2010 Int'l Seminar on Spent Fuel Storage,
nov.15-17, Tokyo, Japan

Spent Fuel Management and Storage in Korea

2010. 11. 15

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Contents

- **Spent Fuel Management**
  - ✓ **NPP & SF Status**
  - ✓ **Policy**
  - ✓ **Storage**

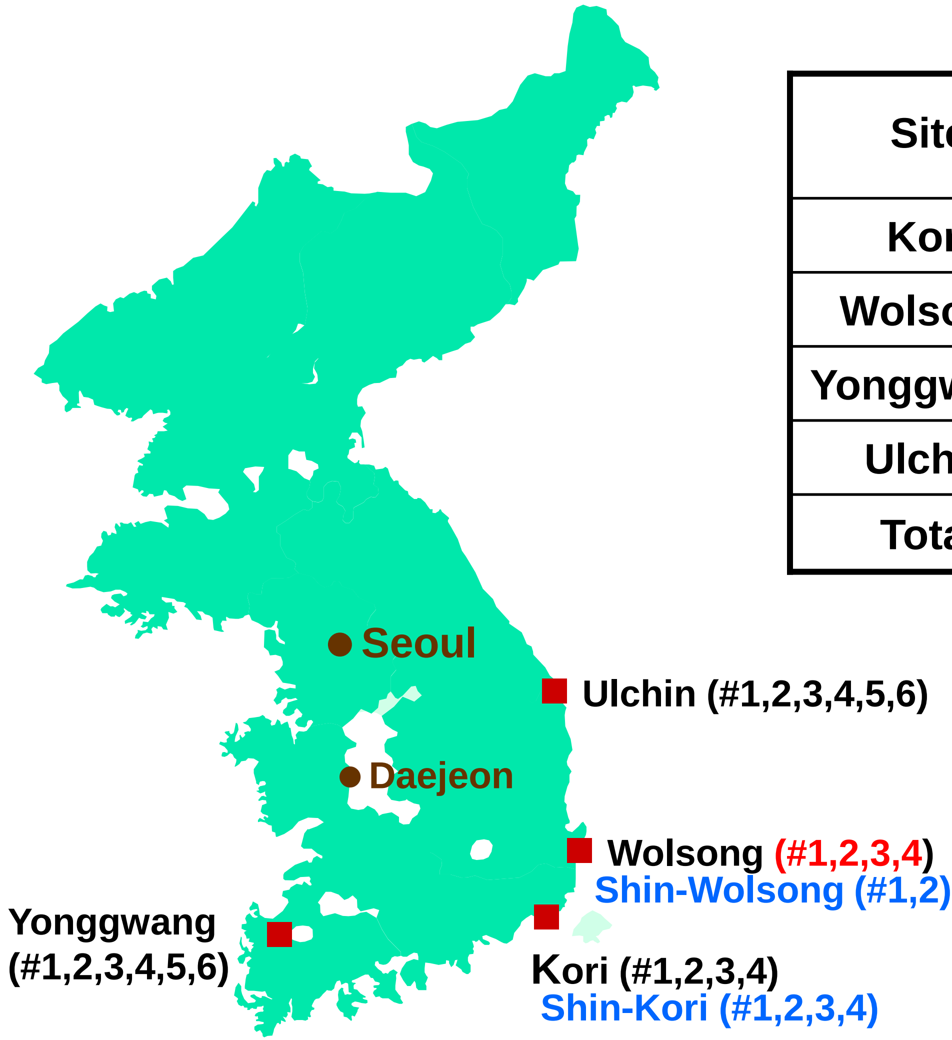
- **R&D Activities for Dry Storage**
  - ✓ **Storage System**
  - ✓ **Spent Fuel Integrity**

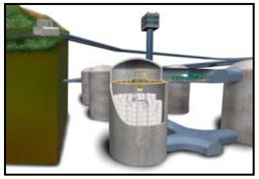
Nuclear Power Plant in Korea

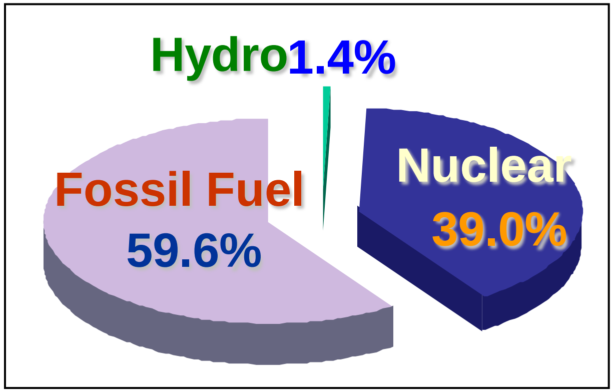
Units (MWe), As of Oct. 2010

Site	In Operation	Under Construction	Total
Kori	4 (3,137)	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 (2,400)	8 (8,300)
Total	20 (17,716)	8 (9,200)	28 (24,516)

❖ ~10 NPPs will be added in 2030.

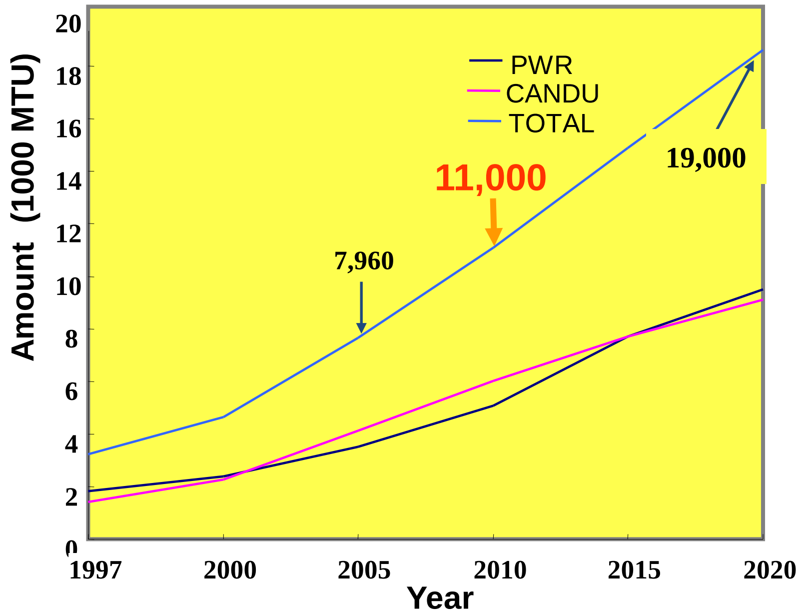




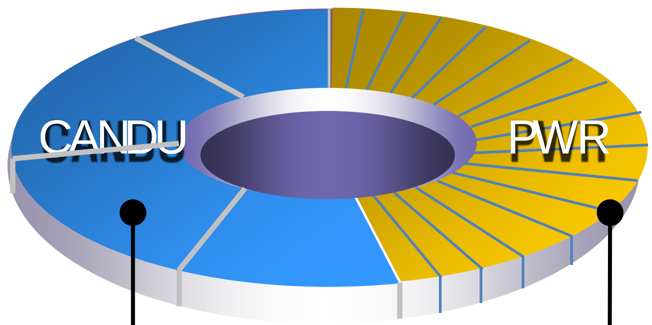


Spent Fuel Amount

SF Amount



Annual arising : 700 tU/Yr



- ~100 tU/yr
- 4 units
- ~400 tU/Yr

- ~20 tU/yr
- 16 units
- ~320 tU/yr

NPP Site	Capacity (ton)	Accu. (ton)	Expected Saturation (year)
Kori	2,190	1,784	2016
Yonggwang	2,670	1,753	2016
Ulchin	2,350	1,449	2017
Wolsong	9,440	5,886	2018
Sum	16,650	10,872	-

National Policy for RadWaste

253rd AEC's Decision (Dec. 2004)

- **Final repository for LILW should be constructed by 2008. → Delayed until 2012 for Safety Reason**
- **Spent Fuel Management**
  - **All spent fuel will be stored at plant sites until 2016.**
  - **Future national policy for SF management will be decided through public participation taking into consideration of national and international trends on policy and technology development.**

RadWaste Management Act

- This Act has been effective since January 1st, 2009.
- Key contents are:

