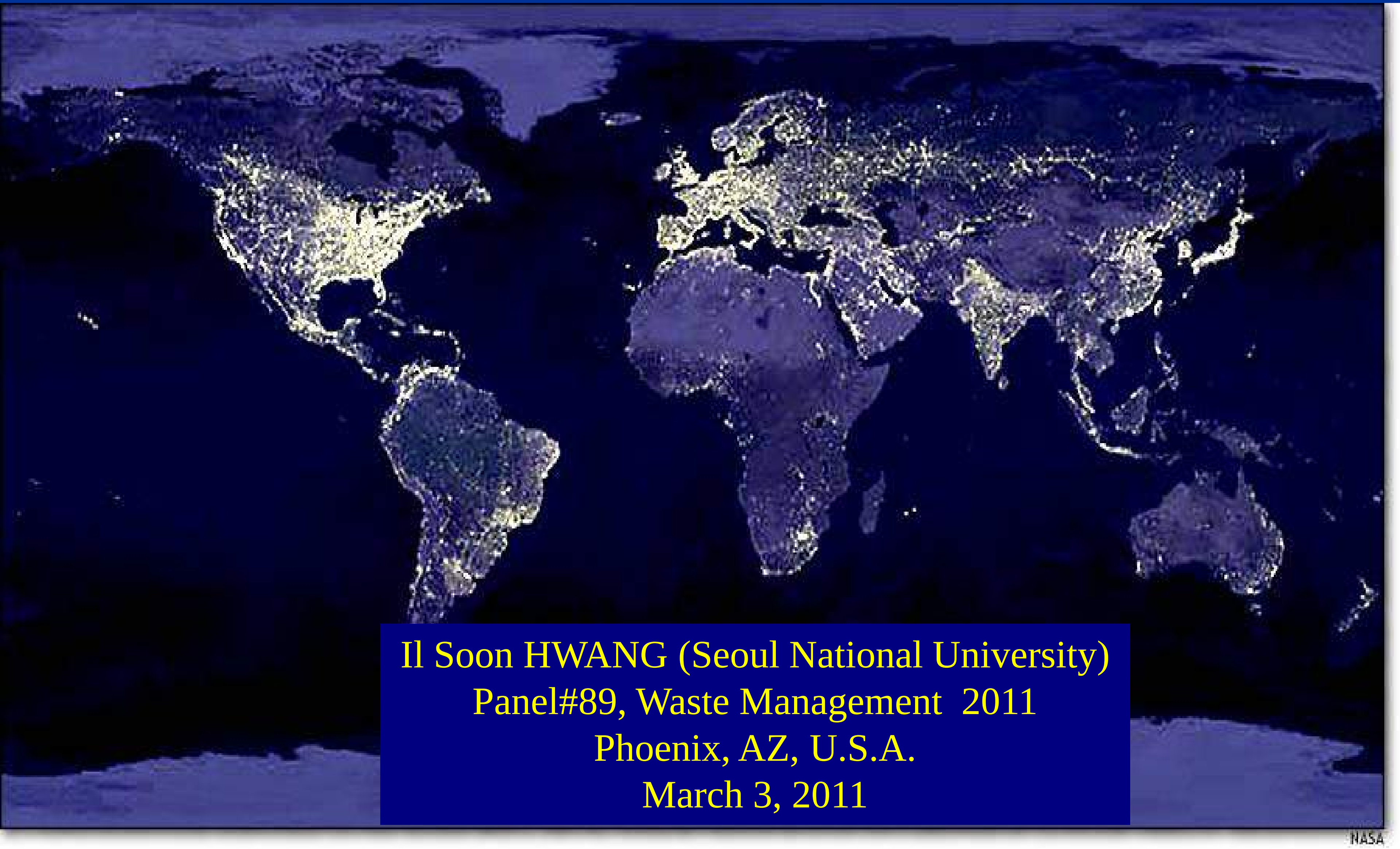
Innovative Approaches to Shorten Radiotoxic Period of Wastes Arising from SNF Recycling: Advanced Pyrochemical Processes



Il Soon HWANG (Seoul National University)

Panel#89, Waste Management 2011
Phoenix, AZ, U.S.A.
March 3, 2011

Korean nuclear power generation

1970s

Completion of Kori Unit1 (’78)

Bắt đầu có năng lượng hạt nhân

Hoàn thành lò phản ứng đầu tiên

1980s

Tích lũy công nghệ

Hoàn thành 8 lò phản ứng

1990s

Completion of First OPR1000 (’95)

Phát triển OPR1000

Hoàn thành 7 lò phản ứng

2000s

Completion of First APR1400 (’13)

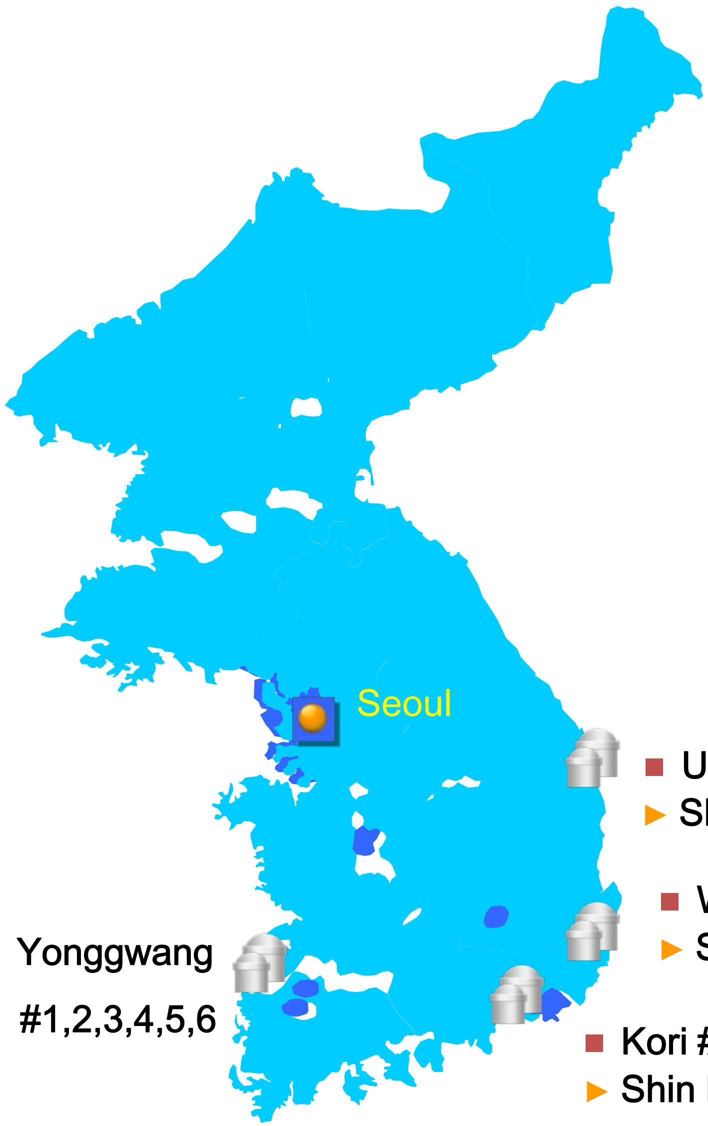
Phát triển APR1400

Hoàn thành 4 lò phản ứng

Có 8 lò đang xây dựng

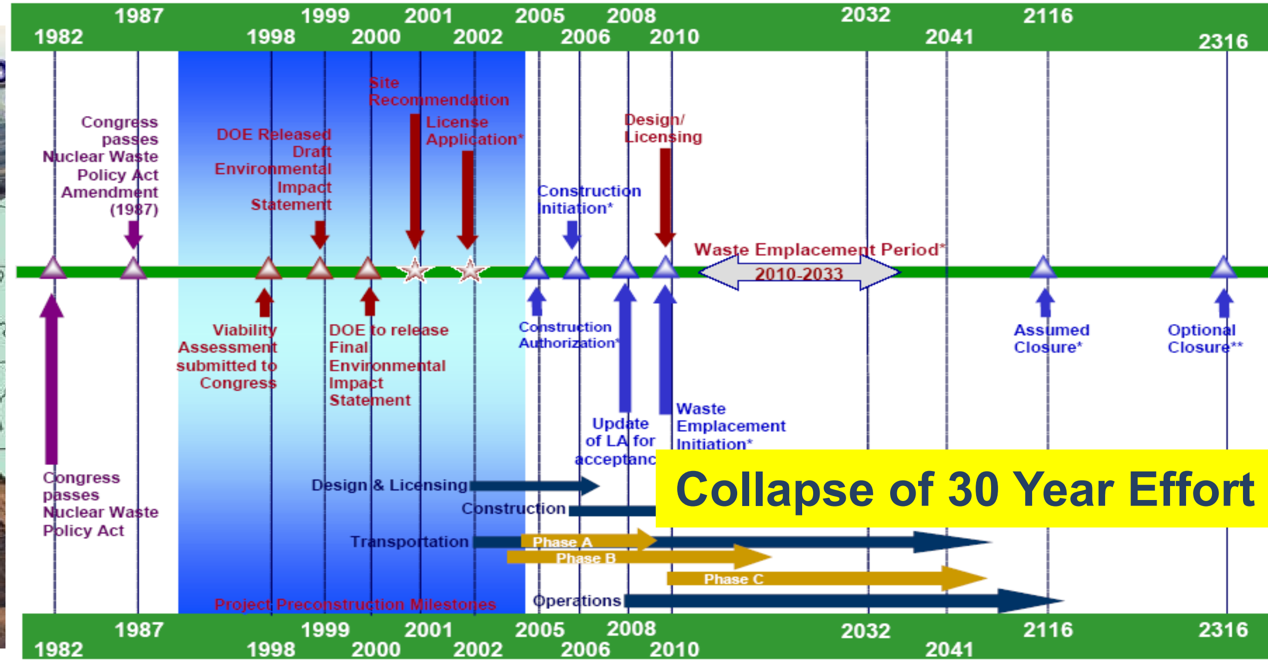
Korean nuclear power generation

Site	In Operation	Under Const.	Total
Kori	5 (4,137)	4 (4,800)	8 (7,937)
Wolsong	4 (2,779)	2 (2,000)	6 (4,779)
Yonggwang	6 (5,900)	-	6 (5,900)
Ulchin	6 (5,900)	2 (2,800)	8 (8,700)
Total	21 (18,716)	8 (9,600)	28 (27,316)



