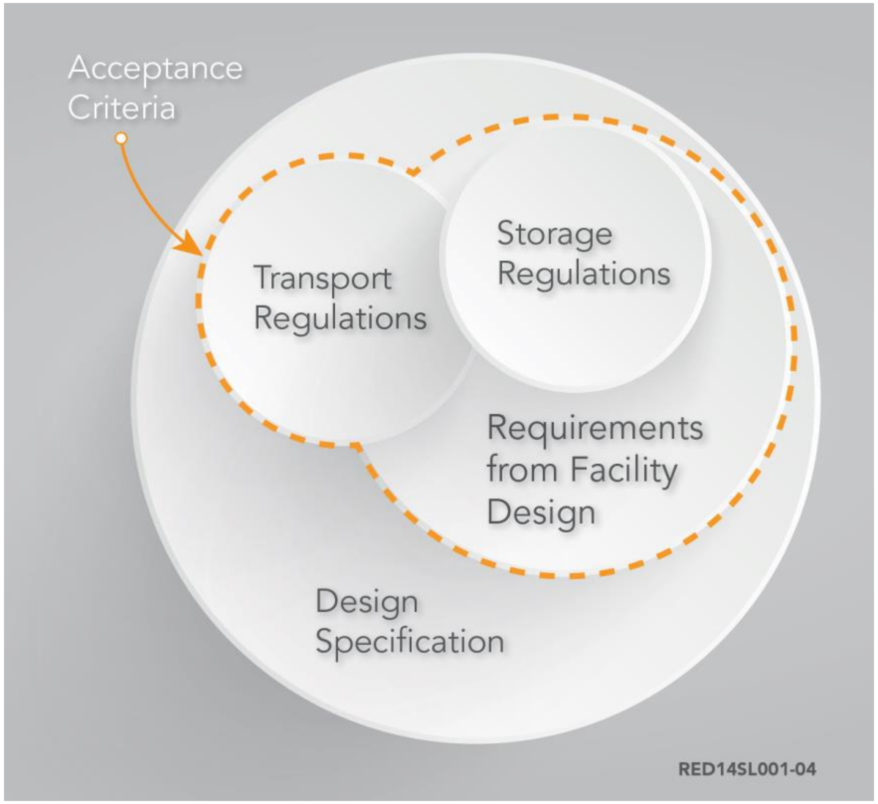
Dual Purpose Cask for Transport and Storage

Performance Criteria

- Containment
- Shielding
- Criticality prevention
- Heat removal
- Retrievability

Acceptance Criteria

- Criticality
- Heat removal
- Release of radioactive materials to the environment
- Radiation dose and dose rate to the public and workers



- Normal operation
- Off-normal operation
- Accident operation

Ageing Consideration for SF Storage

Ageing (up to 100 years or Beyond)

Degradation mechanisms or phenomena (Thermal, Chemical, Mechanical, Radiation)

- Cladding
- Assembly Hardware
- Fuel Baskets
- Neutron Poisons
- Neutron Shielding Materials
- Container
- Inert Fill Gas

