JAEA

The Tenth OECD Nuclear Energy Agency
Information Exchange Meeting on
Actinide and Fission Product Partitioning and Transmutation
Mito, Japan
October 7, 2008

The Current Status of Japanese Nuclear fuel Cycle

- The outline of Japanese nuclear fuel cycle strategy and transition scenario to FR cycle -

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1. Japanese nuclear energy policy
2. Nuclear energy use from present to near future in Japan
3. FR cycle and **Fa**st reactor **C**ycle **T**echnology development (**FaCT**) project
4. Japanese nuclear energy scenario study results

Japanese Basic Nuclear Fuel Cycle Policy

< Background: Energy security and global climate change >

- Energy self-sufficiency rate of Japan is as low as 4%.
- “Cool Earth 50” initiative and Hokkaido-Toyako Summit 2008.
- G8 leaders agreed to implement three principles in framework beyond 2013: (1) participation of all major emitters, (2) flexibility and diversity, and (3) compatibility between environmental protection and economic growth.

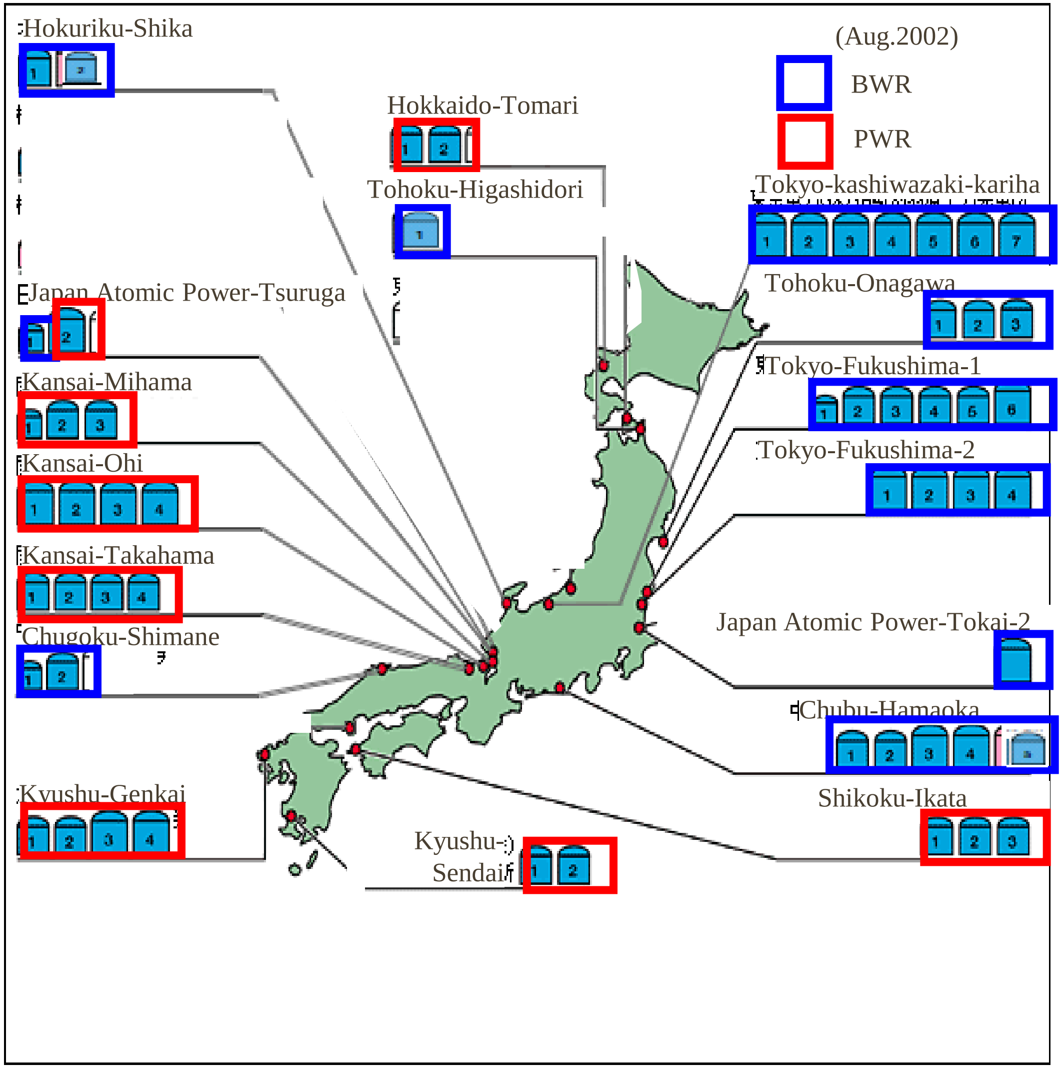
< Basic policy and status >

- Fifty-five nuclear power plants (49.6GWe, 304.5TWh) are in operation.
- FR cycle with MA recycling will be deployed in around 2050 in order to reduce the environment burden and to secure Japanese energy security.
- Transition scenario from LWR to FR is basic strategy.
- Pu from LWR will be recycled in LWR before FR cycle deployment.