- Ulchin #1,2,3,4,5,6
- ▶ Shin Ulchin #1,2
- Wolsong #1,2,3,4
- ▶ Shin Wolsong #1,2
- Yonggwang #1,2,3,4,5,6
- Kori #1,2,3,4
- ▶ Shin Kori #1,2,3,4

Challenge: Spent Nuclear Fuels and HLW



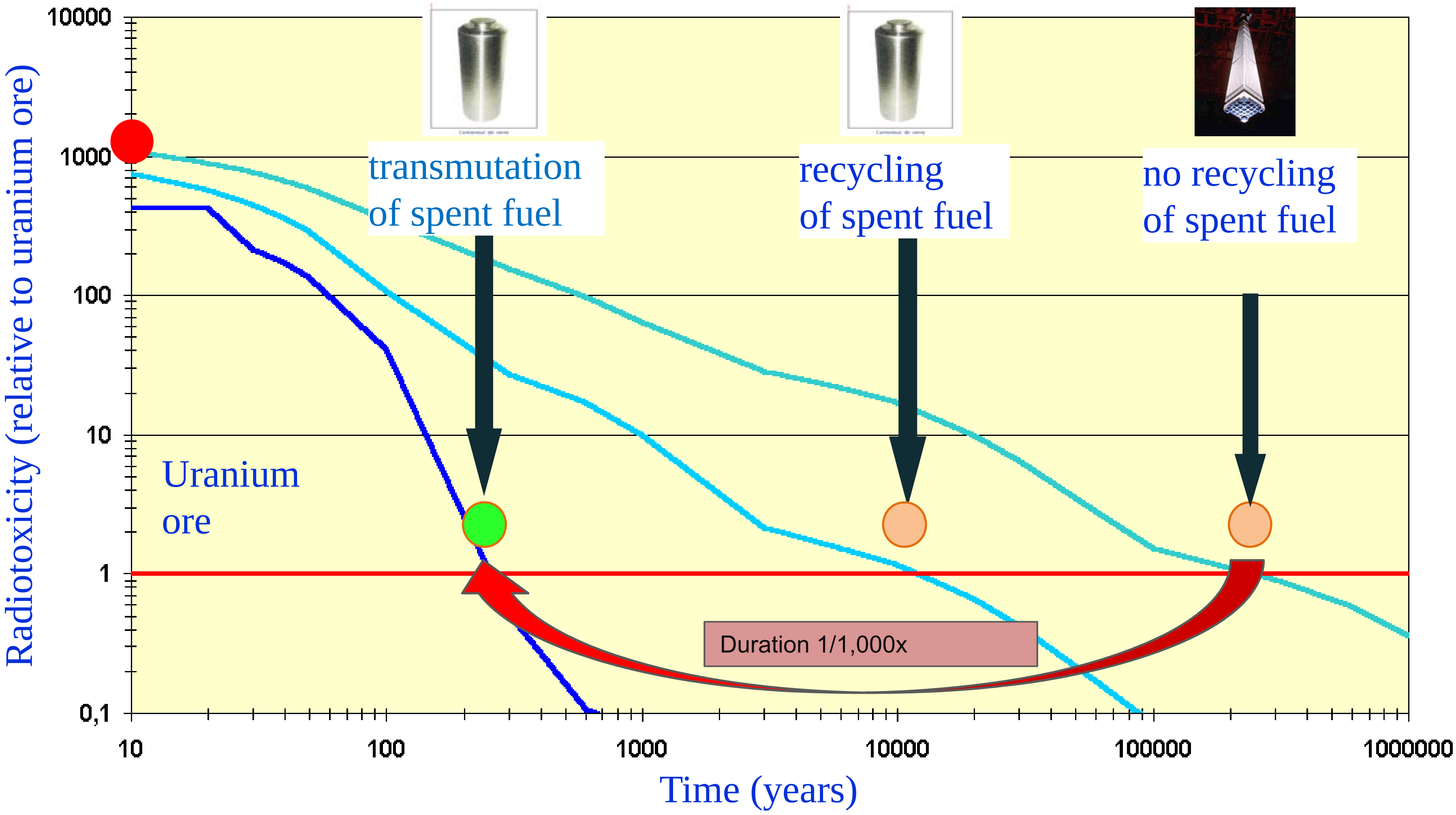
Collapse of 30 Year Effort

Collapse of 20 Year Effort

- Nuclear renaissance faces international opposition due to Spent Nuclear Fuel (SNF)/HLW Repository
- LILW is widely accepted.