Factors Affecting SF Integrity

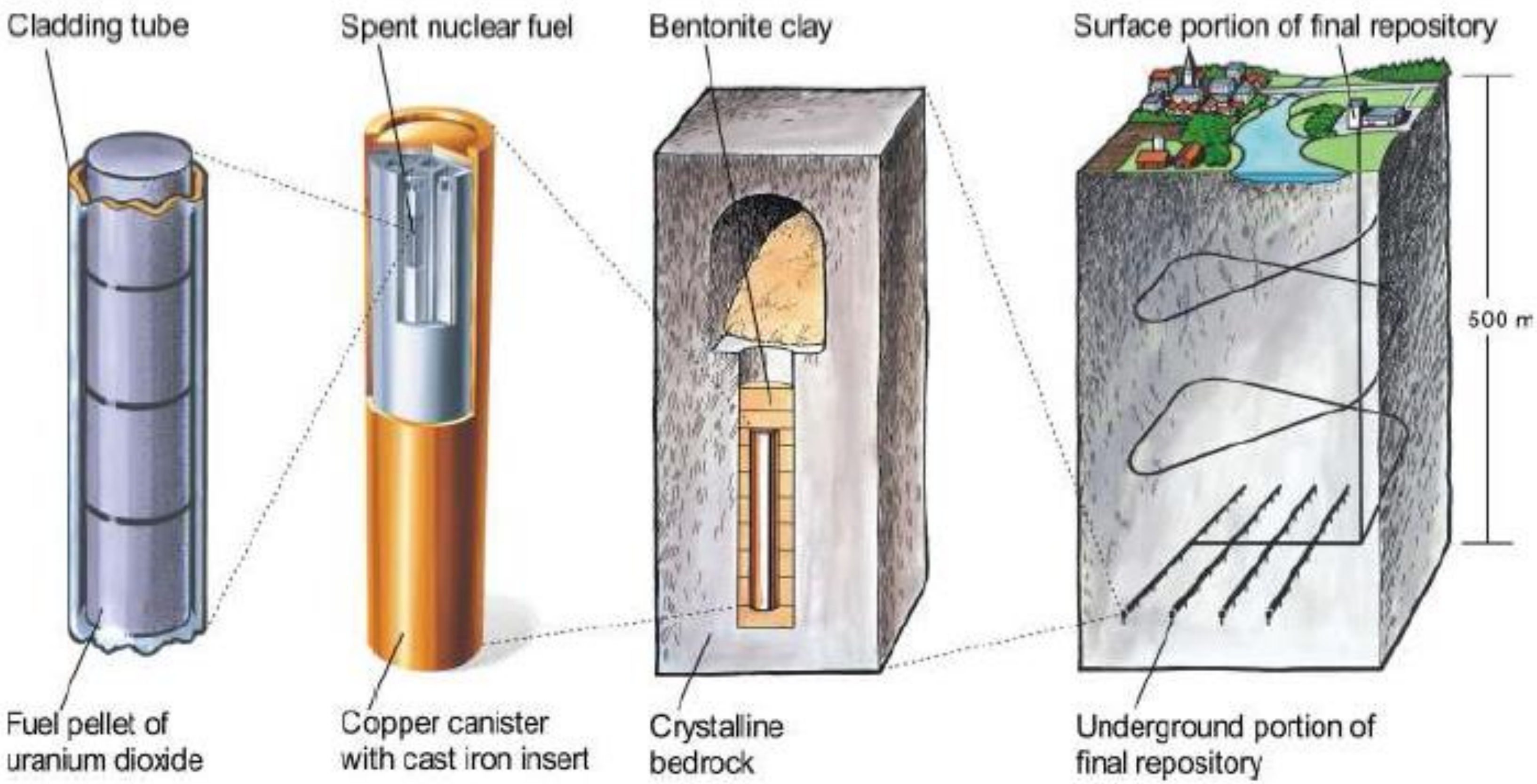
(During Long-term Dry Storage)

- Creep
- Hydrogen Effect (Embrittlement, Reorientation, Axial Diffusion & Migration)
- Irradiation-hardening Recovery
- SCC (Stress Corrosion Cracking)
- Oxidation
- Helium Generation by Alpha Decay
- Physical Properties Change of a Pellet (Lattice Constant, Swelling)

Report of WASSC/TRANSSC joint working group, IAEA
IAEA-TECDOC-1523, IAEA

Repository Concept

- Design objective of geological repositories:
  - **to confine waste and to isolate it from environment**



Swedish SKB concept for SNF disposal with multi-barrier

Performance Assessment

Geochemical Approach

Hypotheses
& Scenarios
↓
Laboratory &
Field experiments
↓
Database &
Parameterization
↑
Uncertainty analysis

