# The Mid-to-Long Term Strategy for the Decommissioning of Fukushima Daiichi NPP

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## Outline

- 1. Mid-to-Long-Term Roadmap for Decommissioning of Fukushima Daiichi NPP
- 2. Technological Challenges and R&D Program
- 3. International Cooperation
- 4. Next Step Forward

## 1. MID-TO-LONG-TERM ROADMAP FOR DECOMMISSIONING

#### Mid-to-Long-Term Roadmap and Primary Targets ⇒See P.19-23

"Mid-to-Long-Term Roadmap for Decommissioning of TEPCO's Fukushima Daiichi " was decided in December, 2011.

It defines the decommissioning work into three phases, and sets major milestones of on-site work and R&D projects.

**Phase 1** (with in 2 years):

Commence fuel removal from spent fuel pools

<u>Phase 2</u>(with in 10 years): Commence fuel debris removal from RPVs

<u>**Phase 3**</u>(within 30 to 40 years): Terminate the decommissioning process

	Filtered Fan	Blowout-pa came down		n. 28, 2013)	Rubble removal from O.F.         completed
		Unit #1	Unit #2	Unit #3	Unit #4
Core Melt		Unit #1 Y	Unit #2 Y	Unit #3 Y	Unit #4N
Core Melt Hydrogen Explo	osion				
Hydrogen Explo	osion (°C)	Y	Y	Y	N
Hydrogen Explo RPV Temp.		Y Y	Y N	Y Y	N Y
Hydrogen Explo RPV Temp.	(°C) (°C)	Y Y 18	Y N 31	Y Y 31	N Y NA
Hydrogen Explo RPV Temp. PCV Temp.	(°C) (°C) el (m)	Y Y 18 20	Y N 31 32	Y Y 31 31	N Y NA NA
Hydrogen Explo RPV Temp. PCV Temp. PCV Water leve	(°C) (°C) el (m)	Y Y 18 20 +2.8	Y N 31 32 +0.6	Y Y 31 31 Unknown	N Y NA NA NA
Hydrogen Explo RPV Temp. PCV Temp. PCV Water leve Dose rate O.F.(n # of SPF	(°C) (°C) el (m)	Y Y 18 20 +2.8 53.6	Y N 31 32 +0.6 880	Y Y 31 31 Unknown 500	N Y NA NA NA 1.3

Four short-term challenges

⇒See P.23-25

Although reactor cores are maintained low temperature, we are now facing at four major challenges;



Management of accumulated contaminated water

Reduction of environmental radiation dose

Improvement of work environment

Retrieval of spent fuel from spent fuel pool

## Three long-term challenges

⇒See P.21,2

Ten years (End of Phase 2) seems far future, but many issues and problems exist to be tackled and solved well before hand.

Preparation for Fuel debris removal

Treatment and disposal of radioactive waste

Development of remote control devices

## 2. TECHNOLOGICAL CHALLENGES AND R&D PROGRAM

Principles for implementing R&D

- Address on-site technological needs
- Government involvement and support
- Open and flexible framework in collaboration with international science and engineering communities



## Key Areas of R&D Projects

Preparation of fuel debris removal

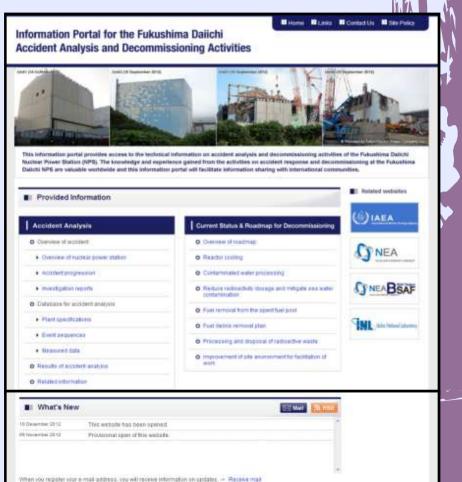
- Equipment/device development
- Core status assessment and analysis
- Fuel debris characterization and management
- Radioactive waste treatment and disposal 
  See P.33-39
- Processing and Disposal of Secondary Waste
- Processing and Disposal of Radioactive Waste
- Remote-controlled technologies as a common tool

⇒See P.27-31

## **3. INTERNATIONAL COOPERATION**

- 1) Bilateral dialogue framework with;
  - France, Russia, Ukraine, UK, US
- Information Portal for Accident Analysis & Decommissioning
  - Opened Dec. 2012.
  - This information portal provides an easy access to the technical information.