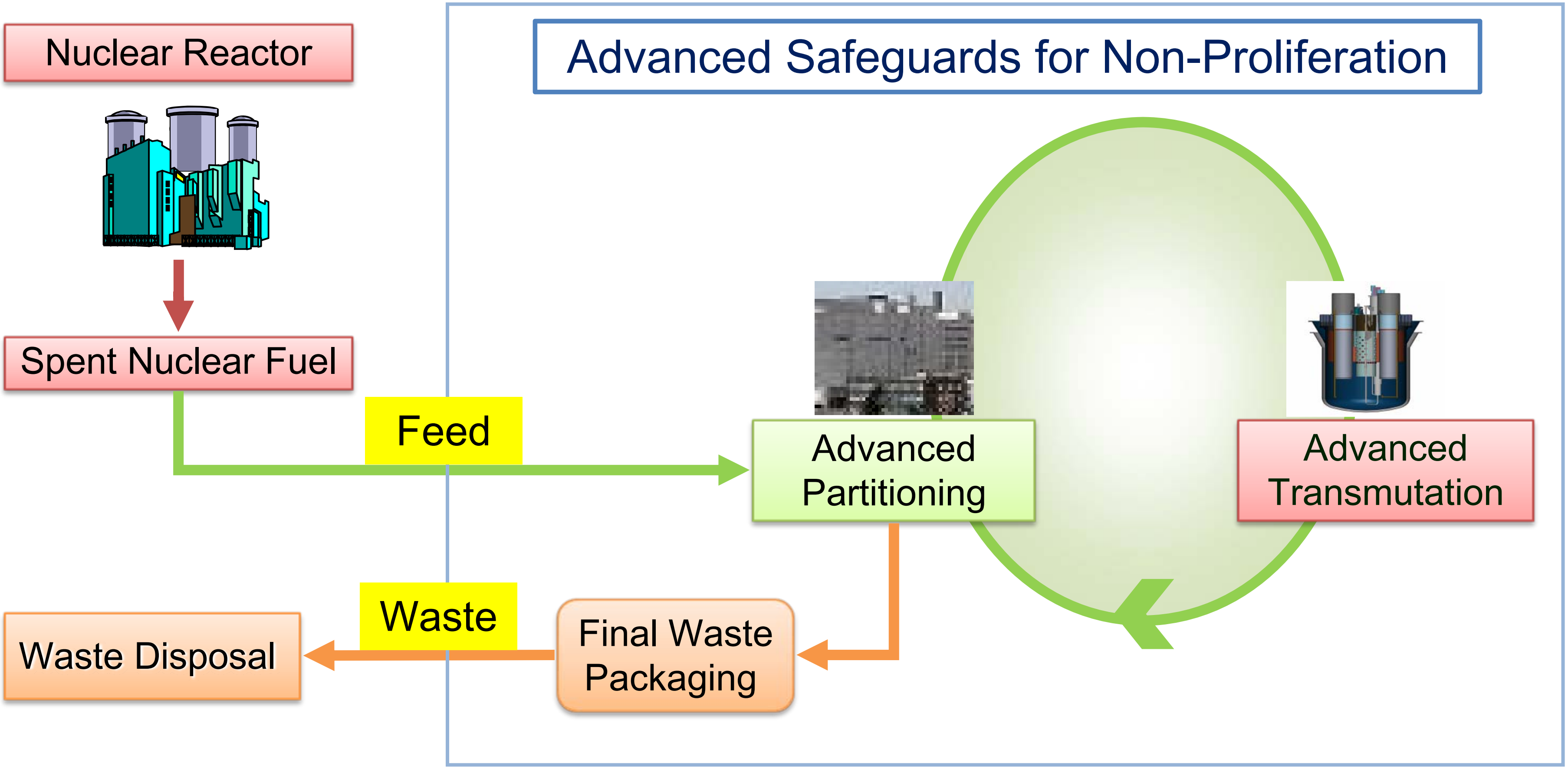
Race for hosting LILW Repository

Advanced P&T to Shorten Radiotoxic Period



Prof. H.A. Abderrahim

Advanced Partitioning & Transmutation

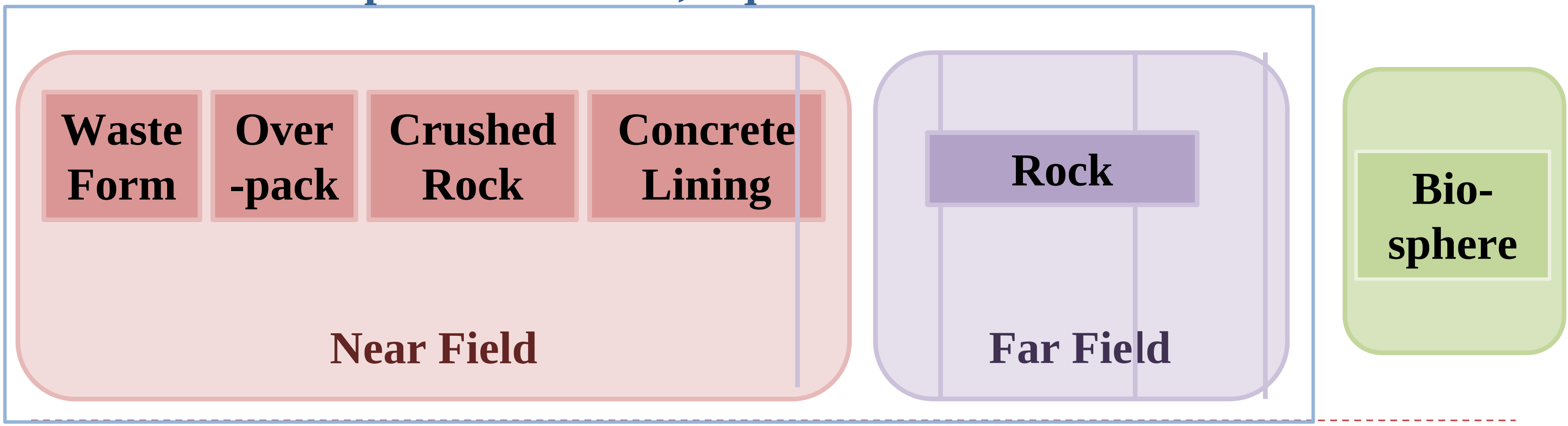


$$\text{Decontamination Factor} = \frac{\text{Feed to P\&T}}{\text{Waste from P\&T}}$$

Key Elements for Decontamination in Advanced P&T

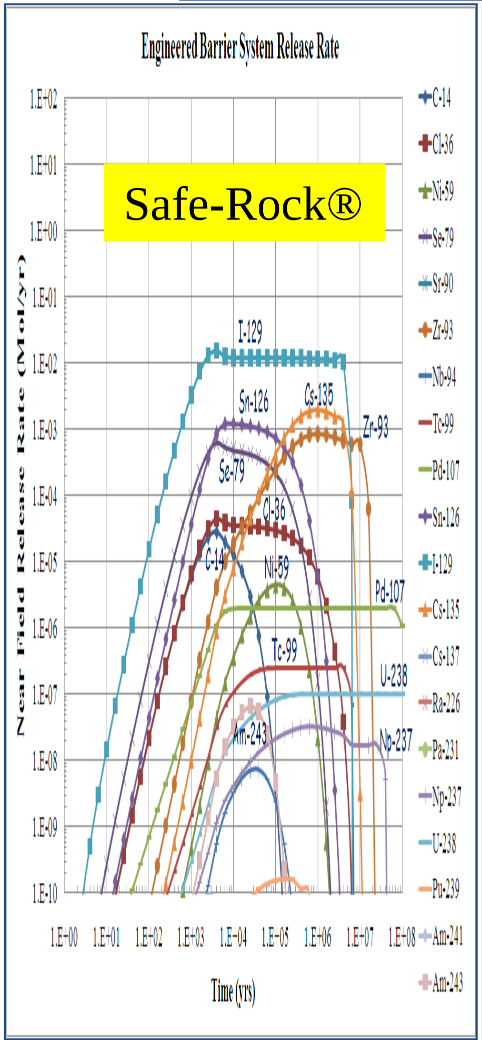
- KHNP's *S*afety *A*ssessment Code for *F*acilitating Groundwater Release *E*valuation-*ROCK* Cavern Disposal (SAFE-ROCK ®).
- Characteristics of SAFE-ROCK ®
  1. Evaluate release of radionuclide to the groundwater in saturated zone.
  2. Consider time-dependent sorption coefficient, groundwater infiltration & flow rate for system evolution analysis.
  3. Perform deterministic analysis for Near/Far Field.

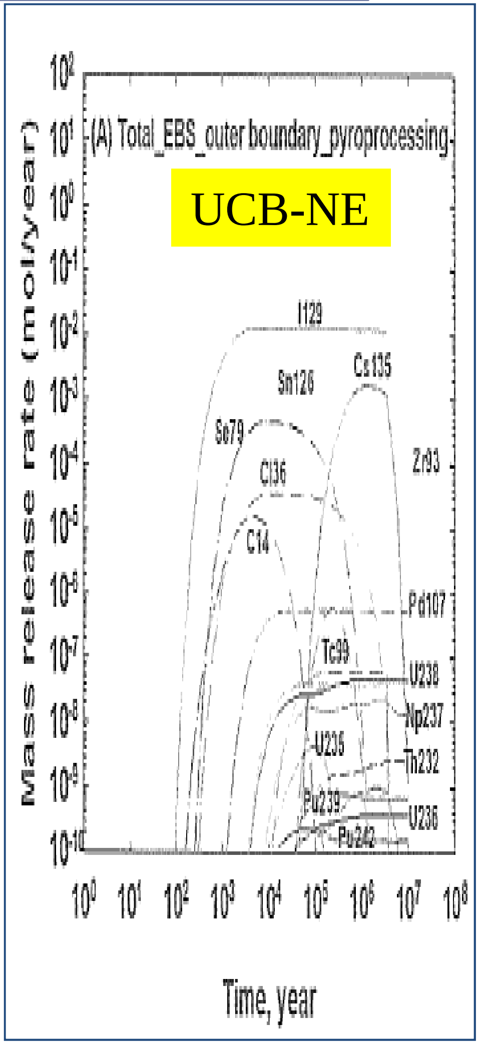
Basic Model of SAFE-ROCK ® :
Compartment model, Equivalent Porous Medium



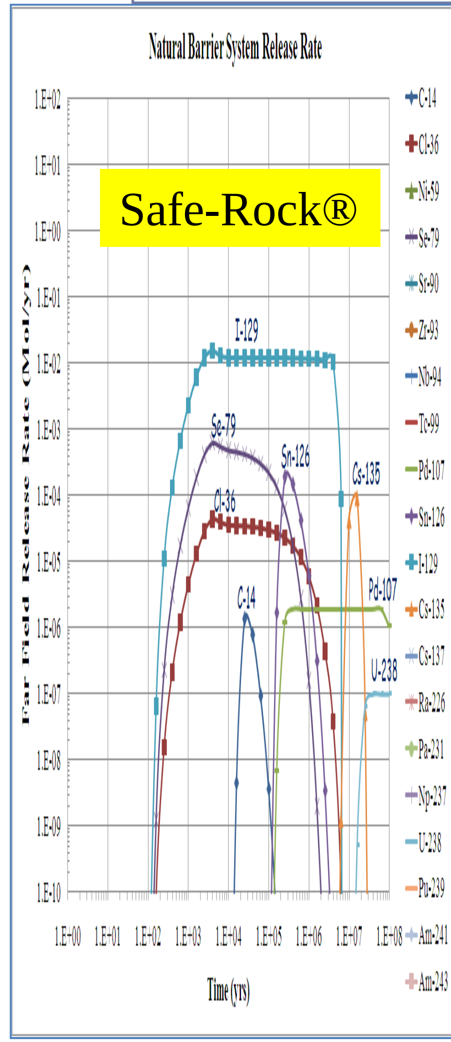
Key Elements for Decontamination in Advanced P&T

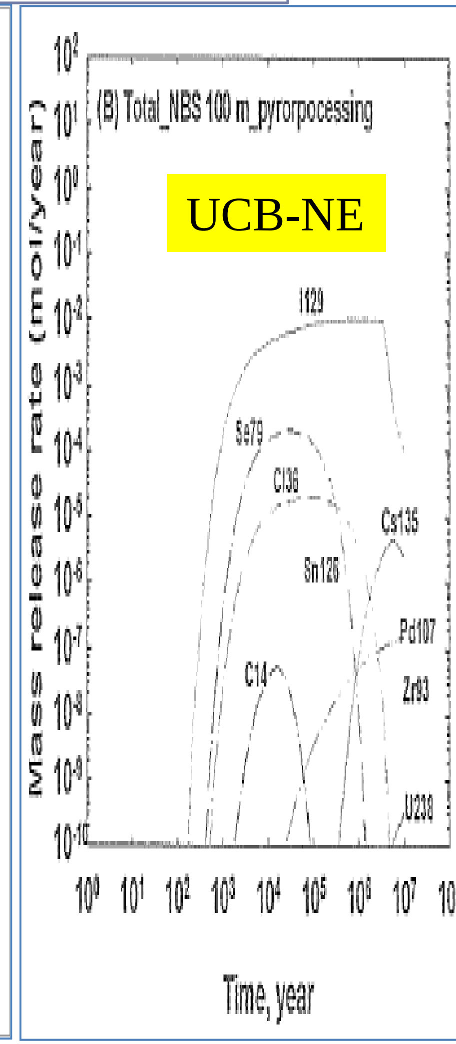
1. Outer Boundary of Engineered Barrier(EBS)