  - Establish. of a new Org., responsible body for radwaste management

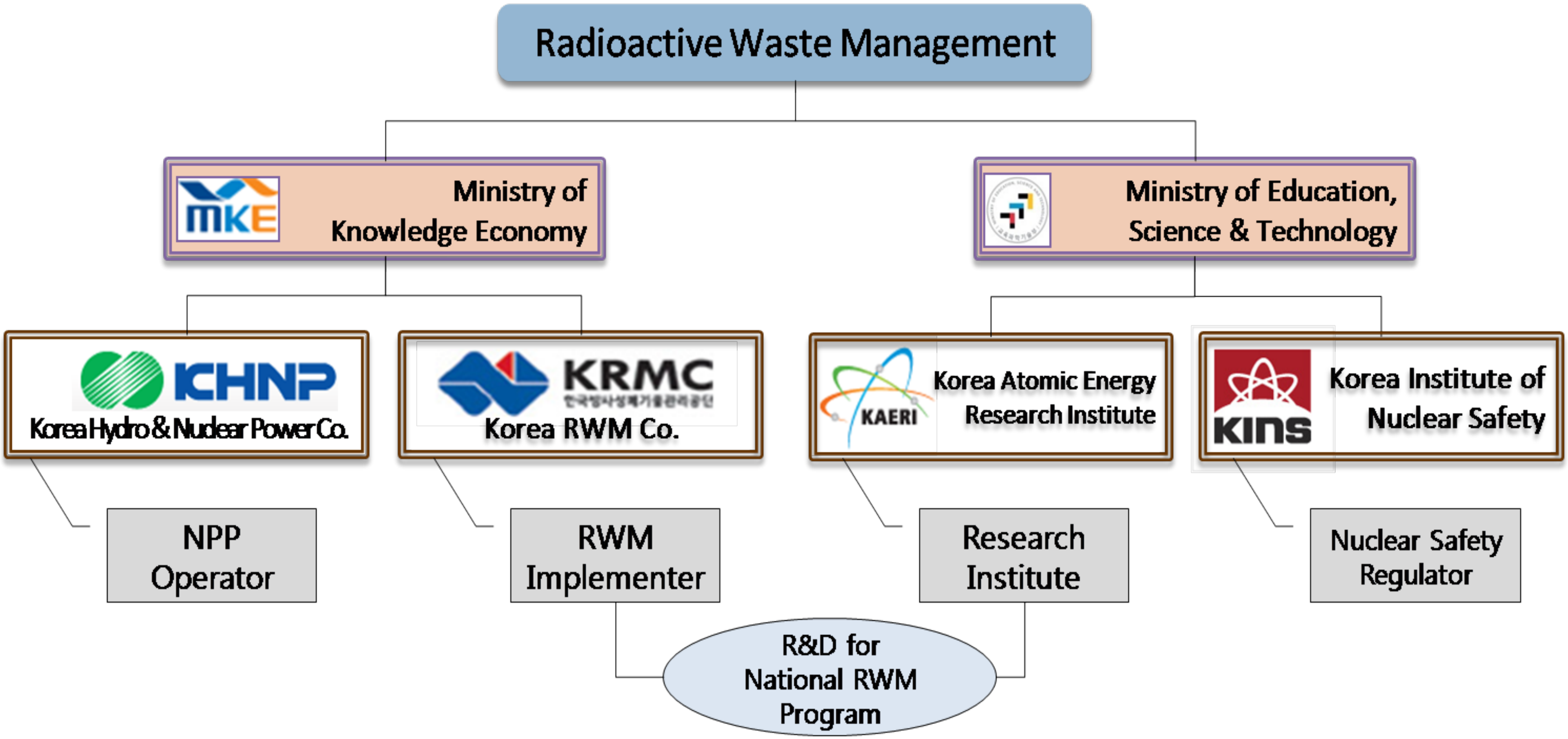
    → Korea Radioactive Waste Management Corporation (KRMC)

  - Establish. of the Radioactive Waste Management Fund

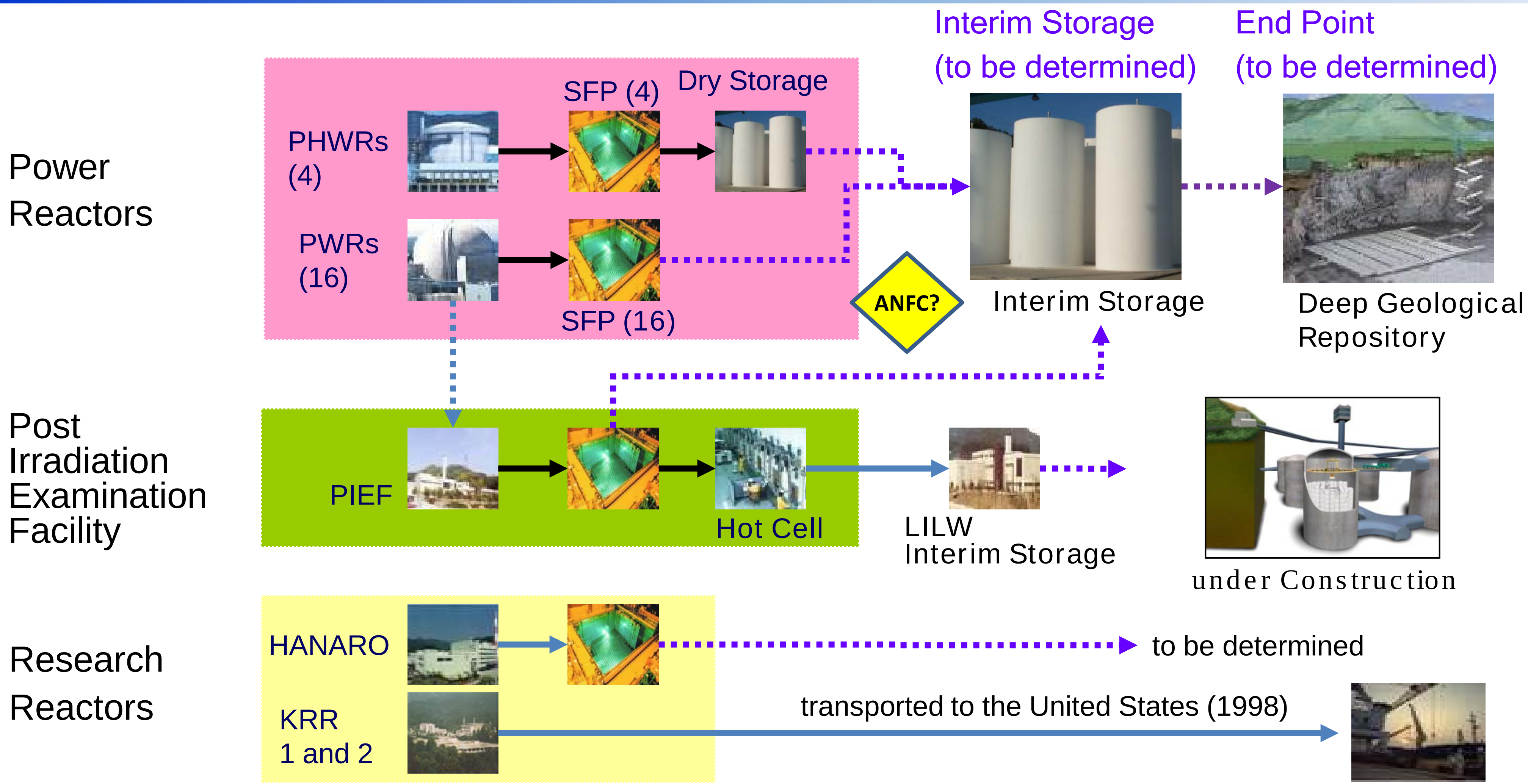
    which will be paid by the Radwaste generator.