#### https://fdada.info/



## 3) Cooperation with IAEA

- Japan proposed the followings at the Fukushima Ministerial Conference on Nuclear Safety in Dec. 2012.
- Hosting IAEA peer review missions
- Expert's review for decommissioning program and activities of Fukushima Daiichi NPP.
- Setting up an international advisory group
- Sharing information and data from the accident and decommissioning process.
- Provide advice and guidance on safety approaches and policies regarding decommission to the international community.

4) International Collaborative Research

- Severe Accident Analysis Benchmark Project (NEA / BSAF Project: Phase I –2014, Phase II Planned)
   Started initial analysis in November 2012 with the participation of 12 institutions from 8 countries
- Detailed data and boundary conditions are also made available to non-participating organizations through portal site.
- Exploring possibility of international joint research projects such as;
- Fuel debris sampling and removal,
  - Processing and disposal of radioactive wastes generated from the nuclear accident.

- 5) Enhancing international business and research partnership
- Government-led R&D projects are seeking expertise from the international community, ensuring openness and transparency.

#### (Example)

- ATOX Co., Ltd., opened a request for proposal on "Integrated Dose Reduction Planning" from Nov 16th to Dec 15th 2012.
- > Six out of thirteen companies were selected as advisors.
  - Areva (France)
  - Babcock International Group (UK)
  - CH2M HILL (US)
  - Onet Technologies (France)
  - Perma-Fix Environmental Services (US)
  - Plejades (Germany)

## **4. NEXT STEPS FORWARD**

## Next Steps forward

- Commitment of Government
  - Support for establishing R&D institution
  - Strengthen of JAEA's ability
- Accelerate and revise the Road Map
- ➢Revise Road Map



Visit of Prime Ministe Abe (Dec. 2012)



Visit of METI's Minister Motegi (Jan.2013)

- Work and walk with international communities
- Shear information, elaborate plans and collaborate
- Contribute to enhance the world nuclear safety

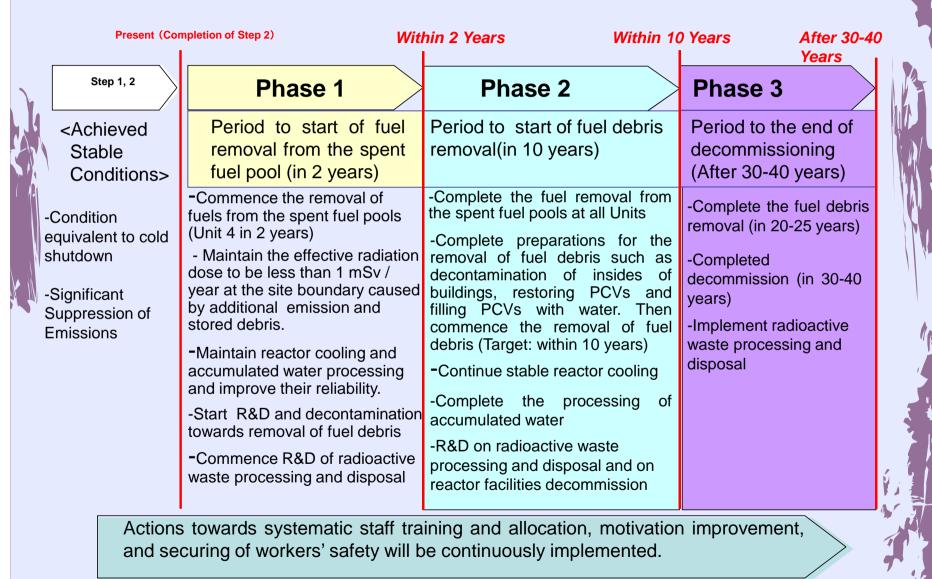
# THANK YOU VERY MUCH FOR YOUR ATTENTION