2. Outer Boundary of Natural Barrier (NBS)

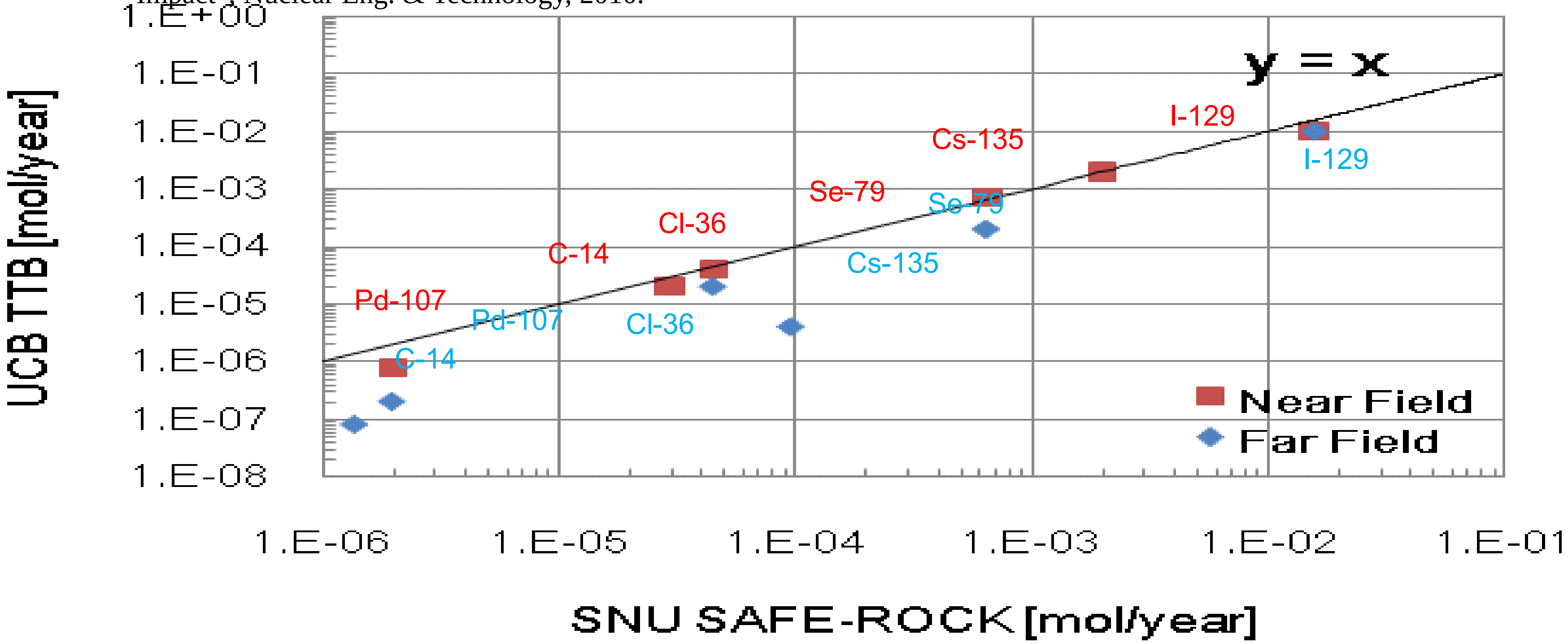




Key Elements for Decontamination in Advanced P&T

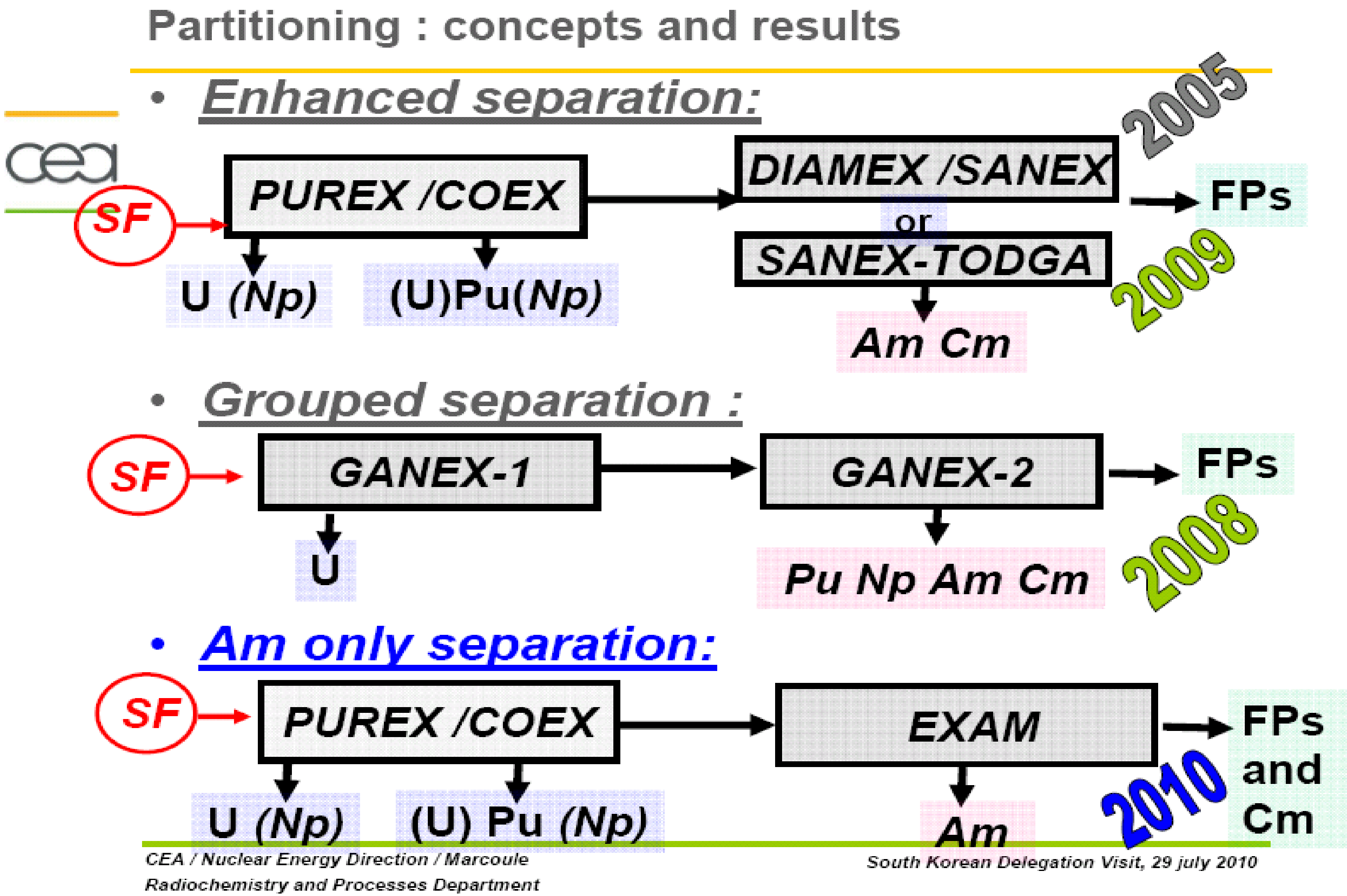
- All SNF from 24 PWR's 40 years of operation: 26,000 MTHM
- Direct Disposal into Granite Bedrock in Reducing Environment
- Korean Safe-Rock ® Model vs. UC Berkeley Model (UCB-TTB)
  - Key Migration & Intrusion Dose : U, Pu, Np, Am, Cm, Tc
  - Key Migration Dose Source: I, Cs, Se, Cl, Pd, C
  - Key Heat Source: Cs, Sr

Yoon et al., "A Systems Assessment for the Korean Advanced Nuclear Fuel Cycle Concept from the Perspective of Radiological Impact", Nuclear Eng. & Technology, 2010.



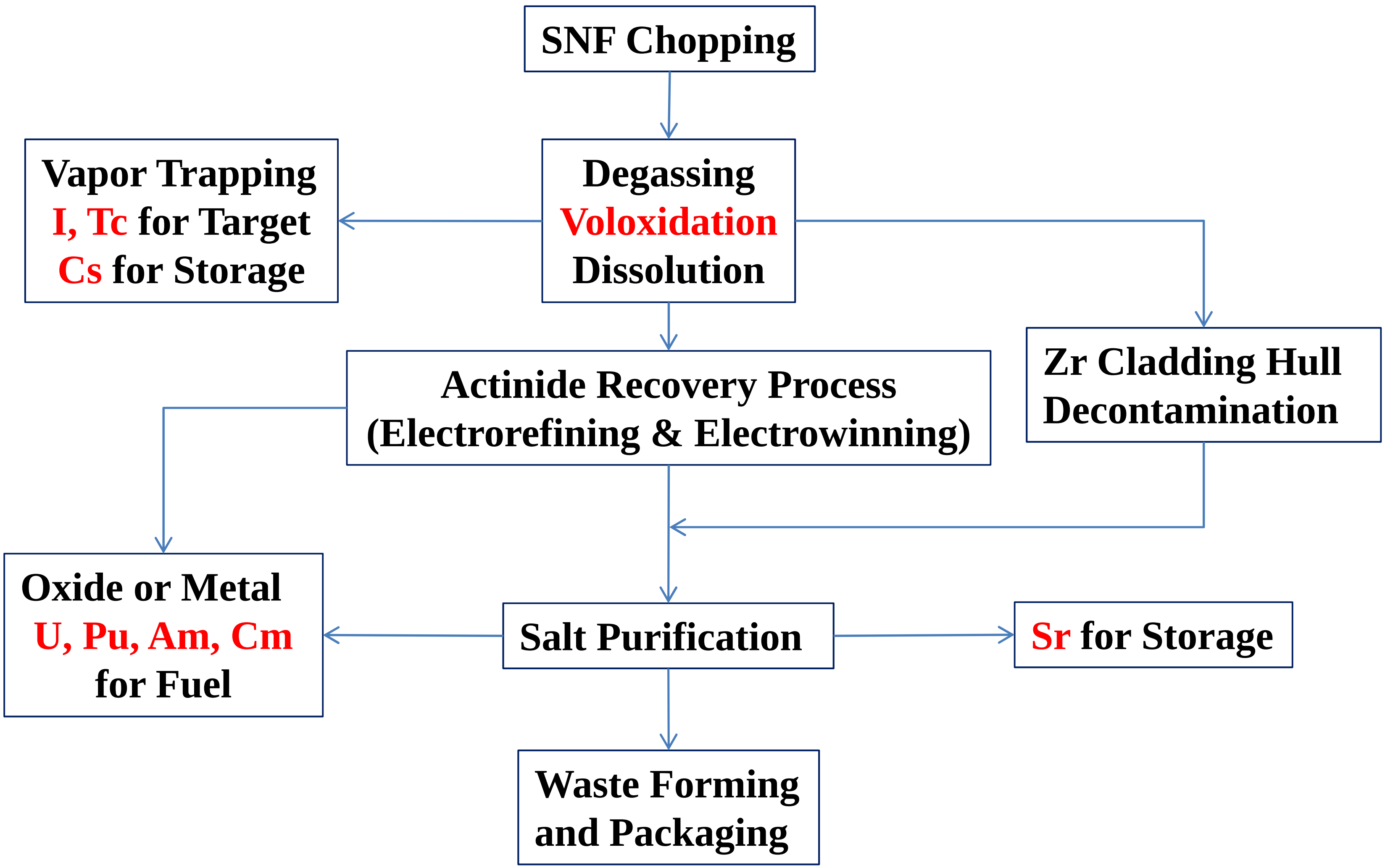
DF in Aqueous Process: ACSEPT

- DF>1,000 demonstrated for TRU's in continuous processes (2010)