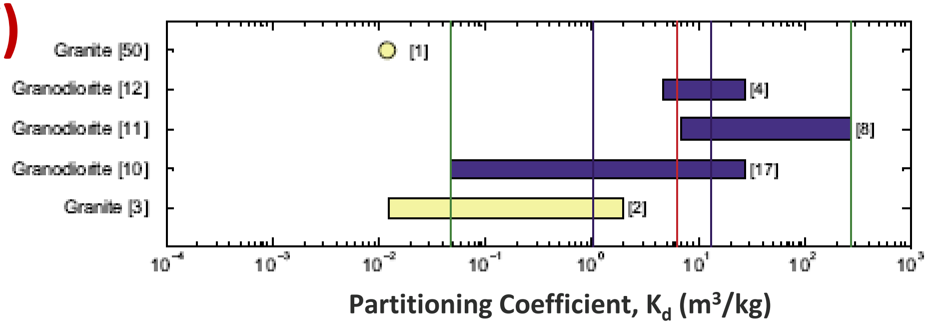
Sub-systems

Engineered barrier
↓
Geo-engineered barrier
↓
Geological barrier

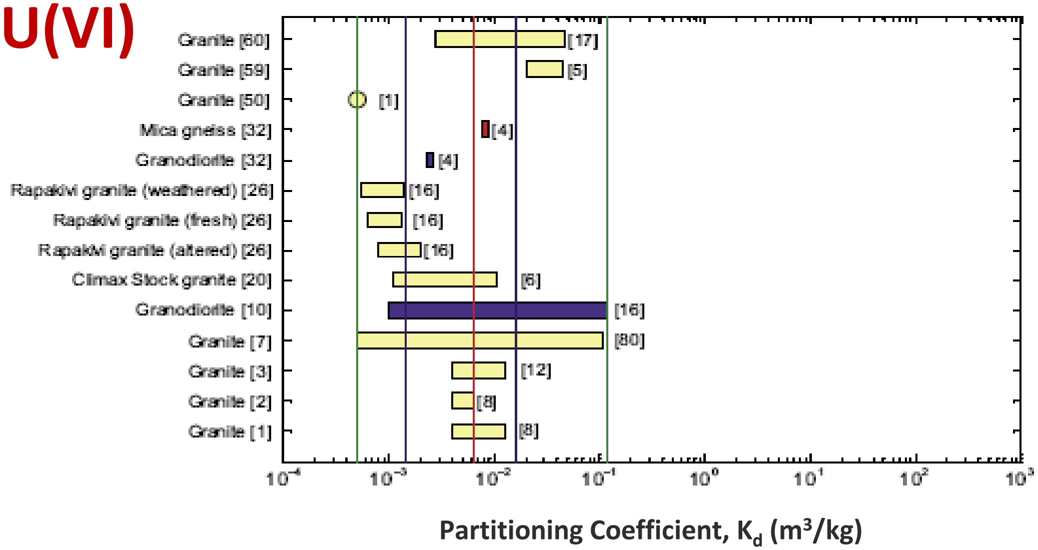
Specific
Parameterization
↓
Geochemical
Modeling
at each subsystem
for RN migration
↓
Uncertainty analysis
↓
Integral long-term
Performance
Assessment (PA)

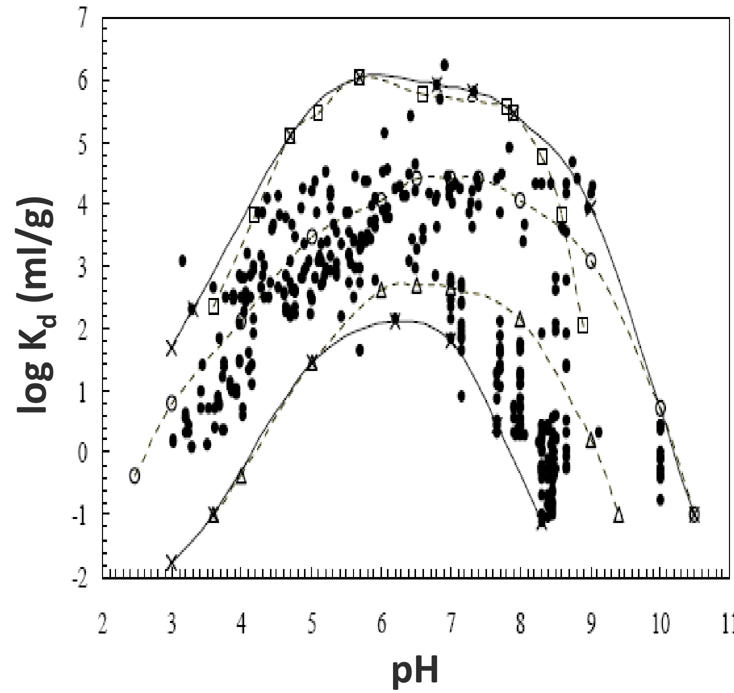
Uncertainty of RN Retention (K_d values for U)

U(IV)



U(VI)