    →KRMC is responsible for managing the RadWaste Fund

Organization related with RadWaste Management



Overall Plan for Radwaste Management



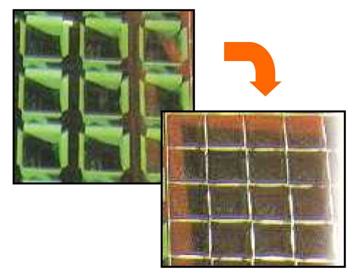
Spent Fuel Storage at NPP

* As of Dec. 2009 (Unit : MtU)

Plant Site	Capacity	Yr of Saturation	Accum.
Kori	2,253	2016	1,685
Yong-gwang	2,686	2016	1,623
Ulchin	2,327	2017	1,294
Wolsong	5,980(9,440)	2018	5,481
Total	13,246		10,083

- To secure the on-site storage capacity
  - PWR's storgae facility has been expanded by re-racking and transshipment.
  - CANDU SFs have been transferred to the dry storage facility (concrete silo) since 1991

- **Kori**
  - **Unit 1 : Transshipment to Units 3&4**
  - **Unit 3&4 : Addition of high density racks**
- **Ul chin**
  - **Unit 1&2 : Full re-racking of AR pool**
- **Young kwang**
  - **Unit 1 : Transshipment to Units 3&4**
- **Wol song**
  - **Unit 1 : 300 Concrete silos for 162,000 bundles**



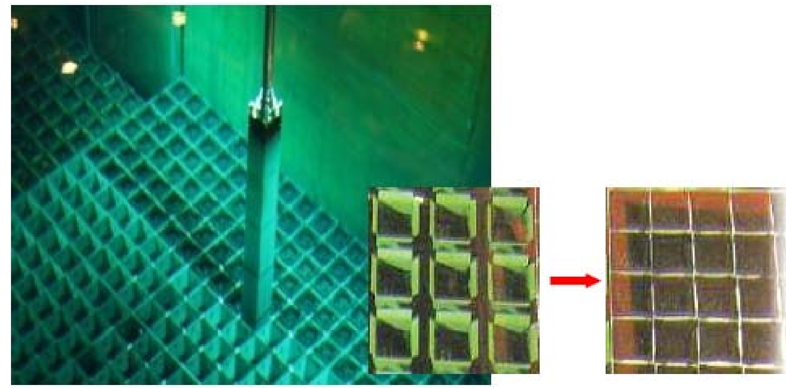
Expansion of Storage Capacity

PHWR(CANDU) SF

① Concrete Silo

② MACSTOR/KN-400

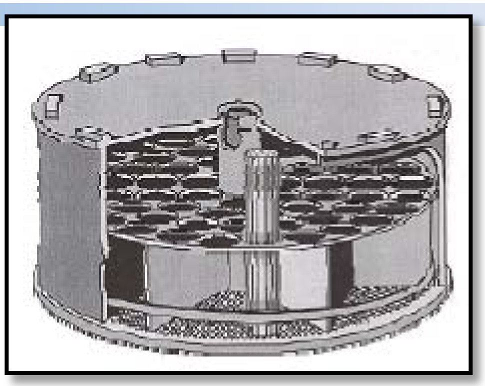
PWR SF



High Density Reracking

Transshipment between NPPs

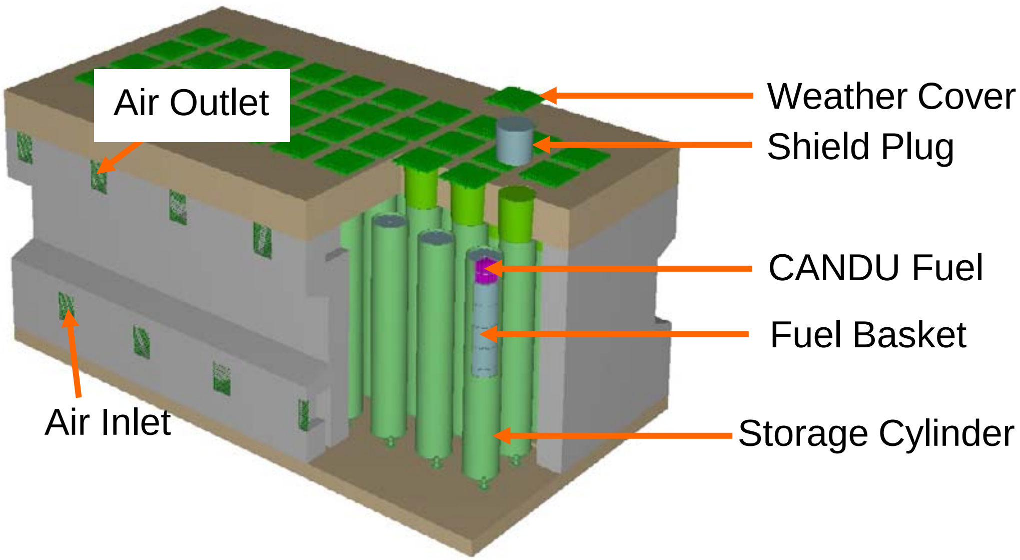
Concrete Silo for CANDU SF Storage

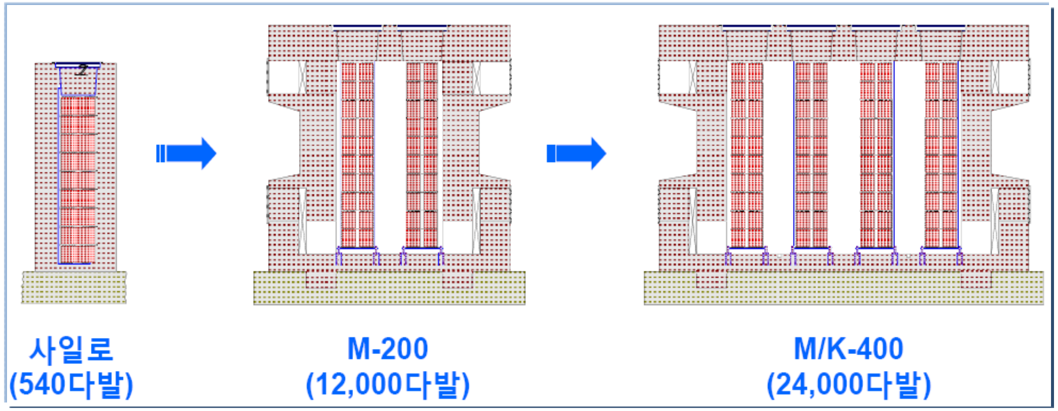


- **Concrete Silo System**
  - ✓ Capacity: 540 Bundle (60 Bundle/Basket x 9 Basket)
  - ✓ Out Diameter: 3.07 m
  - ✓ Height: 6.52 m

- **Total 300 Silos (~3,200 MtU) installed from 1990**

MACSTOR/KN-400 for CANDU SF Storage





- **High-dry Storage Facility**
  - ✓ 7 modules at Wolsong site (2010)
  - ✓ Economy : reduce of Area by 2.7 times compared to concrete silo
  - ✓ Cooling: Passive Natural Cooling

Design Parameters of MACSTOR / KN-400

Storage System	
Lifetime	50 years
Temp. Limit in operation	66 ℃
KN-400 system	24,000 bundles
	System: 40 cylinders
	Cylinder : 10 baskets
	Basket : 60 bundles
5,000 Bundles generation in a PWHR / year 24,000 bundles = 1.2 x All SF generation in 4 PHWR in a year = 44.4 x Silo dry storage	
Dimension	22 (L) x 12.5 (W) x 7.5 (H) m
Structure Material	Reinforced Concrete
Thickness	Side : 0.98 m Top : 1.08 m

PHWR Spent Fuel	
Cooling Time	Minimum 6 years
Average Burnup	7,800 MWd/MtU
Average Heat Flux	6.08 Watt
Initial U mass	19.2 kgU / Bundle
Bundle Max. Temp in dry storage	168 ℃

SF transshipment between NPPs

Transshipment	Year	No. of Spent fuels	Transfer Cask
Kori 1→Kori 3	1990-2004	424	KSC-4
Kori 1→Kori 4	1994-2004	188	KSC-4, KN-12
Kori 2→Kori 4	2000	12	KN-12
Kori 2→Kori 3	2001-2004	244	KSC-4, KN-12
Kori 4→Kori 3	2004	60	KN-12
Total		928	

- Total 928 assembles moved to neighboring units between 1990-2004.