<Targets in “Framework for Japan’s Nuclear Energy Policy”, Oct. 2005>

- Continue to meet at least 30 to 40% of electricity supply even after 2030 by nuclear power generation,
- promote the nuclear fuel cycle, and aim at commercialization of FR by 2050.

Current Status of Nuclear Power Plant in Japan



Installed Capacity in March, 2007

49.6GWe

Nuclear Electricity Generation

Production : **304.5TWh**(2006)

55 NPPs in operation

-PWR : 23

- < 1000MWe : 16
- > 1000MWe : 7

-BWR : 32

- < 1000MWe : 14
- > 1000MWe : 18

Current Status of Japanese Nuclear Fuel Cycle and Actions for the Near Future

- ***Japan is the only non-nuclear weapon state with commercial-scale closed nuclear fuel cycle program.***

Rokkasho Enrichment Plant (JNFL)
March 1992: Start of the operation

Rokkasho Reprocessing Plant (JNFL)
under final commissioning test
Start of the operation is expected in Late 2008

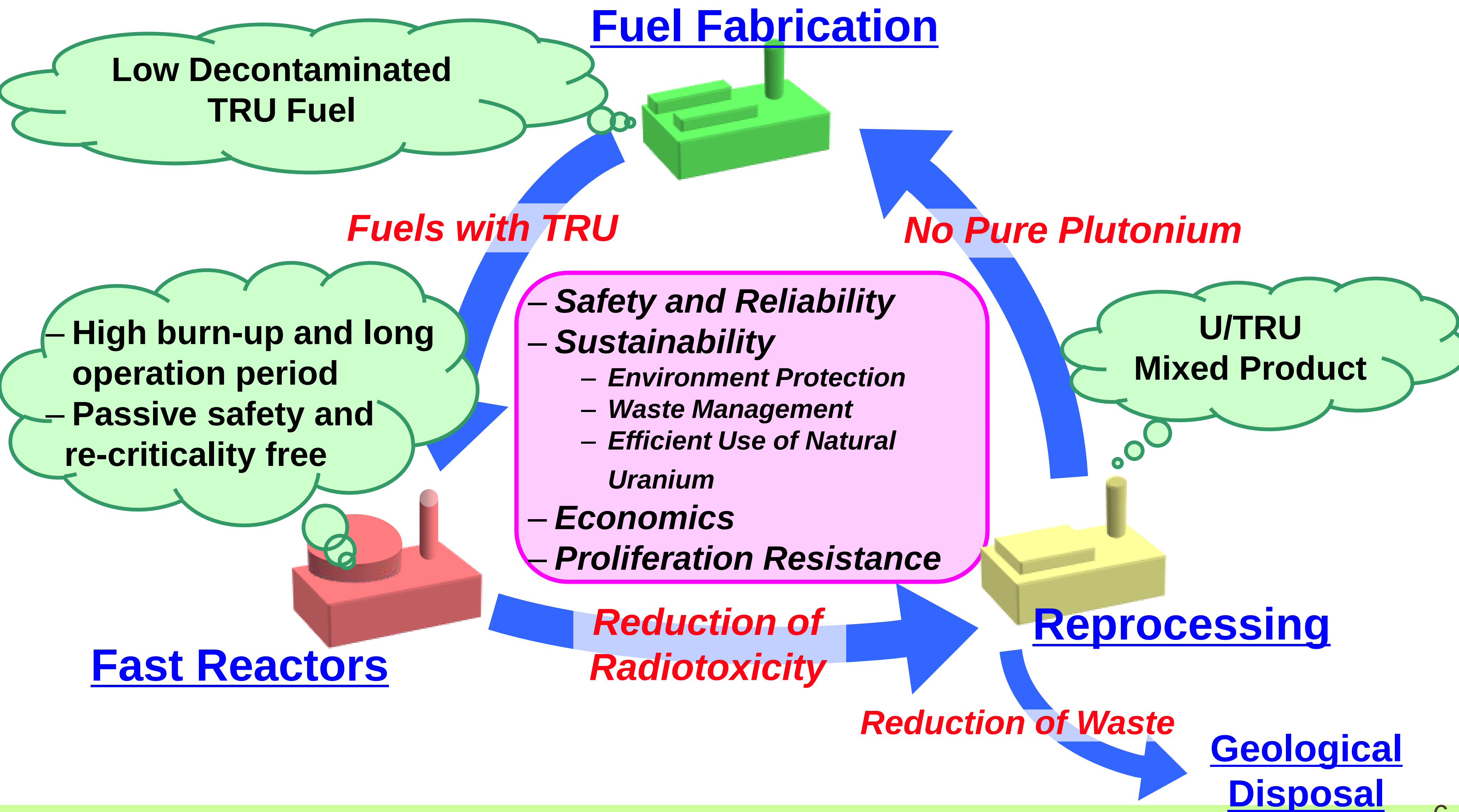
Light-water reactor 55 Units (49.58GWe)
LWR-MOX: Starting from late 2008, 16-18 units around 2010.