Red: Median
Blue: 25-75% range
Green: Overall data limits excluding outliers

K_d(Clay) > K_d(Marl)* > K_d(Sandy)

(Sediment Type)

K_d(Montmorillonite) > K_d(Illite) > K_d(Kaolinite)

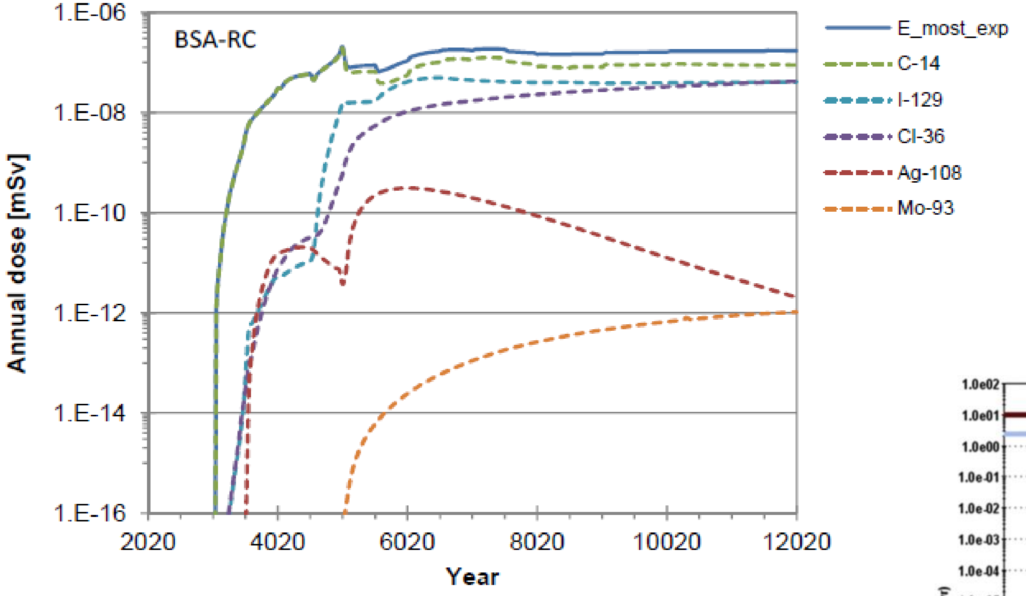
(Single Mineral Phases, 20 °C, pH 6.0)

SKB Report R-06-75, (2006)

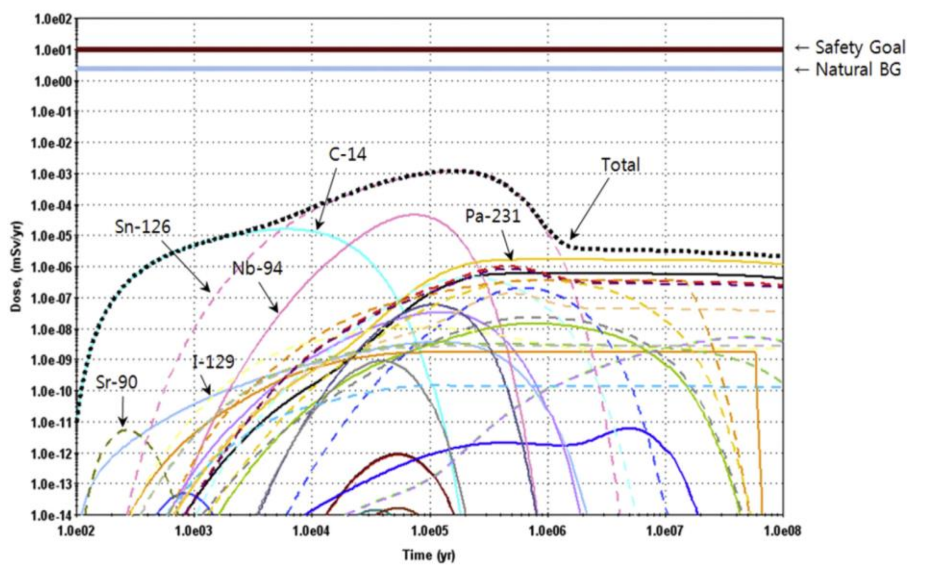
*Marl: 35-65 % clay + 65-35 % carbonate (Bates, Jackson, 1980)