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- **R&D Activities for Dry Storage**
  - ✓ **Storage System**
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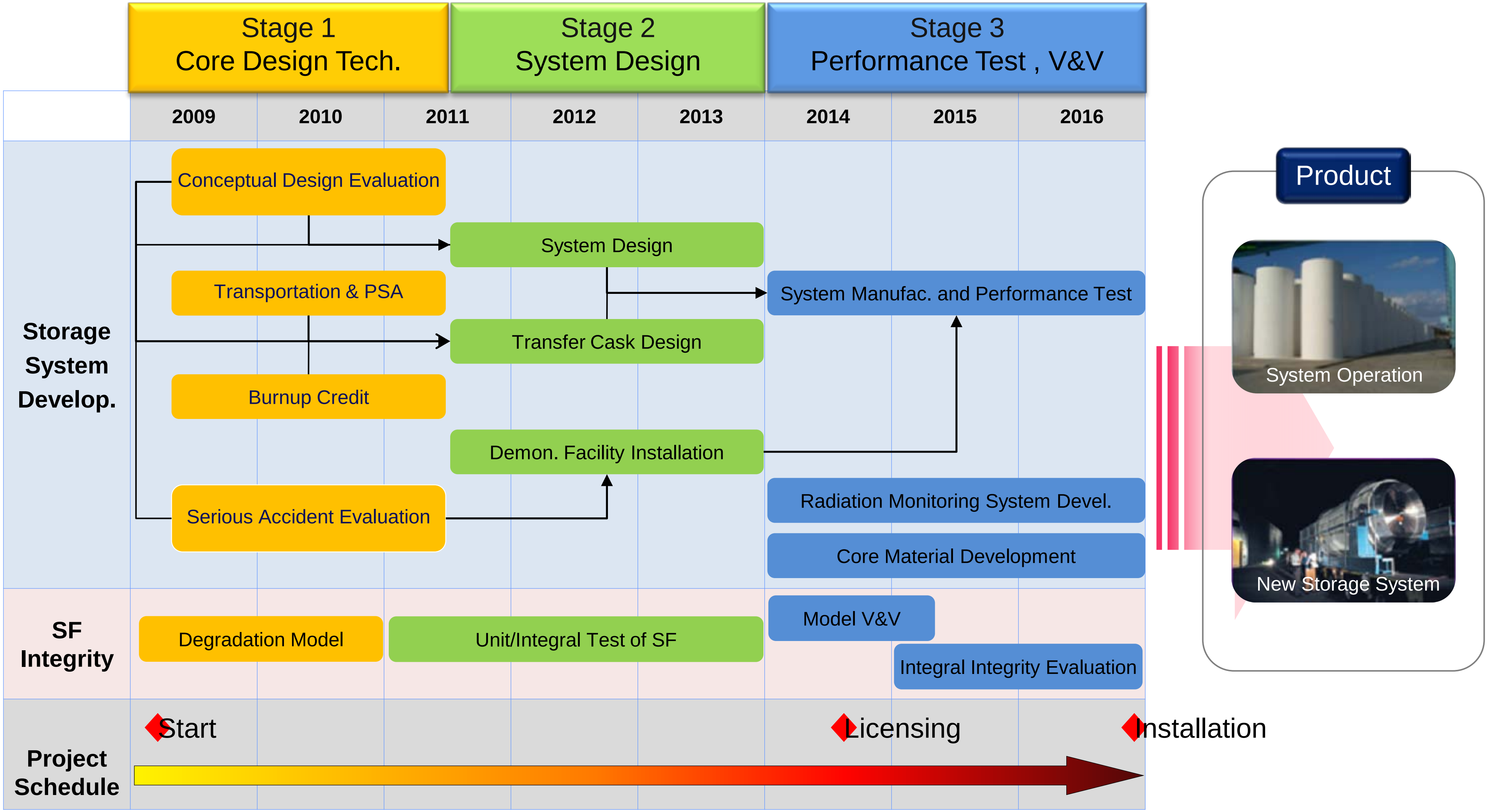
Backgrounds of SF Dry Storage

- **ISFSF should be in commission by 2016**
- **Some prerequisites for dry storage (to be considered)**
  - Integral spent fuel history & properties database
    : new fuel design, increased burnup due to improved op. tech.
  - Thermal cycling limitation due to to in-site transshipment
    for expansion of the on-site storage capacity
  - Technical criteria for safe dry storage system such as the
    long-term integrity of SF and storage facility material

Storage System Develop. Plan



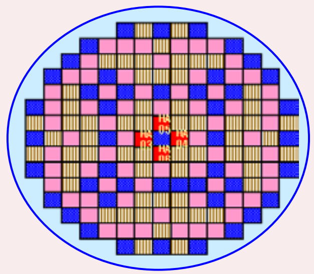
Fuel Environ. Change

Manufacture

- Fuel ID
- Fuel type
- Initial Enrich.
- Fuel Dimension
- Fuel Cladding
- Fuel Pellet
- Loading Date

- Temp: Room
- Clad Pressure: ~20 atm

Burn



- NDR Burnup
- Discharge BU
- Power History
- Damage Info.
- Coolant Chem.
- Radiation Level
- Thermal-Hydro
- Discharge Date

- Coolant : 150 atm ~320°C
- Cladding: ~450°C
- Pellet: ~800°C

Wet Storage

- Discharege BU
- Damage Info.
- Cooling Info.
- Cooling Date

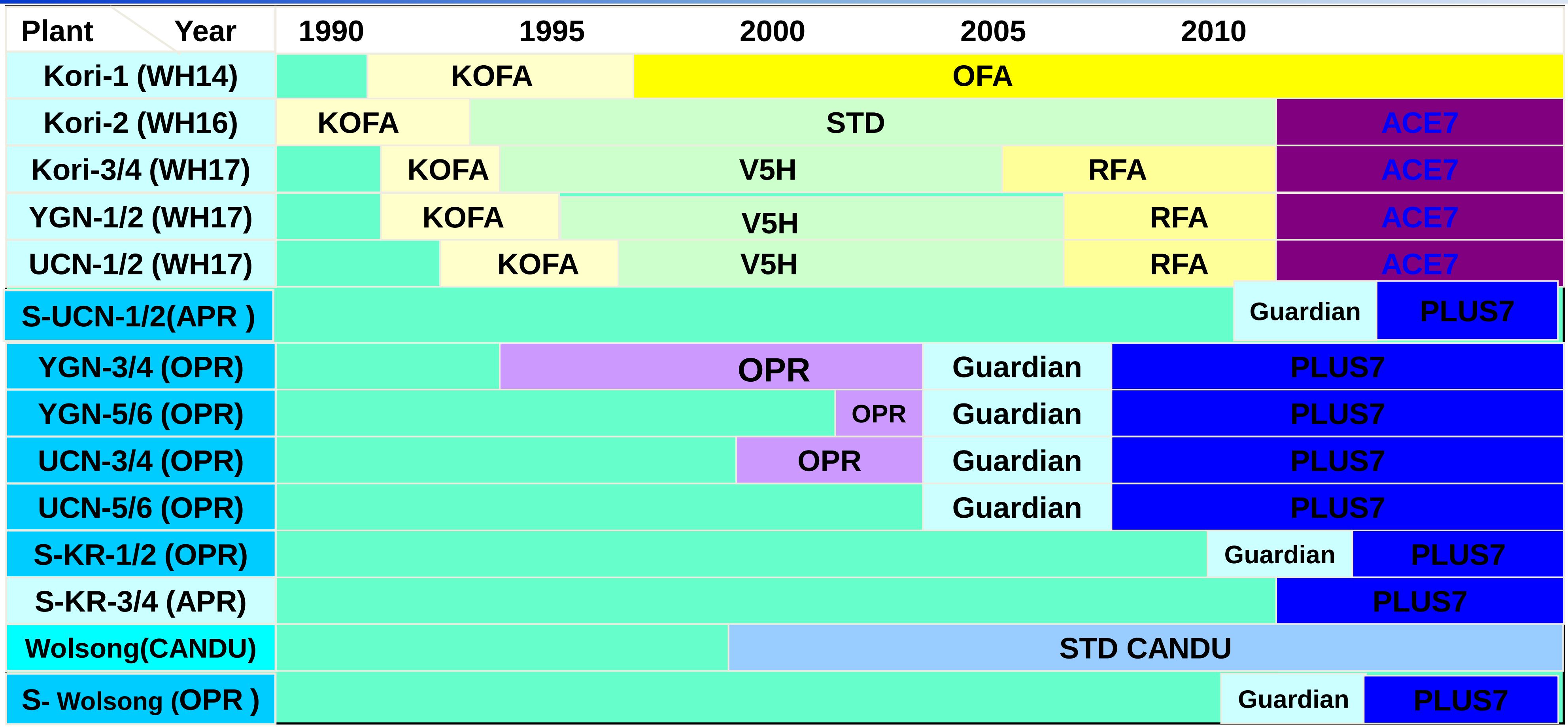
- Coolant : ~1.5 atm ~40°C
- Clad: ~150atm ~100°C