Tokai Plutonium Fuel Center (JAEA)

April 1988: Start of the operation

Prototype FBR Monju (JAEA)
Plant operation has been suspended since December 1995
System start-up test is expected to start in February 2009.

Fundamental Concepts of FR Cycle Systems



The Outline of FaCT Project

2005 | 2010 | 2015 (JFY)

Feasibility Study
(JFY 1999-2005)
Identify Most Promising Concept

C&R

Experimental FR "Joyo"

Prototype FBR "Monju "

Review & Basic Policy by MEXT &AEC

Fast Reactor Cycle Technology Development Project (FaCT)

Decision on Innovative Tech. (2010)

Approved Confirmation (2015)

R&D of Innovative Technologies

Preliminary Design of Commercial & Demonstration FR Cycle Facilities

Commercialized FR Cycle

R&D at "Monju"

- ◆ Demonstrating its Reliability as a Nuclear Power Plant
- ◆ Establish Sodium Handling Tech.

2015

Conceptual Design of Commercial and Demonstration FR Cycle Facilities, with Providing Necessary R&D Programs

Detailed Design & Construction

2025

Start of Operation of Demonstration FR & its Fuel Cycle Facility

Validation of Economy & Reliability

～2050

Commercial Introduction of FR Cycle Facilities

◆Cooperation with various Organizations **◆International Cooperation（GNEP, GEN-IV, INPRO etc.）**

R&D Activities on Innovative Reactor Technologies

Economic Competitiveness

(1) ODS Steel for Cladding Tube

(2) Two-loop System

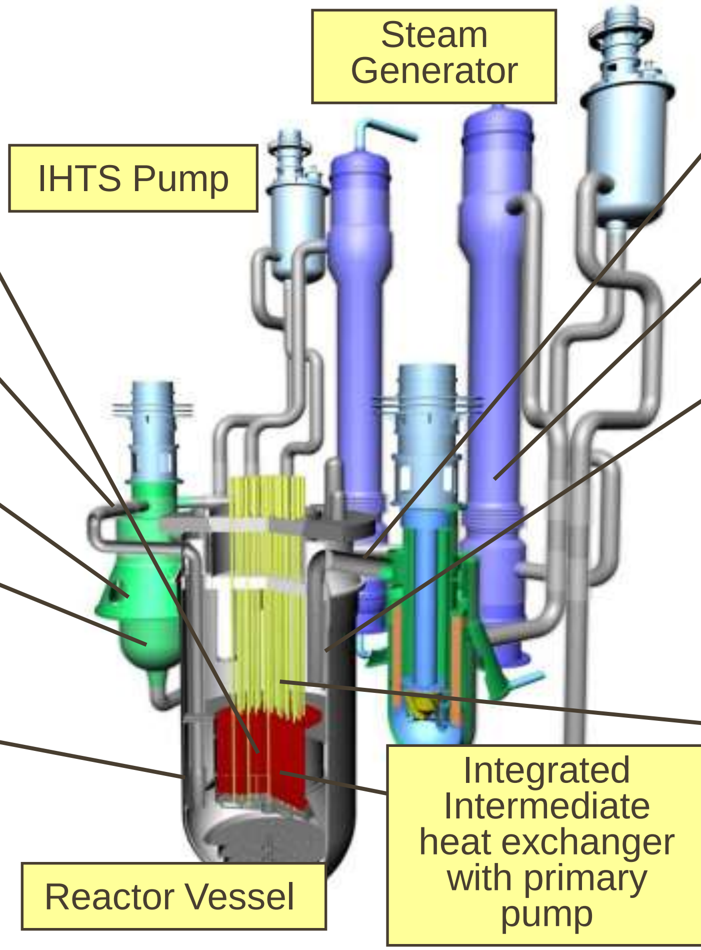
(3) High-chromium Steel for Structural Material