Safety Assessment

Finland (POSIVA[+])



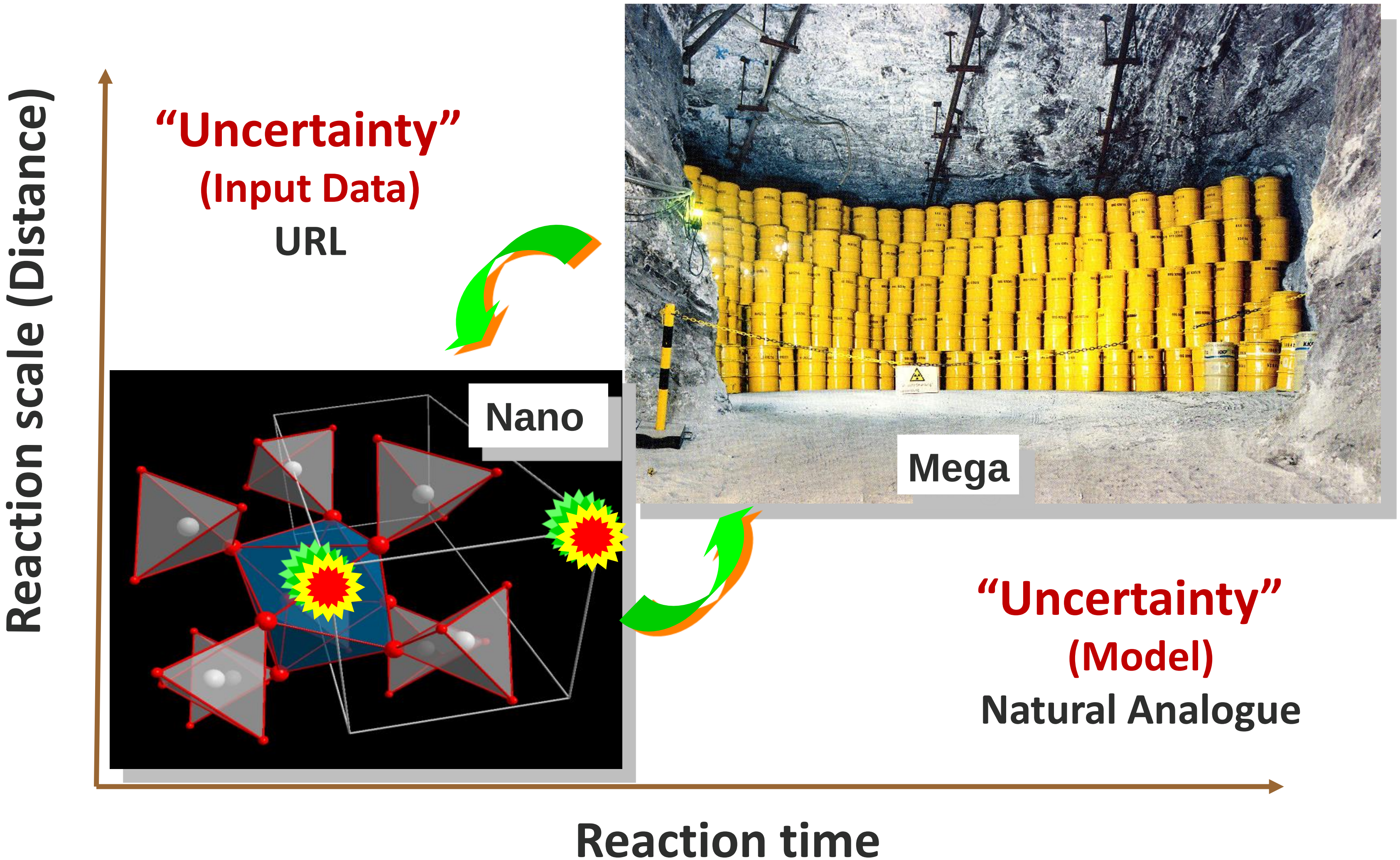
ROK (KAERI-AKRS[*])



† Posiva (2013), Safety Case for the Disposal of Spent Nuclear Fuel at Olkiluoto, Posiva 2012-10, Posiva Oy, Eurajoki, Finland