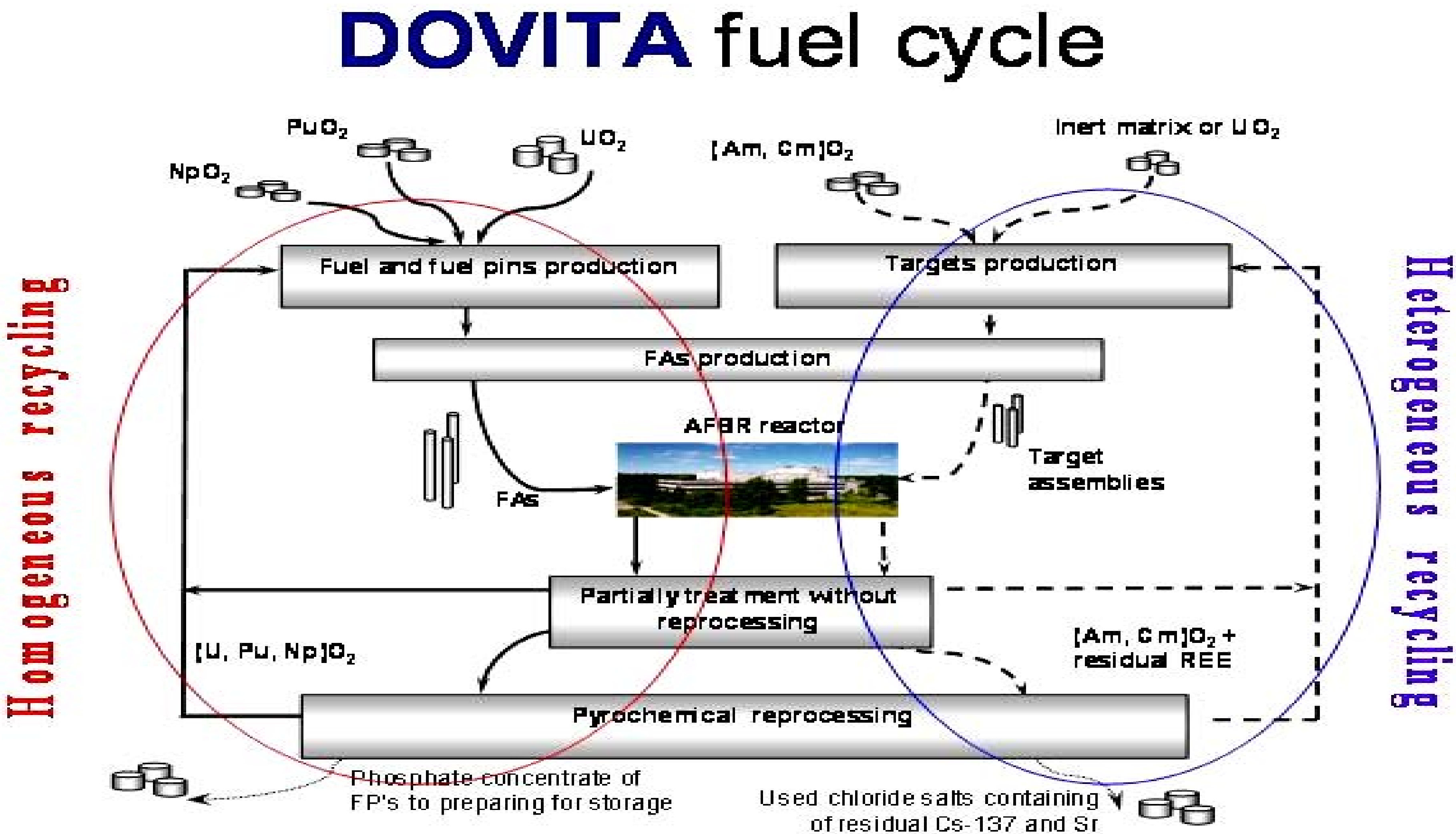


Advacnced Pyrochemical Process

- DF= 260~1,000 for TRU in batch processes (1999)



Advanced Pyrochemical Process



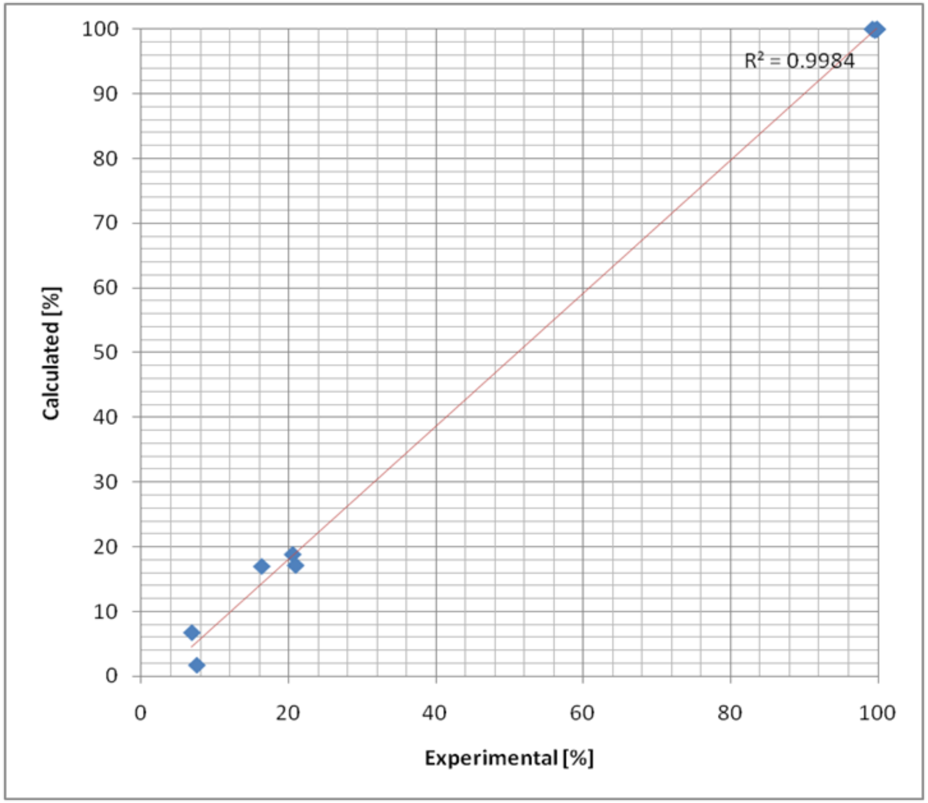
*A. Bychkov, RIAR(2009)

Advanced Pyrochemical Process

Advanced Pyroprocess : Experimental Data on DF*

- Recovery Yield (RY) after Five-stage Con-current Extraction (CRIEPI)

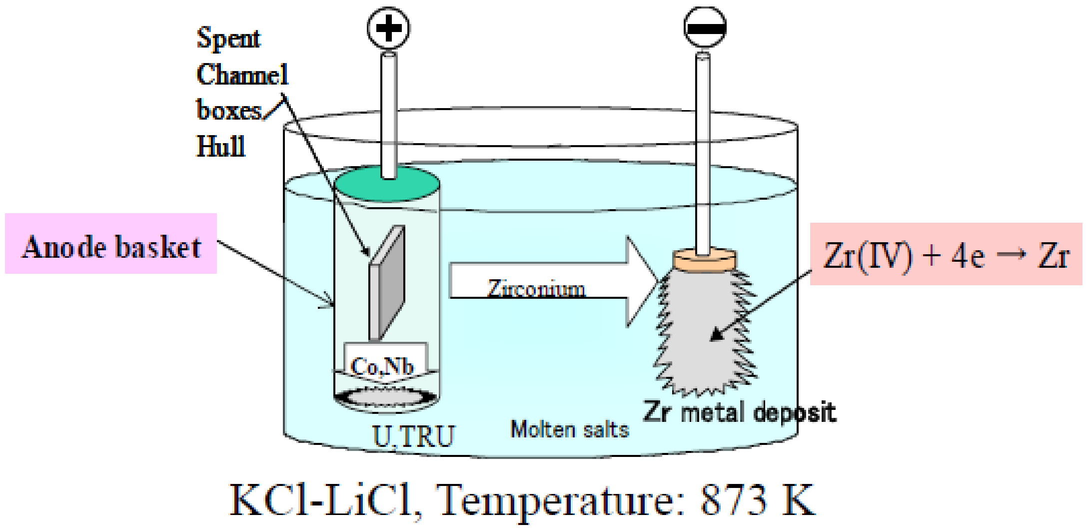
RY(%)	Experimental	SNU Model	DF
U	99.3	100	14,300
Np	99.93	99.998	1,429
Pu	99.94	99.989	1,667
Am	99.66	99.846	294
Ce	20.54	19.868	
Pr	20.94	18.092	
Nd	16.34	17.932	
La	6.85	7.146	
Gd	1.752	1.814	