Please visit our website:

www.meti.go.jp/english/earthquake/nuclear/decommissioning

# **APPENDIX**

#### Mid -to-Long Term Road Map Dec.2012 (Reference)



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### Government and TEPCO Council on Mid-to-Long Term Response for Decommissioning

#### Government and TEPCO Council on Mid-to-Long Term Response for Decommissioning(Dec. 2012)

Co-Chair

Chair : Minister for the Restoration from and Prevention of Nuclear Accident, Cabinet Office Minister of Economy, Trade and Industry (METI)

Vice-Chair : Parliamentary Secretary of Cabinet Office, Vice Minister of METI, and President of TEPCO

- Members : Agency of Natural Resources and Energy(ANRE), TEPCO
- Observer : Nuclear Regulatory Agency (NRA)

#### **Management Board**

Co-Chair: Parliamentary Secretary of Cabinet Office Vice Minister of METI Executive Vice-President of TEPCO Adviser : Vice Minister of MEXT Members: METI/ANRE TEPCO MEXT JAEA (Japan Atomic Energy Agency) Toshiba Hitachi-GE

#### **R&D Management Headquarter**

Chair :	Vice Minister of METI
Vice-Chair:	Parliamentary Secretary of Cabinet Office
	Vice Minister of MEXT
Members :	METI/ANRE
	TEPCO
	MEXT
	AEC (Atomic Energy Commission)
	JAEA, AIST, CRIEPI
	Toshiba
	Hitachi-GE
	and a couple of academic advisors

Ма	in Schedule of	Mid-and-lon	g Term Road	dmap towa	ards the De	commiss	ioning of	Fukushir	na Daiic	hi Nucle	ar Powe	r		eni Ere		
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				Within 2		arly)		(Mid	)	$\sim$	(Late)	ye Fuel Debris R		fter 20-25 years el Debris Removal	y	ears
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	Plan for Reactor Cooling		ernal PCV Inspe	·/ I				h to Water Withdra		Buliding (or lower		Circ	ulating Water Cooling			nsiderations
Plan for		Improving the Relia	ability of Circulating W			<b>y</b>		reactor build	ng (or lower part	of PCV))		🔶 Witl	ndrawal from PCV (sho	rt loop)	:Information Flo	··· /
Maintaining Plant in an				(*1): To [HP3-1]; PC	CV Repairs, Stopping In	ter-building Water	Leakage	(*2)		tor Building Conta of reactor building			on based on the instal			
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		Installation of Multi-r Removal Facilities	niclide					Reduction	of Accumulated \	Water in Turbine/F	Reactor Buildings	$\rangle$				
	Plans to Mitigate Sea Water Contamination	Additional Silt Fence Installation Covering Seabed Soil in fr the Intake Canal	Purification (ongoing)	ion of Radioactive \$	ubstance Concentration			Sea Water Contami nounced density)	nation when Cont	taminated Water L	.eaks					
Plan to				n (ongoing) Covering Dredged Sand at Seaway/Anchor Ground Underground Water and Seawater Monitoring (ongoing)  V Target: Attainment of Dosage Below 1 mSv/year at Site Boundaries due Sources such as New Emissions of Radioactive Substances etc. from the Power Station as a Whole	Kr.											
Reduce	Rubble		<b></b> ⊺	Target: Attainmer						missions of Rad	lioactive Subst	ances etc. fr	om the Power Sta	tion as a Whole		
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the Power Station as a Whole, and	ent and	Stored Water Process Reduce Radiation Dose	sing via Shielding etc. e from Secondary Waste	Continue Re	eduction Effort	s	$\rightarrow$	Continue St	orage		_		Facility Replaceme (as needed)	Carry out to Dispo	osal Site	
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	s Waste	Land/Sea	Area Monitoring	(ongoing)												$\square$
				Anti-earthquake Buil	ding into an Area where	Radiation Contro	s are not Required									1
	Plan for Field Test	Systematic Ons	ite Decontamination (Imple					o reduce radiation	dose outside of th	ne site)					<u> </u>	•
		Circulation C	Cooling of the Pools	s (Improve Reli	ability via mainte	nance and re	placement et	o.)			X IX	>				
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_		Long-term Integrity	Assessment of Fuel Assen	nblies Removed from	Terzet: Complete Con	alinau cool Mõdilica	IN LAN BIAL LAG STOL									
	R&D				r Handling Metho	d of Damageo	d Fuels from t	he SFPs			•					