Dry Storage

- Discharege BU
- Cladding Info.
- Cooling Date
- Enrichment
- Transfer History

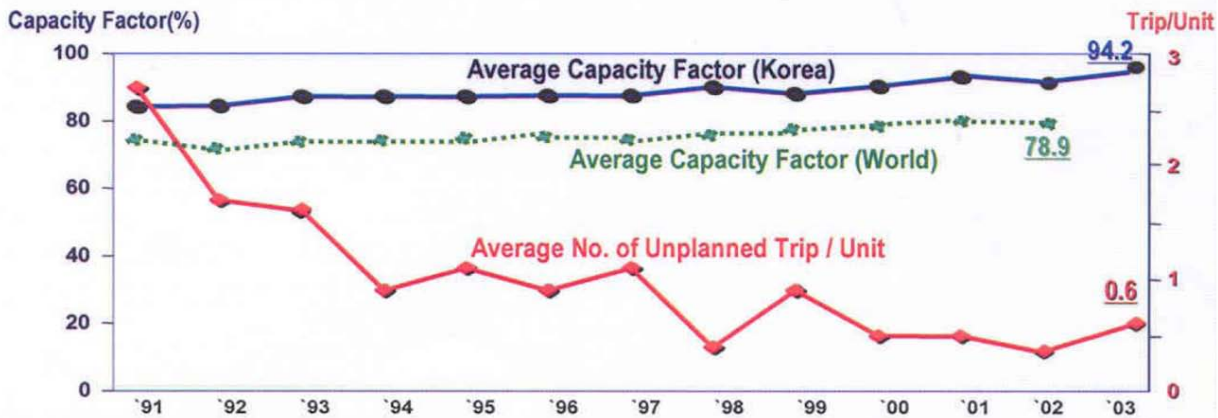
- Air : ~1 atm ~20°C
- Clad: ~150 atm ~400°C

Fuel Supply History in Korea



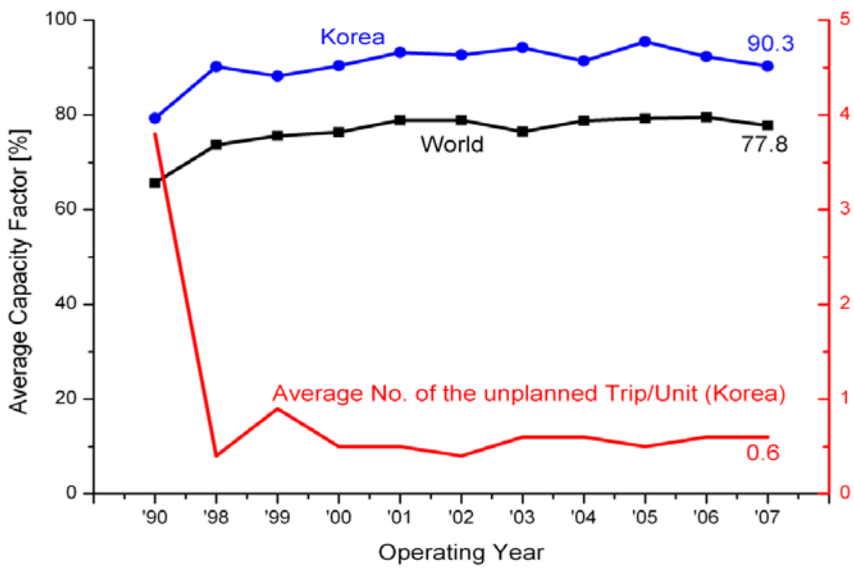
KOFA : Korean FA, OFA : W's Optimized FA, STD : W's Standard FA
V5H : Vantage5H FA, RFA : Robust FA, NGF : Next Generation FA
OPR : OPR FA, Guardian : OPR FA with Debris Filtering Grid, PLUS7 : Advanced OPR FA,
STD CANDU : Standard CANDU Fuel Bundle

Capacity Factor in Korea



C.F.(%)	84.4	84.5	87.2	87.4	87.3	87.5	87.6	90.3	88.3	90.4	93.2	92.7	94.2
Trips	2.7	1.7	1.6	0.9	1.1	0.9	1.1	0.4	0.9	0.5	0.5	0.4	0.6

1984 ~ 1994



1998 ~ 2007

Source: Ministry of Knowledge and Economy

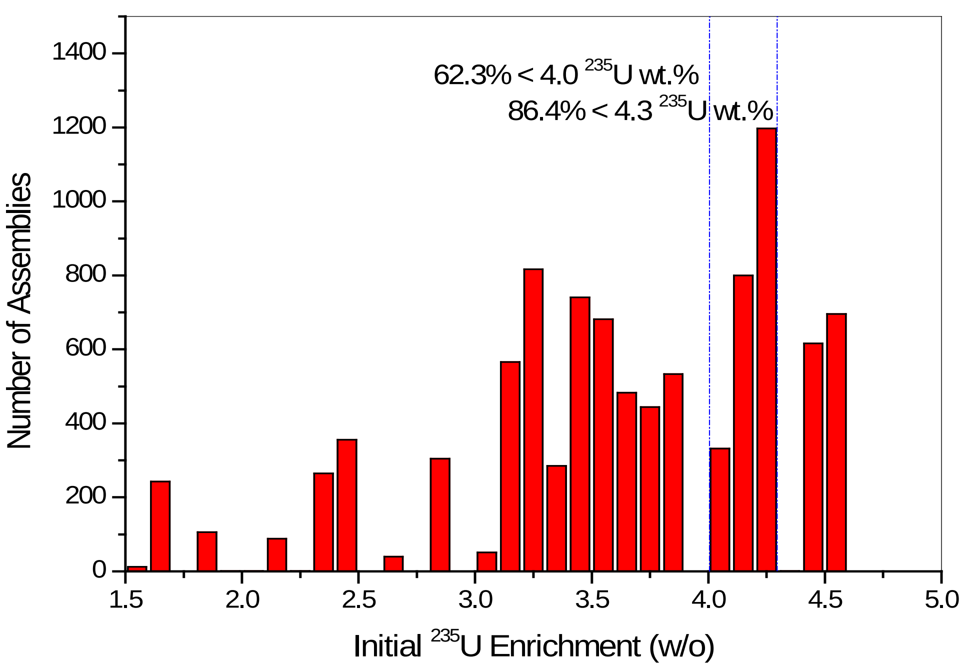
2008 Nuclear Power Note

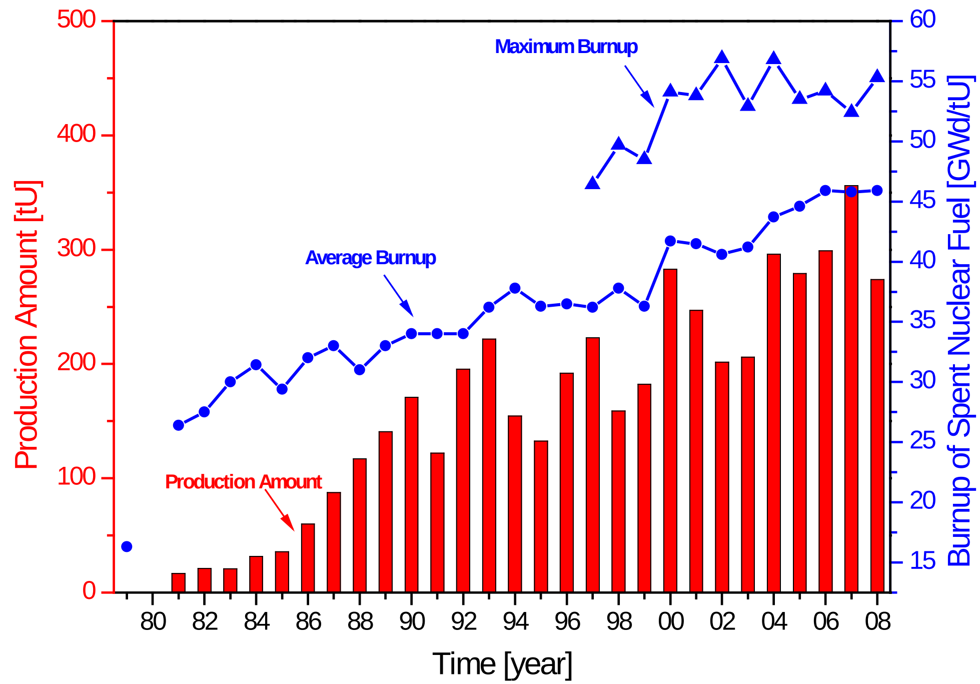
Discharge Burnup Increase

- **Discharge Burnup Increase as longer NPP operating cycle**

^{235}U enrichment period	3.2 wt.% 1980's	→	4.0~4.2 wt.% 1990's	→	4.2~4.5 wt.% 2000's(early)	→	4.5 wt.% 2000's(current)