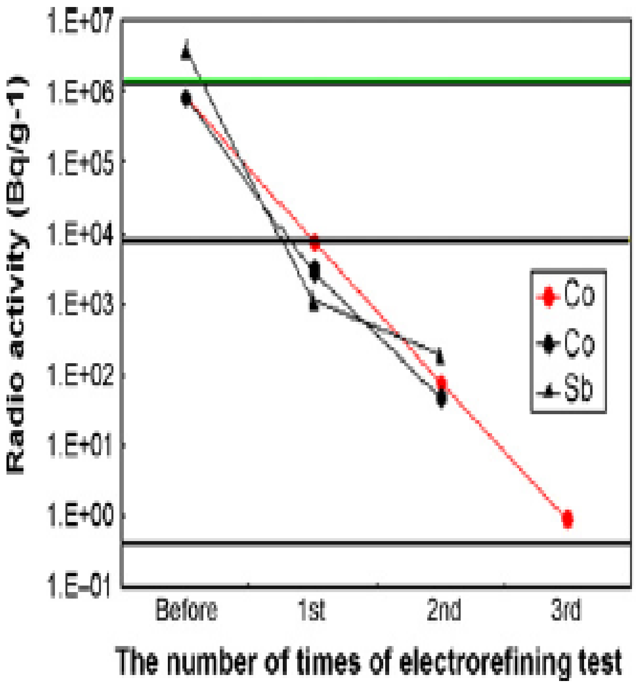
*Kinoshita et al., CRIEPI (1999)

Advanced Pyrochemical Process

- DF=10^4 in Zr Hull electrorefining
  - From Toshiba's research in 2008



Schematic diagram of hull electrorefining



The Results of Hull Electrorefining Tests

LILW-GD (or Intermediate Level Waste)

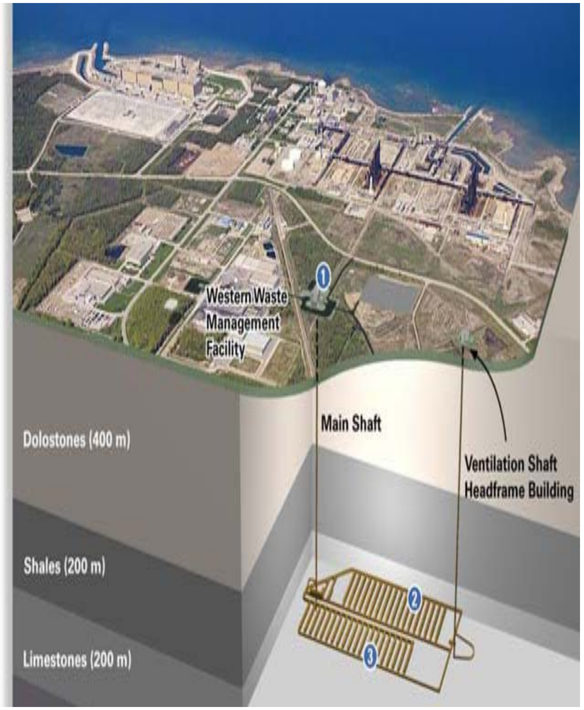
- Advances in Partitioning Technology meet the need for LILW-GD (ILW)

Element	DF-lowerbound for Advanced P&T Assessment	DF achieved by Advanced Aqueous Partitioning (continuous column)	DF achieved by Advanced Pyrochemical Partitioning (batch)
U	1,000	10,000	14,300
Np	1,000	1,000	1,429
Pu	1,000	1,000	1,667
Am	200	1,000	264
Cm	200	1,000	N.A.
I	50		100
Tc	50	1,350	50
Cs	10	10	10
Sr	10	10	10

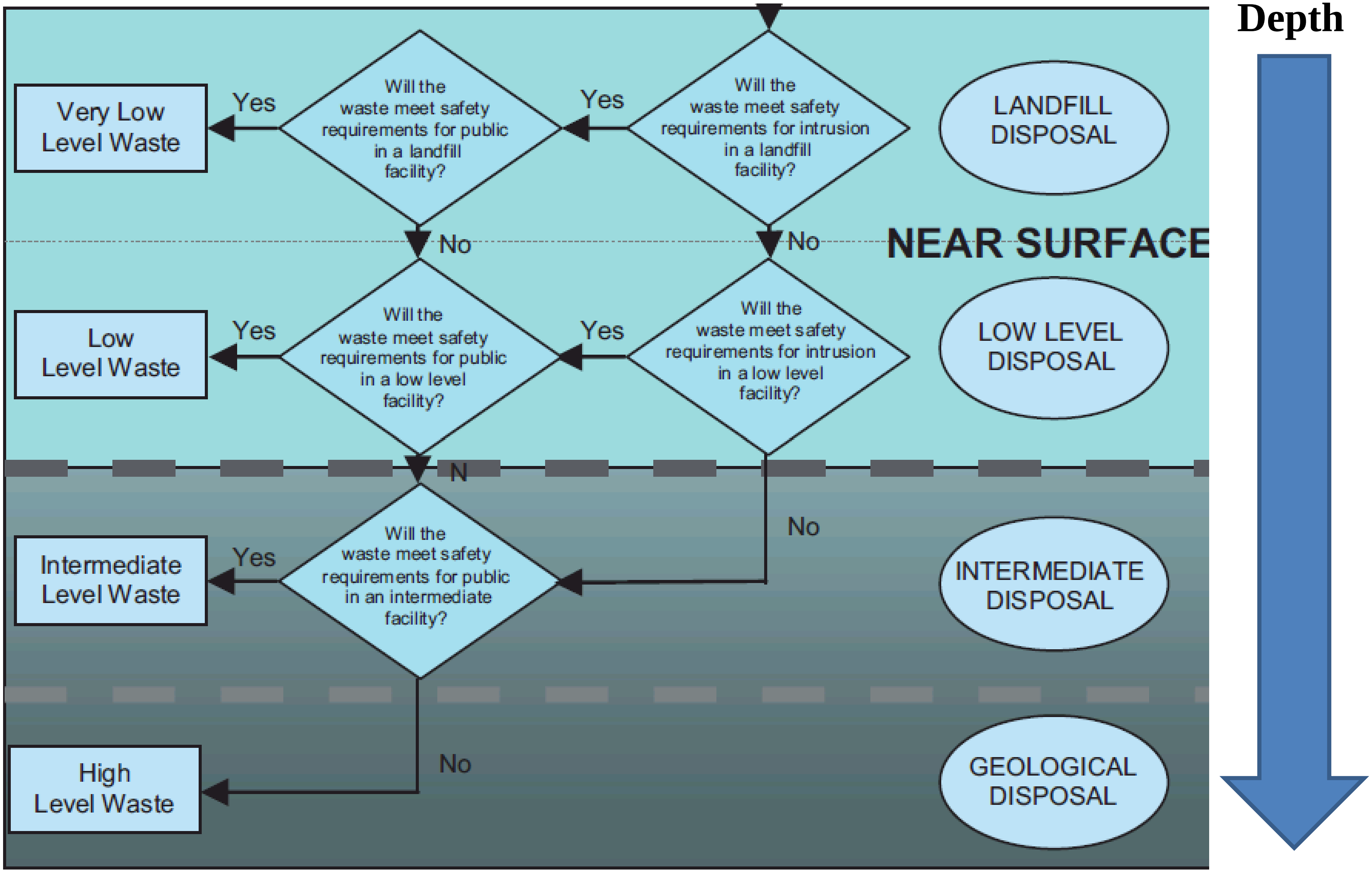
Geological Disposal with Advanced P&T

Disposal Depth	Human Intrusion	Leaching & Migration
Near Surface Disposal	Dose for intrusion Ex) 100 mRem/yr ➔nuclide concentration Eg.) 4,000 Bq/g	Biosphere radiation dose limit Ex) 10 mRem/yr
Deep Geological Repository	The amount of nuclear waste that can be excavated is drastically reduced and its dose rate is low even when the concentration is significantly raised.	10 mRem/yr ➔Low migration dose rate due to nuclide diffusion and dilution in deep geological repository.

Canadian RWMO Approach for LILW (Decommission Wastes)



Standards: IAEA Waste Classification (2009)