#### Main Schedule of Mid-and-long Term Roadmap

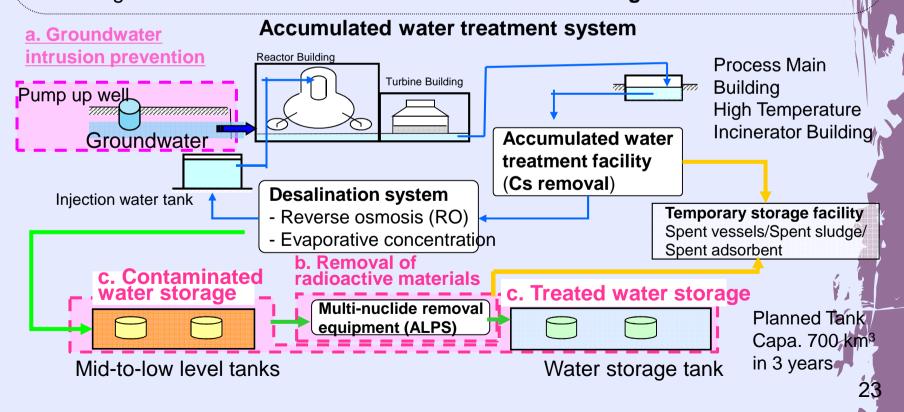


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						-				-							
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#### Accumulated water increased by groundwater intrusion

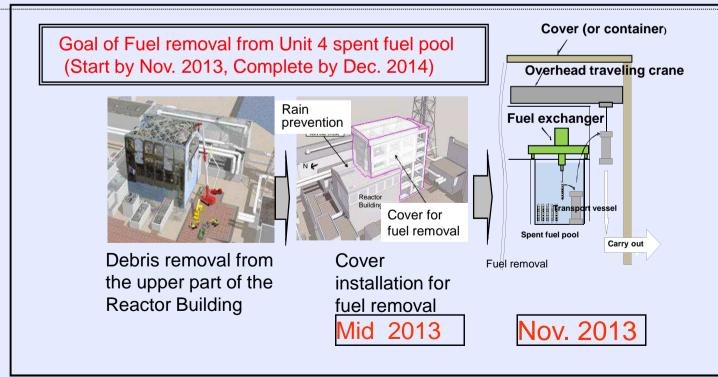
The highly contaminated water accumulated in the building basement is treated to be used for reactor cooling again. And there exists grand water intrusion (400t/day) to basement as well. The contaminated water generated in this process treated and stored in tank.