(4) Integrated IHX with Primary Pump

(5) Compact Reactor Vessel

(6) Fuel Handling System

(7) Steel Plate Reinforced Concrete Structure Building



1,500 MWe Large FR

Specific Issues of Sodium

(1) Double-walled Piping System

(2) Double-walled Tube Steam Generator

(3) In-service Inspection and Repair Technologies

Reactor Core Safety

(1) Passive Reactor Shutdown System and Decay Heat Removal by Natural Circulation

(2) Re-criticality Free Core Concept

(3) A Seismic Design

R&D Activities on Innovative Fuel Cycle Technologies

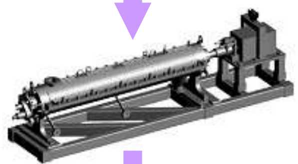
Advanced Aqueous Reprocessing

(1) Disassembling and Shearing

Mechanical Disassembling and Shorter Length Bundle Shearing

(2) Dissolution

Compact Continuous Dissolver



(3) Uranium Crystallization

Compact Continuous Crystallizer

(4) U, Pu and Np Co-extraction

Centrifugal Contactor

(5) MA Recovery

Extraction Chromatography Method

(6) Salt Free Waste Treatment

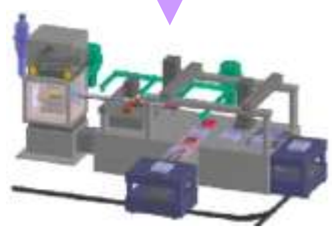
Simplified Pelletizing Fuel Fabrication

(7) Conversion and Granulation

Microwave Heating Denitration and Granulation

(8) Pelletizing

Die Wall Lubrication Pelletizing



(9) Sintering

Sintering and Adjustment of O/M Ratio

(10) Studies of Fuel Physical Properties

Physical Properties of MOX Fuel with MA etc.