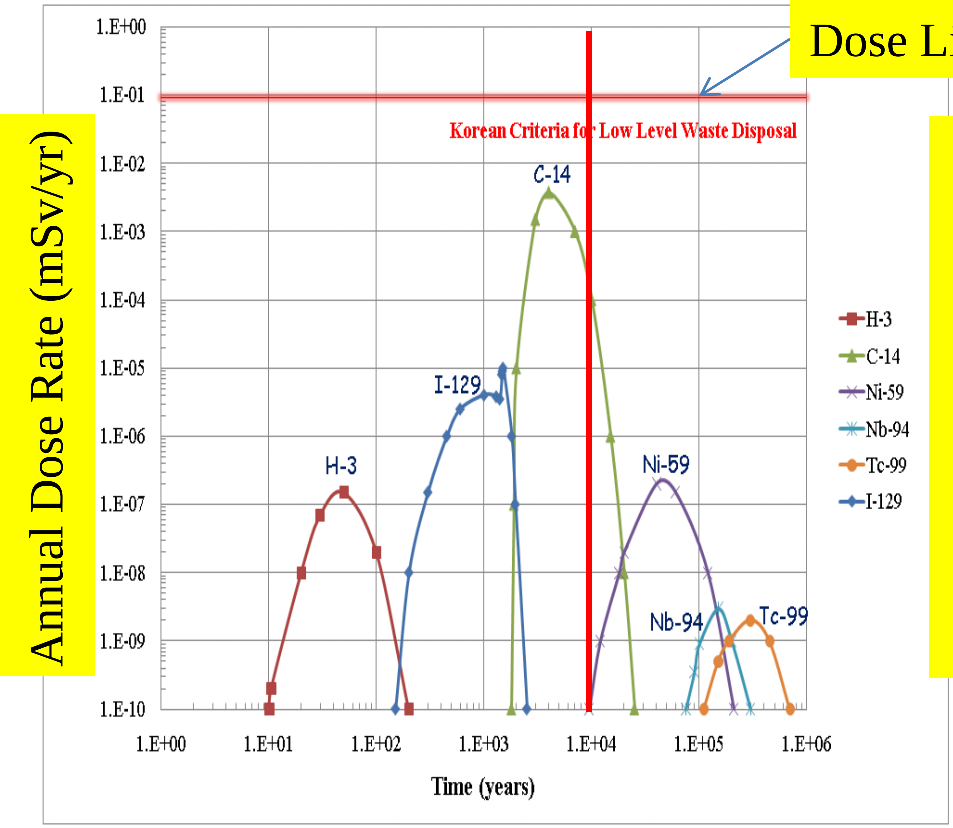


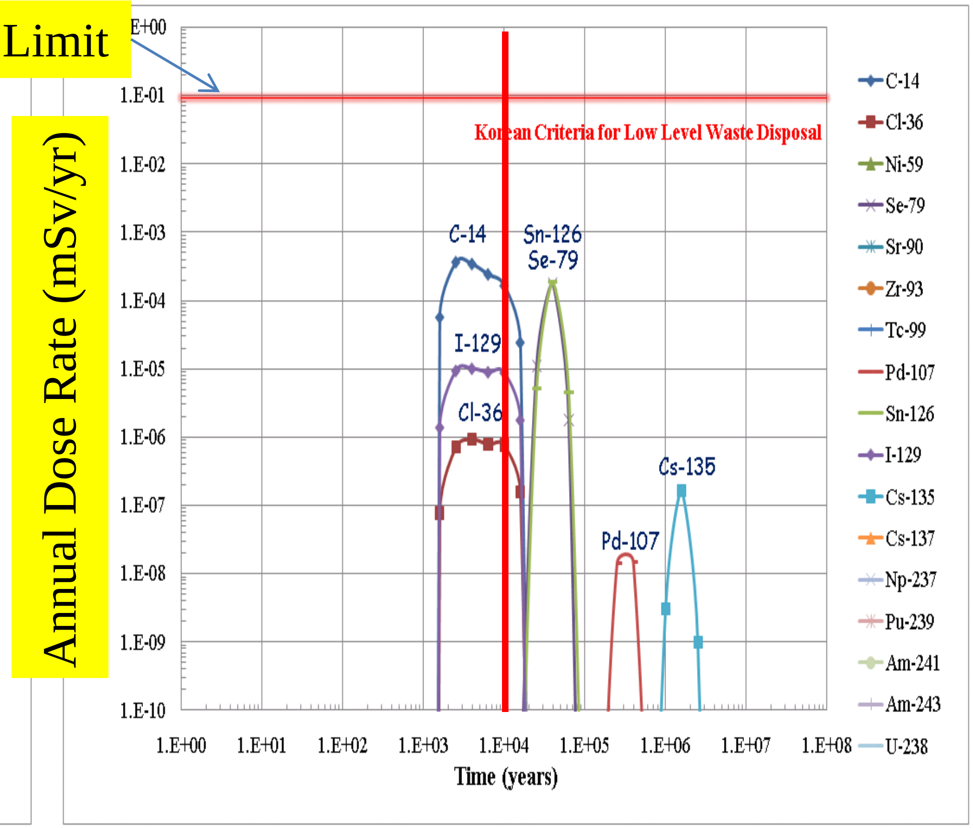
IAEA GSG-1 (2009)

LILW-SD vs. LILW-GD

LILW-SD Site: Near Surface Disposal (Predicted for the First Stage of Wolsung Site in Gyongju, Korea)

LILW-GD: Advanced P&T Wastes for SNF form 40 years of 24 PWR operation in Geological Disposal in Korean Granite Bedrock

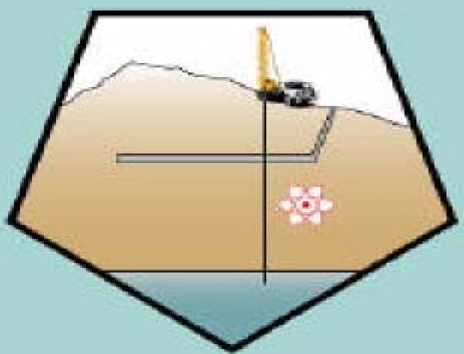


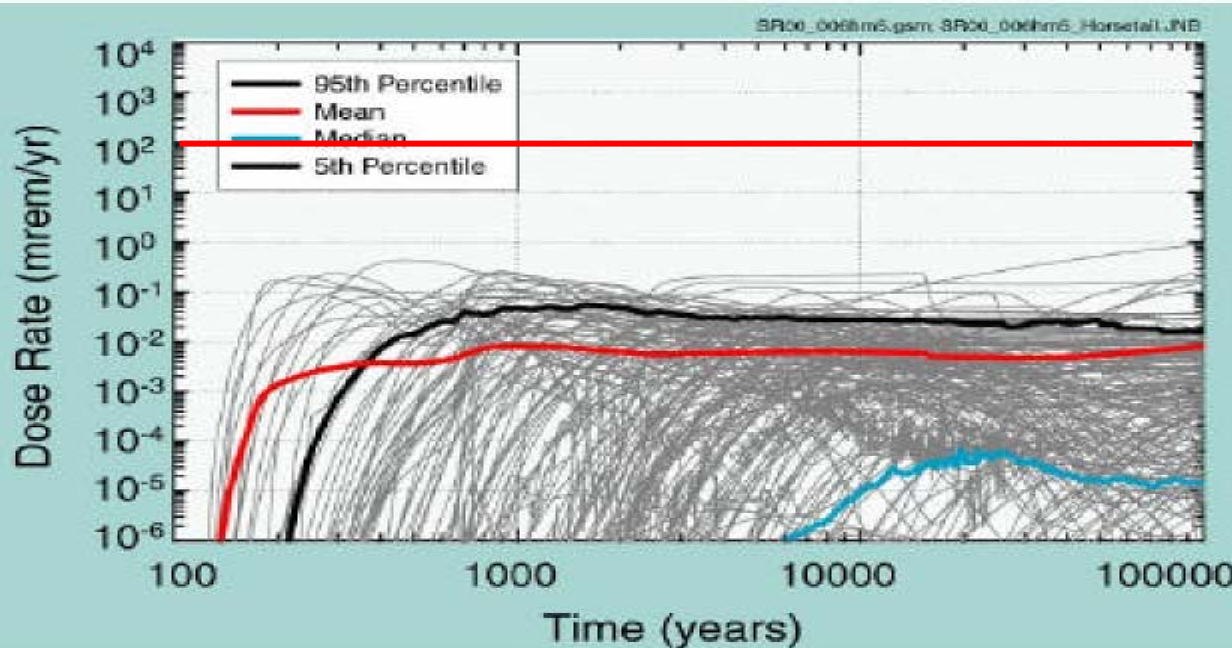


*Reference: Joo Wan Park et al., A Safety Assessment for the Wolsong LILW Disposal Center: As a part of safety case for the first stage disposal, Journal of the Korean Radioactive Waste Society, Vol. 6(4), P. 329-346, 2008.

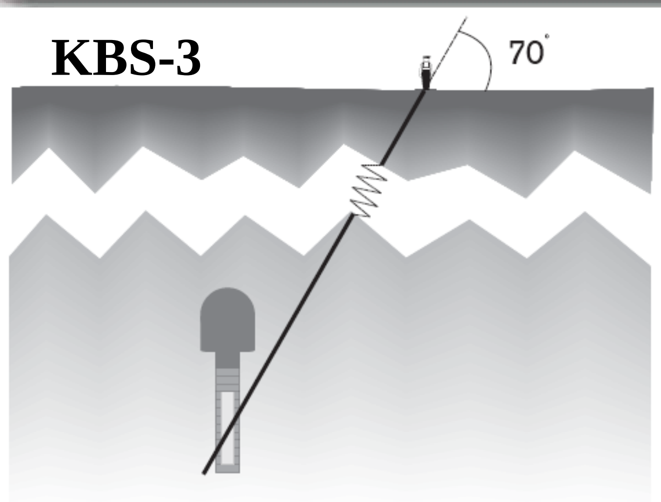
Human Intrusion Scenario: YMP & KBS-3

YMP





KBS-3



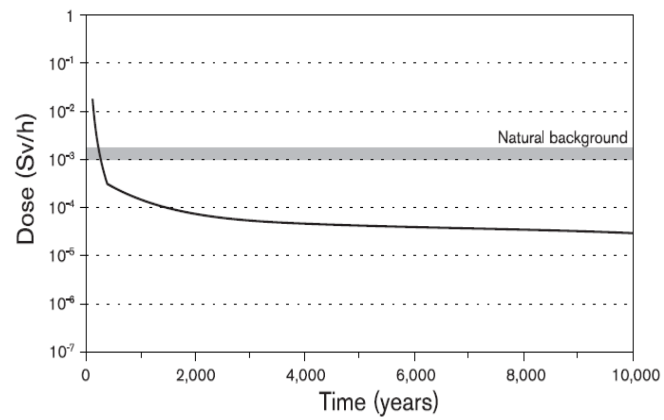


Figure 12-8. Dose to drilling personnel as a function of time after repository closure. The exposure time is one hour. The personnel inhale contaminated dust and are exposed to external irradiation. The radiation sources and the position of the exposed individual in relation to them are shown in Figure 12-7.