- a. Prevent groundwater flow into the building  $\rightarrow$  **Develop groundwater bypass** b. Remove the radioactive materials in the contaminated water
- $\rightarrow$  Install multi-nuclide removal equipment (Tritium cannot be removed) c. Storage of contaminated water  $\rightarrow$  Build additional storage tanks in the site



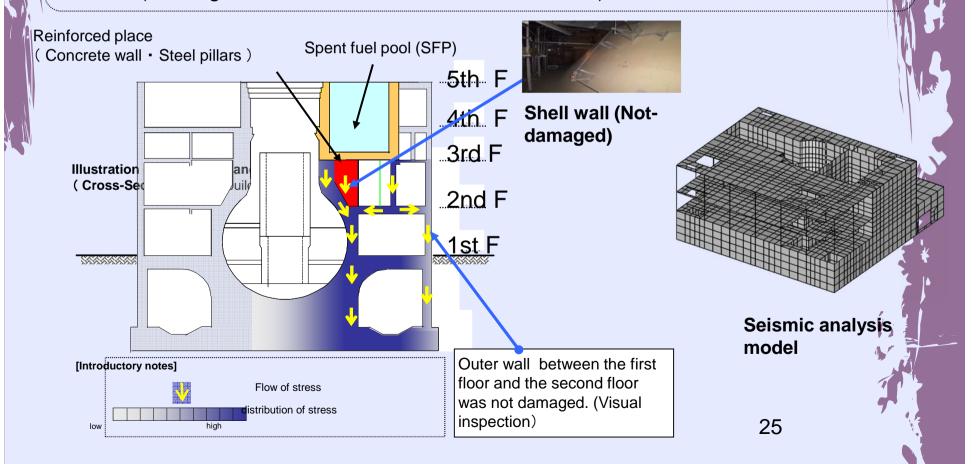
#### Plan and progress of fuel removal from the spent fuel pool

- The Circulating Cooling System had started operation. And desalination of the water in Spent Fuel Pool were in operation.
- Confirmed conditions inside the spent fuel pool via an underwater camera, corrosion investigation of removal unused fuel removal.
- Debris removal from the upper part of Units 3-4 Reactor Building is in progress. (to be completed in end of FY 2013 at Unit 3, in Dec, 2012 at Unit 4)
- >At Unit 4, cover installation for fuel removal is on going.
- Preparation of Common Pool which stored removal spent fuel and construction of Dry cask temporary storage facility is on going.



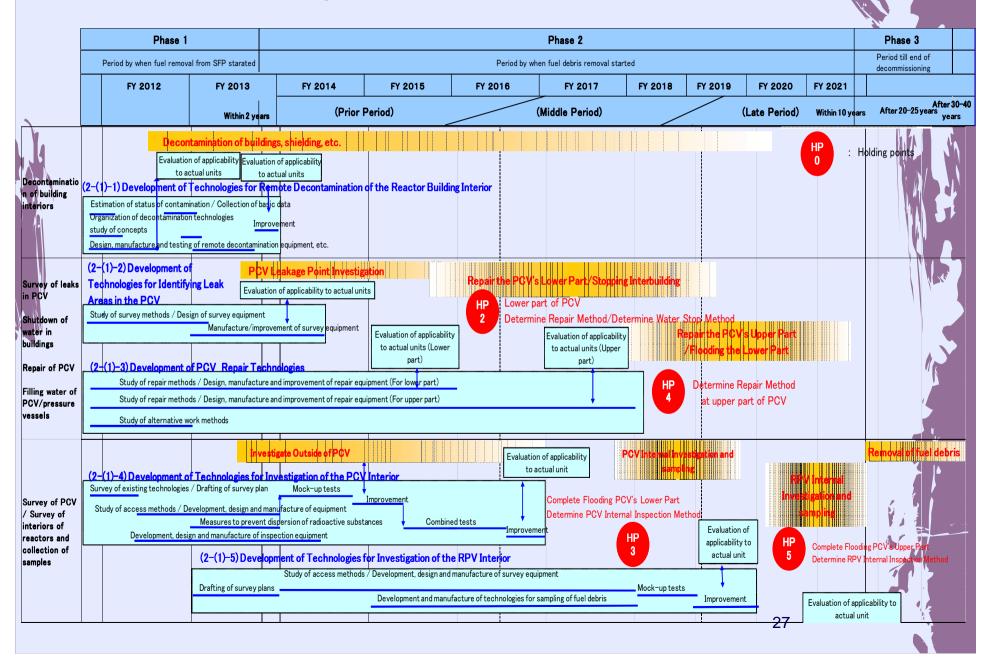
# Structural integrity of the spent fuel pool and the Reactor Building at Unit 4