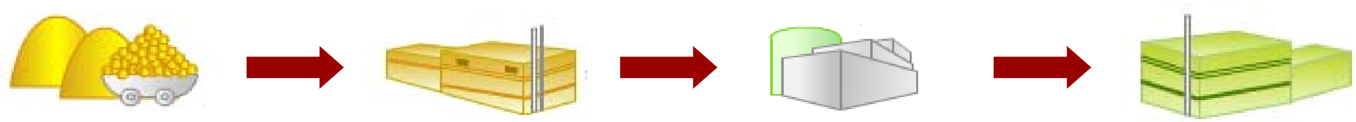
- **Current average discharge burnup : 45 GWd/MTU**
- **4.5 wt.% enriched spent fuels from 2010 with average 55GWd/MTU burnup**





Spent Fuel DB (1/2)

❖ SNF DB : planed tracing system on ID basis



Mining → Milling → Conversion → Enrichment

Fuel Fabrication

- Uranium Provenance
- Fuel ID
- Fuel Type
- Cask Type
- Fuel Storage Facility
- Fuel Storage Location
- Initial Enrichment
- Fuel Loading Date

Reactor Operation

- Fuel Discharge Date
- Discharge Burnup
- Fuel Inventory
- Fuel Activity
- Defect Fuel Check
- Heat Generation
- End Cycle Enrichment

Storage (AR)

- Storage Type (Wet / Dry)
- Fuel Discharge Date
- Storage Cask Information
- Fuel Inventory
- Fuel Activity
- Heat Generation

Interim Storage

- Fuel Undertaking Date
- Fuel Disposal Date
- Storage Cask Information
- Transport Procedure
- Fuel Inventory
- Fuel Activity

Final Disposal

- Fuel Disposal Date
- Storage Cask Information
- Transport Procedure
- Fuel Inventory
- Fuel Activity

Spent Fuel DB (2/2)

❖ SNF DB Module Structure

Fuel Storage Information
- Storage Facilitty
- Cask Serial Number
- Cask Type
- Storage Date

FA Information
- Manage Facility
- Total Assembly Number
- Occurrence Cause
- Minimum Burnup Period
- Final Burnup Period
- Initial Core Loading Date
- Final Core Discharge Date
- Ass. Arrangement Type
- Fuel Type
- Reactor Equipment

Radiation Information
- Initial Uranium Enrichment
- Fuel Material Mass in Assembly
- Discharge Burnup
- Total Mass of Assembly
- Volume of Assembly
- Heat Generation Rate Evaluation Date
- Heat Generation Rate
- Total Radioactivity Evaluation Method
- Total Radioactivity
- Total Radioactivity Evaluation Date
- Remaining Uranium Inventory
- Defect Fuel Rate
- Nuclide Activity Detection Method
- Nuclide Activity Detection Date

Defect Fuel Information
- Defect Fuel Rod Occurrence Date
- Management Facility
- Extracted Ass. No.
- Storage Facility
- Storage Location
- Specific Matters

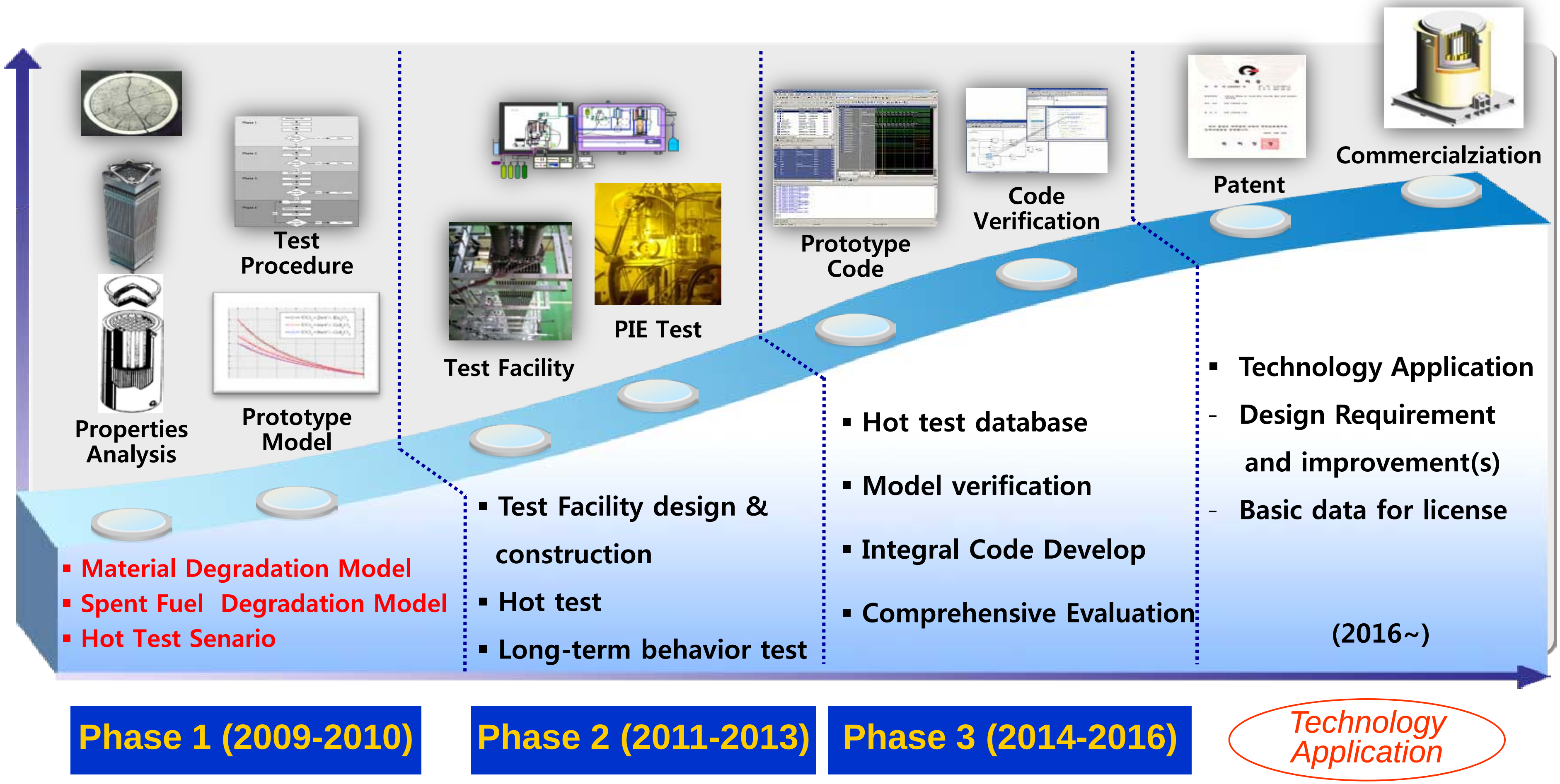
Fuel Rod
- Management Facility
- Separation Factor for Assembly/Fuel Rod
- User ID
- Cause Information
- Acquisition Date
- Extracted Ass. No.
- Fuel Defect Check