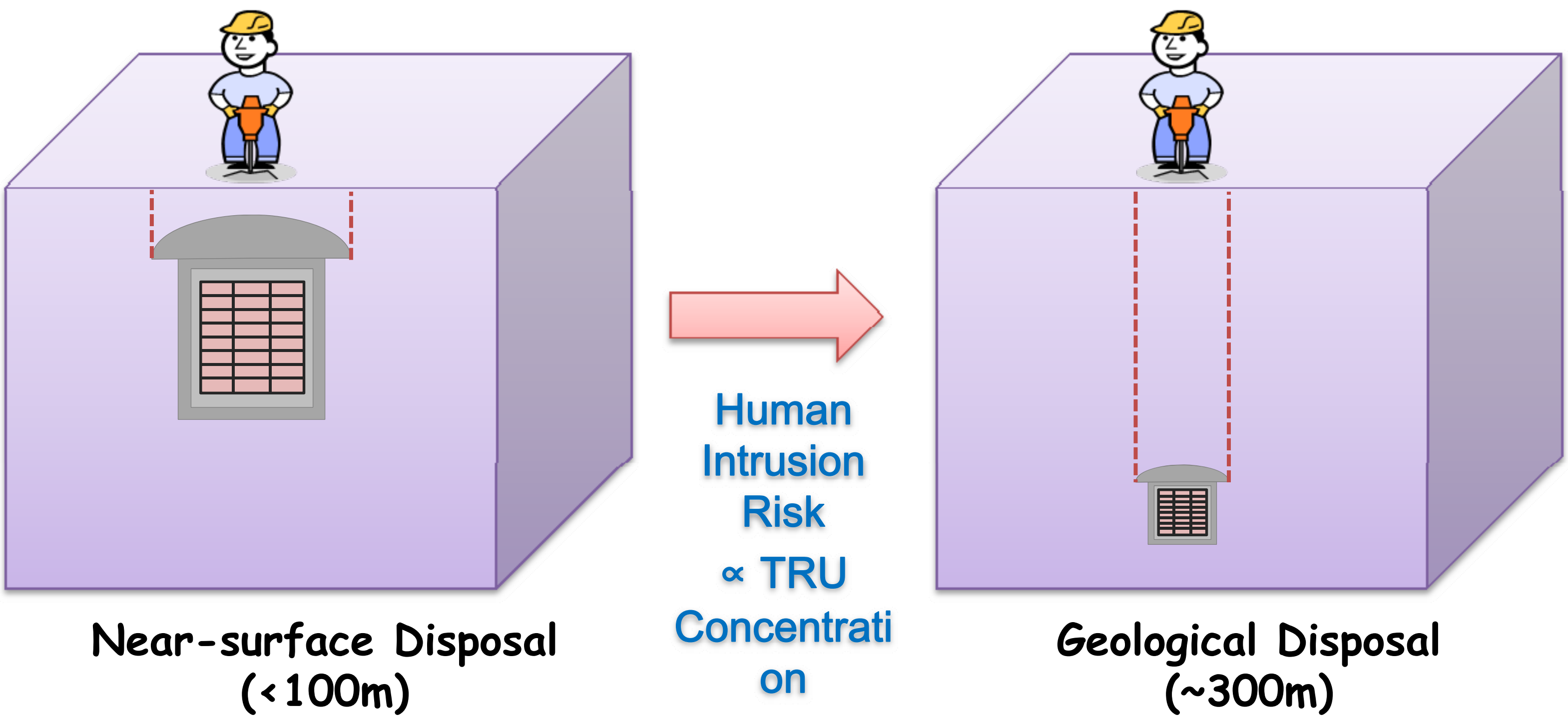
Human Intrusion Scenario & Advanced P&T

- US Rule (10 CFR 63.321)

  (1) 0.15 mSv (15 mrem) for 10,000 years following disposal;

  (2) 1.0 mSv (100 mrem) after 10,000 years, but within the period of geologic stability (~1,000,000 year).

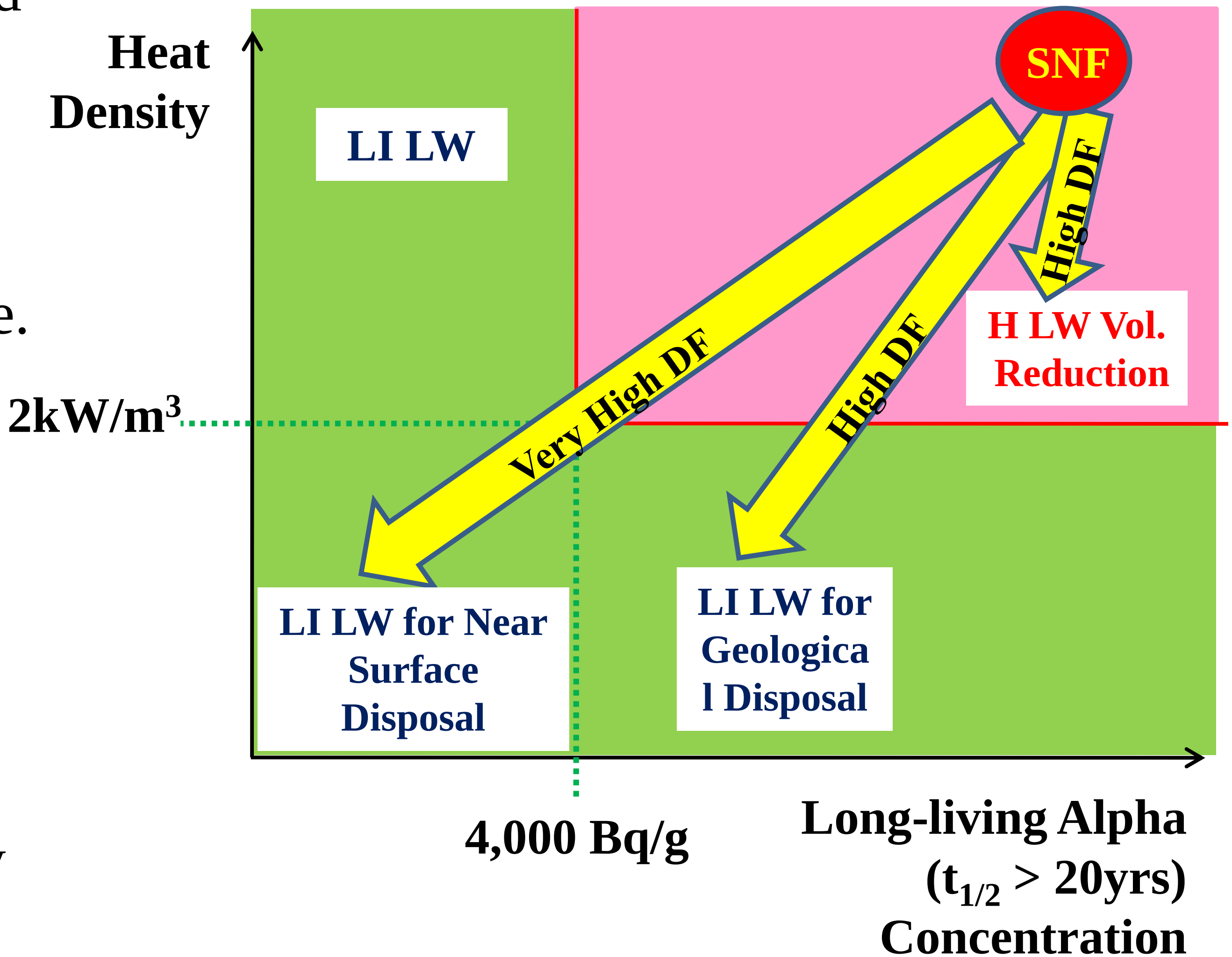
- Korean Wolsung LILW-SD Site Assessment <1 mSv/yr
- Advanced P&T has very large safety margin against intrusion.



Summary : Advanced Partitioning & Transmutation

- Safety of LILW-GD with Advanced P&T can be equivalent to that of LILW-SD, both in Migration Dose and Intrusion Dose.
- LILW-GD with Advanced P&T can greatly reduce waste volume.
- In the long-run, isotopic partitioning & transmutation may lead to LILW-SD

Korean Radioactive Waste Classification



Summary : Advanced Partitioning & Transmutation

- LILW-GD (or Intermediate Level Waste) vs. HLW

	SNF	HLW	LILW-GD (ILW)	LILW-SD (LLW)
Radiotoxic Period (yr)	~300,000	~5,000	300	300
Heat	Very High	High	Low	Very Low
Prediction Confidence	Low	Low	High	High
Safety Assessment Period (yr)	1,000,000	1,000,000	10,000	10,000
PR-PP	Very Low	Low	High	Very High
Waste Volume	1	~0.25	<1	>>1 (without isotopic partitioning)

Needs for Global Standards on LILW-GD (ILW)

UK Guidelines

- ILW is radioactive waste with radioactivity levels exceeding the upper boundaries for Low Level Waste (LLW):
  - Alpha emitters greater than 4 GBq/tonne. (4,000 Bq/g)
  - Beta/gamma emitters greater than 12 GBq/tonne.
  - Waste that does not need radiological self-heating to be taken into account in the design of storage or disposal facilities.
- ILW arises from:
  - Reactor operation
  - Decommissioning
  - Spent fuel reprocessing
  - Research facilities
  - Historic ILW in legacy storage

Needs for Global Standards on LILW-GD (ILW)

- International Task Force
  - State-of-the-art Review of Advanced P&T
  - Waste Classification for LLW Class A,B, C & GTCC (US)
  - LILW(ILW) Specification (IAEA, UK, US)
  - LILW-GD (ILW) Cost-Benefit Assessment
- IAEA Safety Guide
  - SNF Management Planning Guidelines
- Proliferation Resistance – Physical Protection
  - Multinational Approach