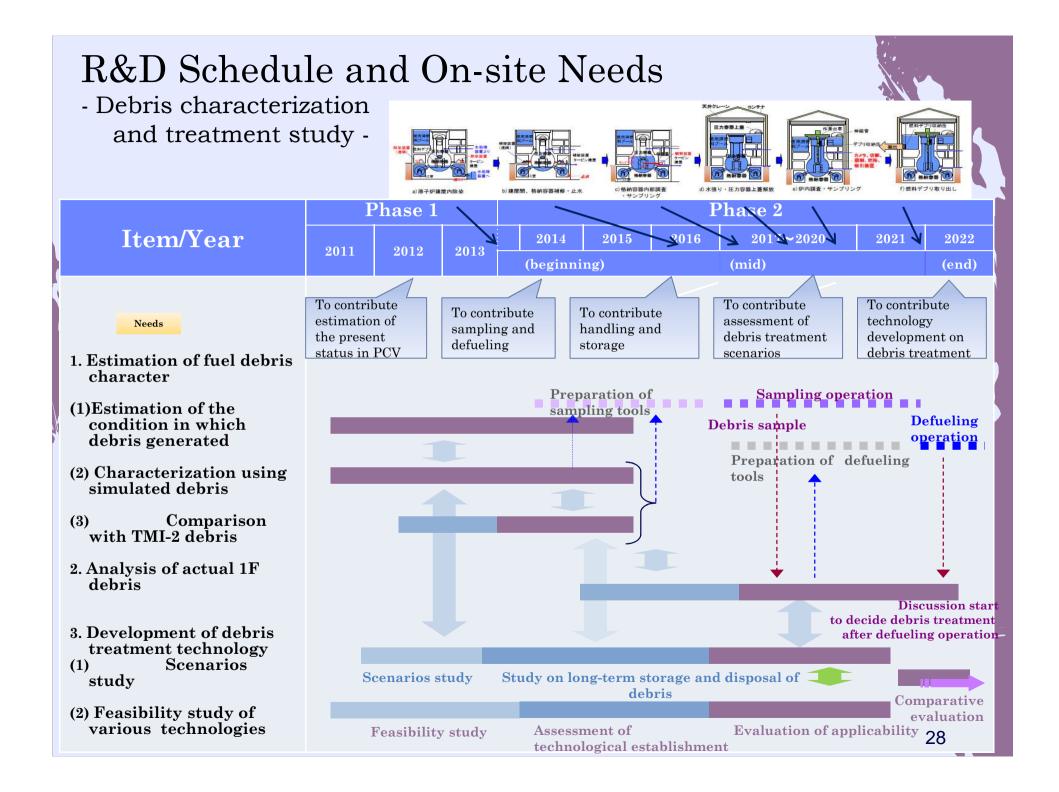
We confirmed that the building, including the spent fuel pool, has a sufficient margin of seismic resistance even if an earthquake equivalent to the Tohoku-Pacific Ocean Earthquake (JMA Seismic Intensity Scale 6+) occurs in the area.
 We installed a support structure at the bottom of the spent fuel pool at the Unit 4. The structural integrity of the spent fuel pool has been confirmed by quarterly checks.(building tilt, no more than 1mm crack width, etc).