Nuclide Activity
- Nuclide Code
- Radiation Intensity

H-3
C-14
Co-60
Sm-151
Cs-135
Cs-137
U-235
U-238
Np-237
Pu-238
Pu-239
Pu-240
…

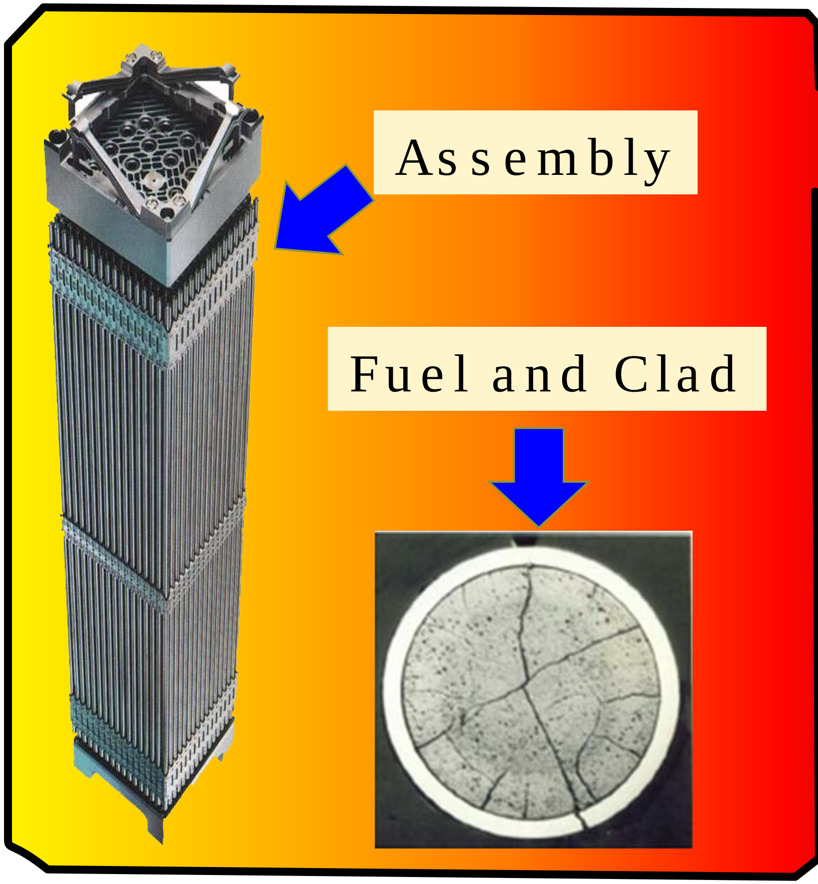
Tech. Roadmap for SF Integrity study

Objective Technology development for the dry-stored SF integrity evaluation

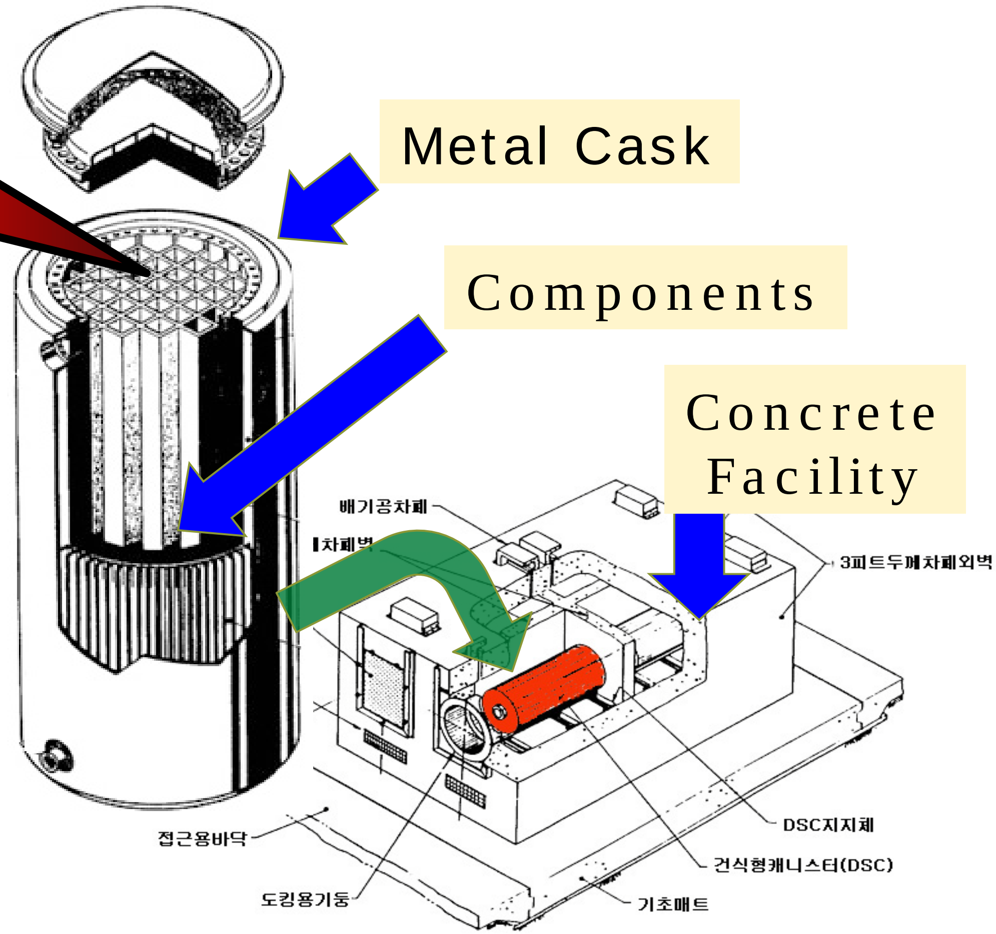


Objects of the Study

Spent Fuel



Structural Components



Ongoing Project (1/2)

To develop reference degradation mechanism model under SF characteristics and storage condition

Target

① Developing prototype model

② Evaluating SF structural deformation

③ Analyzing previous SF test data

④ Developing integrity evaluation code system

Product

- Patent/report/article for degradation models
- Integrity evaluation code design and model PIRT (Phenomena Identification and Ranking Table)

Ongoing Project (2/2)

To develop hot-test scenario of 2nd Phase experiments

Target

① Characterization test scenario of SF

② Unit test scenario of SF

③ Integrated test scenario of SF

Product

- Conceptual design of unit test experiments
- Patent application for conceptual design
- Scenarios for Char./Unit/Integrated test