* Jeong et al., (2016) Porgress in Nuclear Energy **90**, 37-45

Uncertainty in Long-Term Disposal Safety

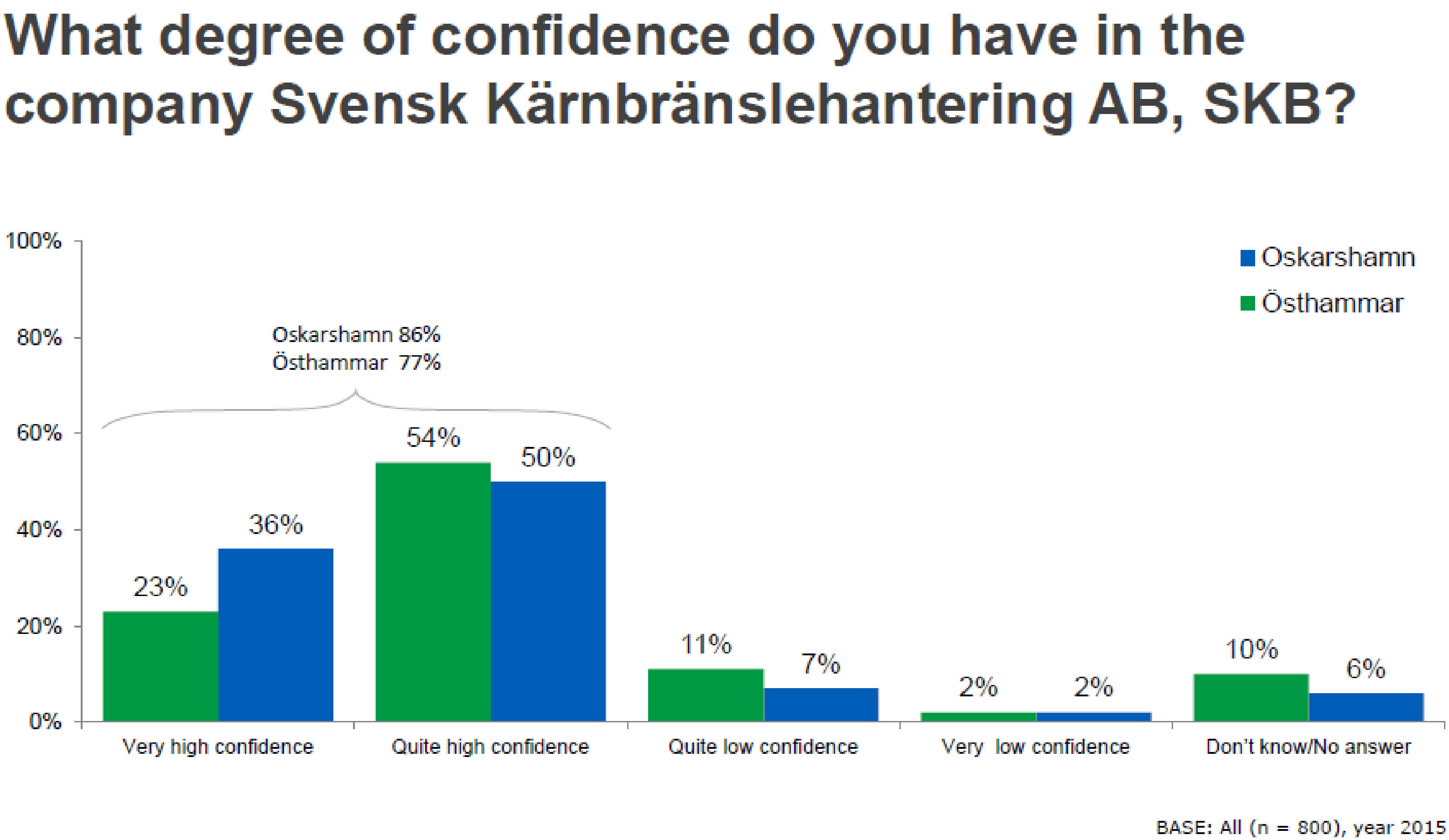


National Policy of HLW Management

- Review SF/HLW national policy due to energy transition policy

- Outcomes from review committee must be
  - **legalized by National Assembly**

Sweden: Public Acceptance (Dialogue and Openness)



Sweden: 40% For, 51% Against, 9% Undecided

Thank you for your attention