## TECHNOLOGICAL CHALLENGES FOR FUEL DEBRIS REMOVAL

## R&D Roadmap (Fuel Debris Removal)





#### Challenges for fuel removal :

1) Development of Remote Equipment and Devices

#### Short-term

- Monitoring devices for the R/B under high dose environment
  - Remote-controlled UAVs, etc.
- Sensing devices for water surface in the S/C and PCV to identify location of leaks
- Remote-controlled robots running in the water to repair leaks
  - · Identify self location in the water
  - Automatic treatment of long-length communication cable
  - Sensor for the shape and water-flow

#### Mid-term

PCV repair devices and defueling equipment

#### Challenges for fuel removal:

2) Accident analysis for evaluating the core status

#### Short-term

- Accident progression analysis and benchmark study, by using existing and improved integral severe accident codes (cf. TMI-2 experience of OECD/NEA joint research)
- Database/information portal to make accident data readily available to the international community.
- Assessment on the validity of severe accident codes and leading greater confidence in the code predictive capabilities

#### Mid-term

- Further analysis applying various models and methodologies
- Collection of physical data during sampling and defueling

#### Challenges for fuel removal:

3) Characterization and Sampling of Fuel Debris

#### Short-term

- Simulated fuel debris for evaluating its characterization
- Creating and updating database by making use of the experience of the TMI-2 debris study
- Management and storage of fuel debris, and development of a new accountancy method

#### Mid-term

- Sampling and analyzing actual fuel debris
- Deployment of defueling equipment, devices, and storage.

# TECHNOLOGICAL CHALLENGES FOR RADIOACTIVE WASTE PROCESSING AND DISPOSAL

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#### R&D related to processing and disposal of radioactive waste

			Phase 1		Phase 2								
		Period by when fuel removal from SFP starated			Period by when fuel debris removal started								
			FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 202	1
				Within 2 years	2 (Prior	Period)		Middle Period)		(	Late Period)	Within ' years	0 After 20-25 After years ye
ain ev	vent	▼St	ep2 Completion S		va  Start(Unit 4) ⊽			Fu	el Debris Re Fuel De	bris Remov	t(First unit) al Complete nissioning C	d (All un	
		Sto	rage and manag	gement of radio	pactive waste				lon		itation of mo	easures f	or
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vaste		Survey of characteristics of secondary waste											
> >		Study of measures for long-term storage											
bact		ing distribution											
of radioactive waste Z		_	Verification of applicability of existing concepts of disposal / Identification of problems										
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R&D related to							olicability of exis roblems (Rubble,		disposal /				for manufacture of
(3) R&D													oncepts of dispos disassembly, etc.)
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# R&D Issues for Radioactive Waste Processing and Disposal

#### **1. Properties Investigation and Characterization**

Properties differ from conventional waste, such as rubble, sludge, and decontaminated waste liquid (nuclide composition, chloride content, etc.)
Basic information needs to be assessed for the development of each technologies

Examples of differences with conventional waste

- Main nuclides: Co-60, C-14, etc.
  - $\rightarrow$ Fukushima Daiichi: Cs-137, Sr-90, etc.
- Sodium concentration is 5 times that of the TMI case due to 50-90% contamination by seawater
- $\rightarrow \! \text{Lower}$  Cesium absorption performance, increased waste generation
- Presence of sludge and other materials of unknown chemical composition
  - $\rightarrow$ Need to identify these materials through analysis

#### **Outputs**

- Radioactive concentration of each type of nuclide
- Component content
- Physicochemical characteristics, etc.

The installation of a hot lab near 1F must also be considered, as large volumes of high-dose, untransportable samples are expected to be generated accompanying decontamination and fuel debris removal. <sup>34</sup>