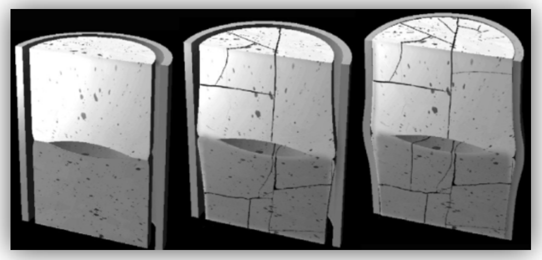
Major Degradation Mechanisms

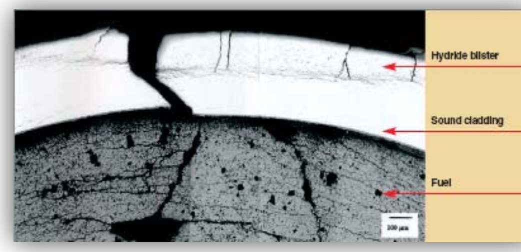
Clad Degradation

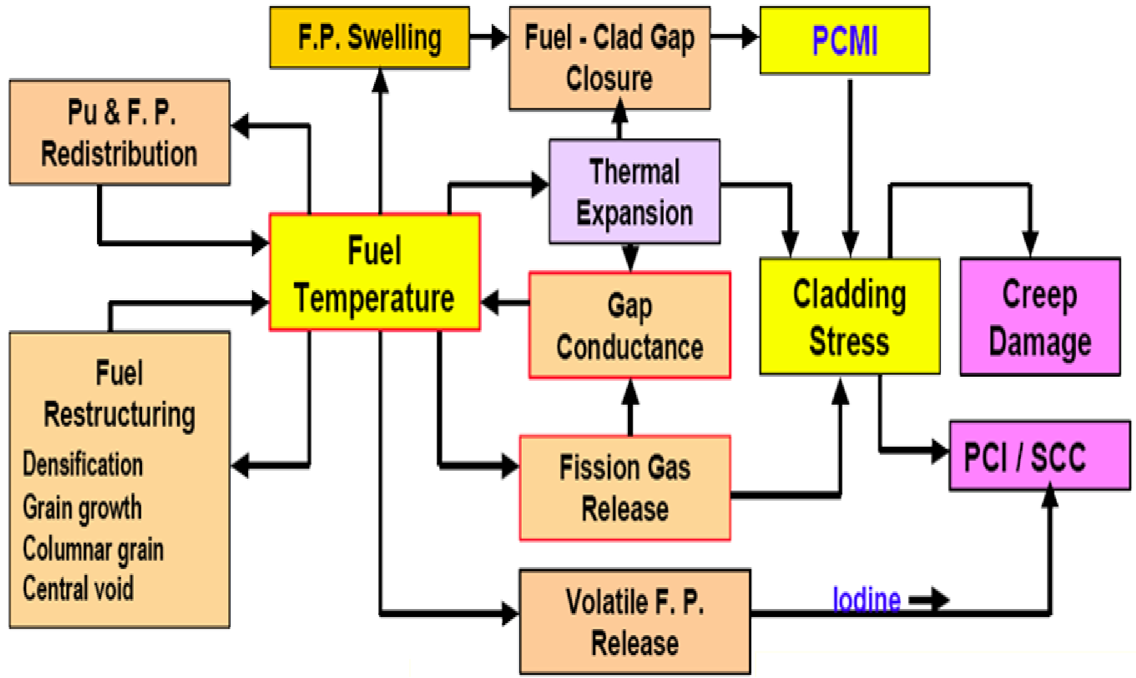
- Creep Rupture
- Hydrogen re-orientation
- Delayed Hydride Cracking
- Oxidation
- Stress Corrosion Cracking
- Diffusion Controlled Cavity Growth

Pellet Degradation

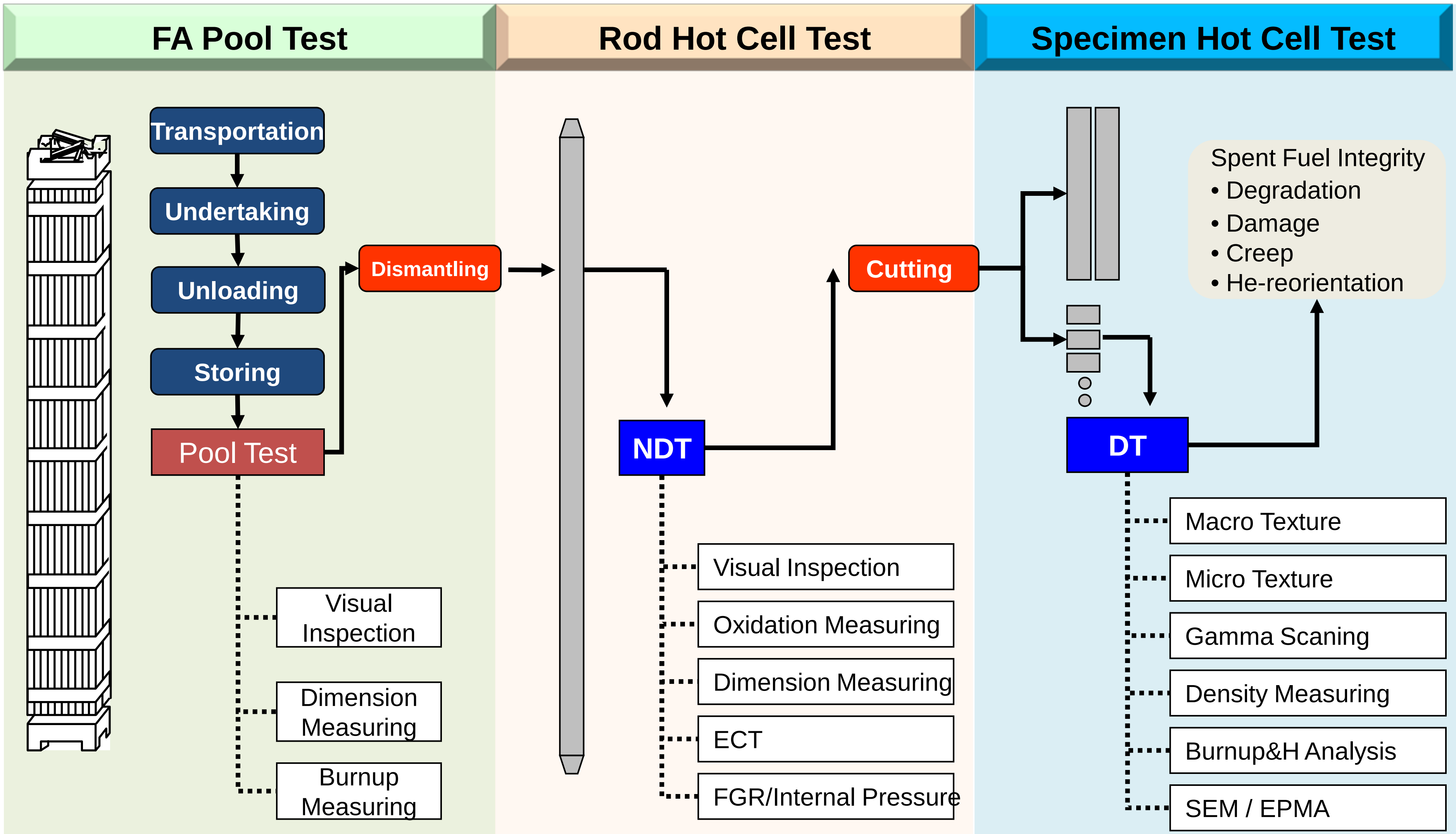
- Oxidation
- Fragmentation







Characteriz. Test of SF in PIEF



Characteriz. Test of SF in PIEF

Design type			Westinghouse type												OPR			Sum
Array type			14X14			16X16				17X17					16X16			
Fuel Name			STD	KOFA	OFA	STD	KOFA	STD	16ACE7	OFA	KOFA	V5H	RFA	17ACE7	KSNP	Guardian	PLUS7	
Own	Assembly	**Owned Assembly**	**6**	-	-	-	**1**	-	-	-	-	**1**	-	-	-	-	-	**8**
		Enrich (U-235 wt %)	2.1~3.2				3.5					4.2						
		Burnup (GWd/tU)	17~38				35					53						
		Cladding	Zry-4				Zry-4					Imp. Zry-4						
	Rod	**Owned Rods**	-	-	-	-	-	**9**	-	-	**3**	**16**	**6**	-	**2**	**6**	**10**	**52**
		Enrich (U-235 wt %)						3.8			3.8	4.2~4.49	2.61~4.51		2.3~3.4	4.49	4.49	
		Burnup (GWd/tU)						32~42			7~12	40~56	34~54		1.8~2	48~55	55~58	
		Cladding						Zry-4			Low Tin Zry-4	Adv. Zry-4 Zirlo	Zirlo		Zry-4	Zirlo	Zirlo	
Characterization Test	NDT	Visual Test	**19**	-	-	-	**8**	**9**	-	-	**3**	**22**	**4**	-	**2**	**6**	**3**	**76**
		Dimension Measure	**19**	-	-	-	**8**	**9**	-	-	**3**	**17**	**4**	-	**2**	**2**	**3**	**67**
		ECT	**19**	-	-	-	**8**	**9**	-	-	**3**	**21**	**4**	-	**2**	**6**	**3**	**75**
		γ-spectroscopy	**19**	-	-	-	**8**	**9**	-	-	**3**	**21**	**4**	-	**2**	**6**	**3**	**75**
	DT	Rod Internal Pressure/FGR Measure	**13**	-	-	-	**2**	**6**	-	-	**2**	**16**	**2**	-	**0**	**2**	**2**	**45**
		Ceramography/Metallography	**13**	-	-	-	**2**	**7**	-	-	**2**	**20**	**2**	-	**2**	**2**	**3**	**53**
		Chem. Analy(Burnup,Hydroge)	**13**	-	-	-	**2**	**7**	-	-	**2**	**19**	**2**	-	**0**	**2**	**2**	**49**
		Pellet/Clad Material Properties	**13**	-	-	-	**2**	**7**	-	-	**2**	**9**	**2**	-	**2**	**2**	**2**	**41**

Conclusions

- Long-term SF management program will be established through public engagement.
- For mid-term policy of SF management, interim SF storage facility will be in operation by 2016
- Since June 1^{st} in 2009, we have started R&Ds on SF Integrity Study.
- Integrity Evaluation Code and Indigenous test data will be expected.

Thank you

Implementation Schedule for 1st Phase