# R&D Issues for Radioactive Waste Processing and Disposal

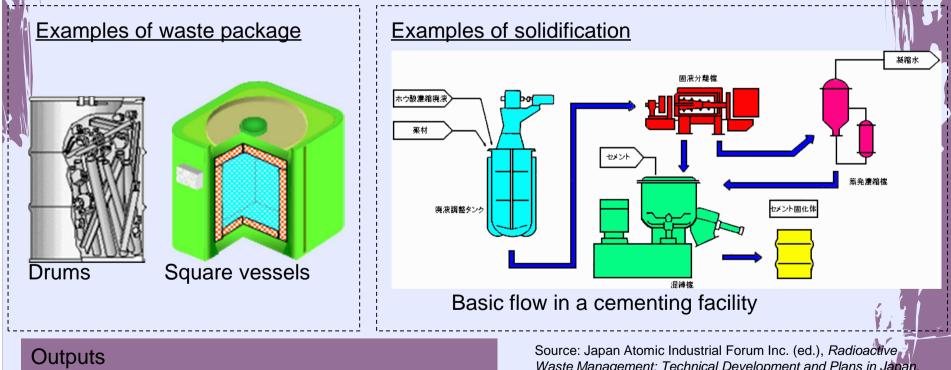
#### 2. Long-term storage technologies Impact of chloride (corrosion) and high radioactivity (heat, hydrogen. surface radiation) Duration of storage: how long should it be? Is treatment necessary before storage? Cross section B, A, C Facility for secondary waste storage after water A-A cross section **B-B** cross section treatment (example) Hydrogen Temperature distribution distribution Water inlet Flotation as a result of temperature increase Temperature of zeolite layer Water outlet Approx. 170°C max. Evaluation of temperature and hydrogen distribution in a KURION absorption vessel (by JAEA)

Output: Long-term storage method for each type of waste

## R&D Issues for Radioactive Waste Processing and Disposal

#### **3. Processing technologies**

Can technologies used for existing processing technologies be applied?

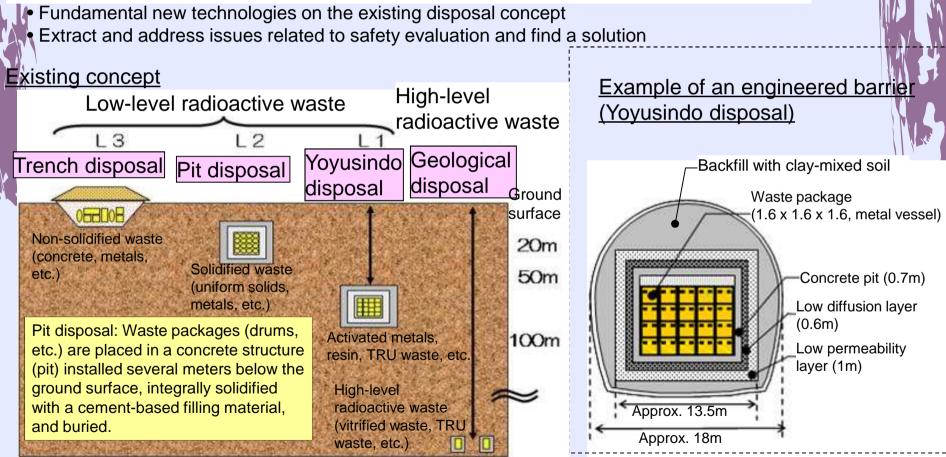


- Treatment methods for storage
- Methods for production of waste packages
- Performance of waste packages

Waste Management: Technical Development and Plans in Japan, July 1997, p.81.

# R&D Issues for Radioactive Waste Processing and Disposal

#### 4. Disposal technologies



Output: Waste disposal methods (required burial depth, construction of an engineered barrier<sup>3</sup>/<sub>6</sub>tc.)

## Challenges for Radioactive Waste Treatment

#### Short-term



Development of analysis techniques and methods for the characterization of accident-origin solid waste

- Pre-treatment of solid radioactive waste
- Simplified and standard methodologies
- Regulatory and institutional framework
- Management and processing secondary waste storage after water treatment

#### Mid-term

- Exploring possibility for building a research center for international collaborative research program
- Researchers/experts exchanges with international community

## Challenges for Improving the Work Environment

#### Short-term

Technologies and systems to reduce the doses of workers

- Dose reduction management, including shielding
- Improving materials for workers' suits
- Studying methodologies for increasing human performance
  - Advancing human health and performance innovations for severely challenging environments
  - Designing a better work environment
- Mid-term
- Address human resource needs for the mid-to-long term