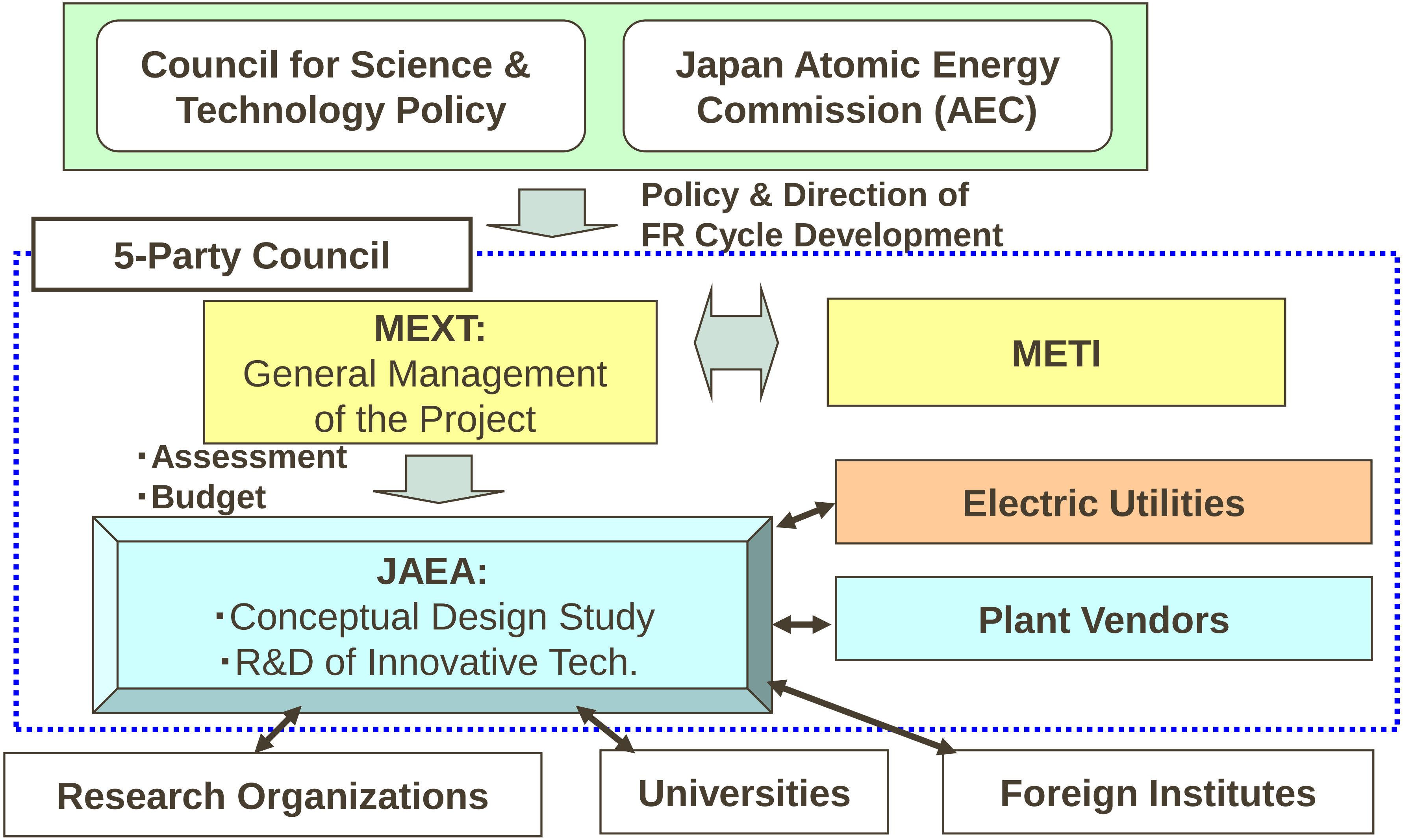
(11) In-cell Remote Handling Technology

Automatic Operation and Remote Maintenance

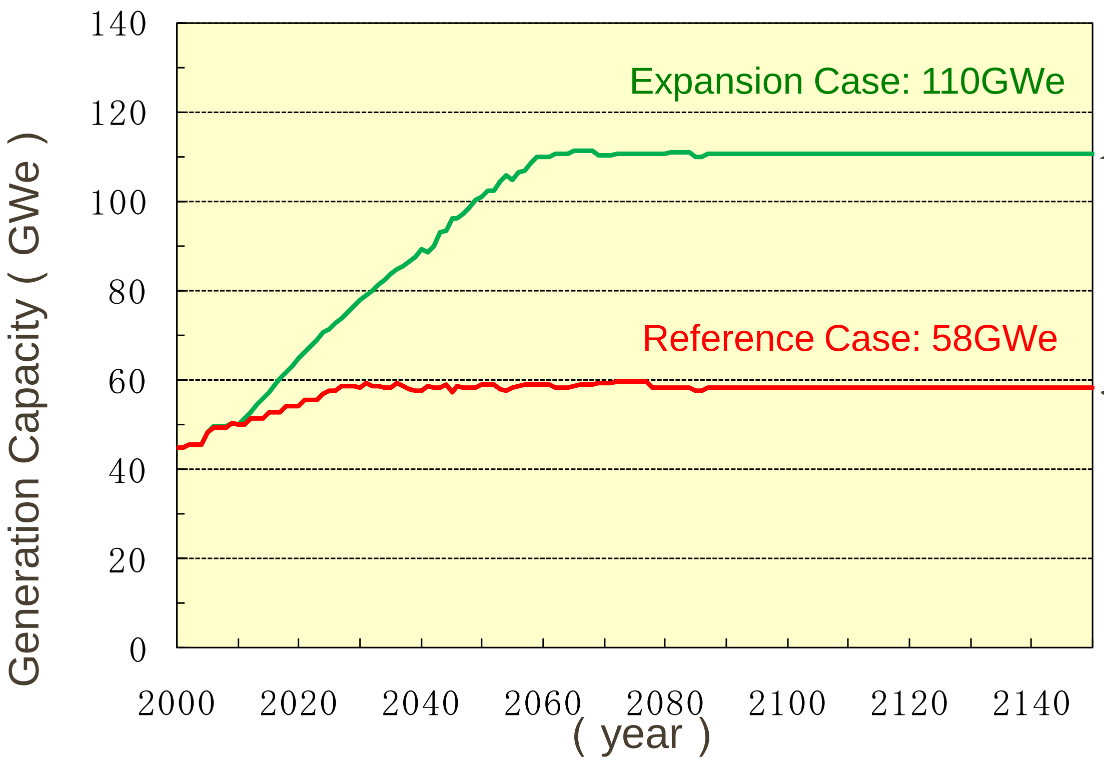
(12) Fuel Handling Technology

Cooling System for MOX fuel with MA etc.

All-Japan Regime toward FR & Fuel Cycle Commercialization in Japan



Assumptions on Nuclear Power Generation Capacities in Japan



- Large shift from fossil to electricity in civil sector
- Considering broader use of hydrogen in transport sector, and strengthening global warming countermeasures

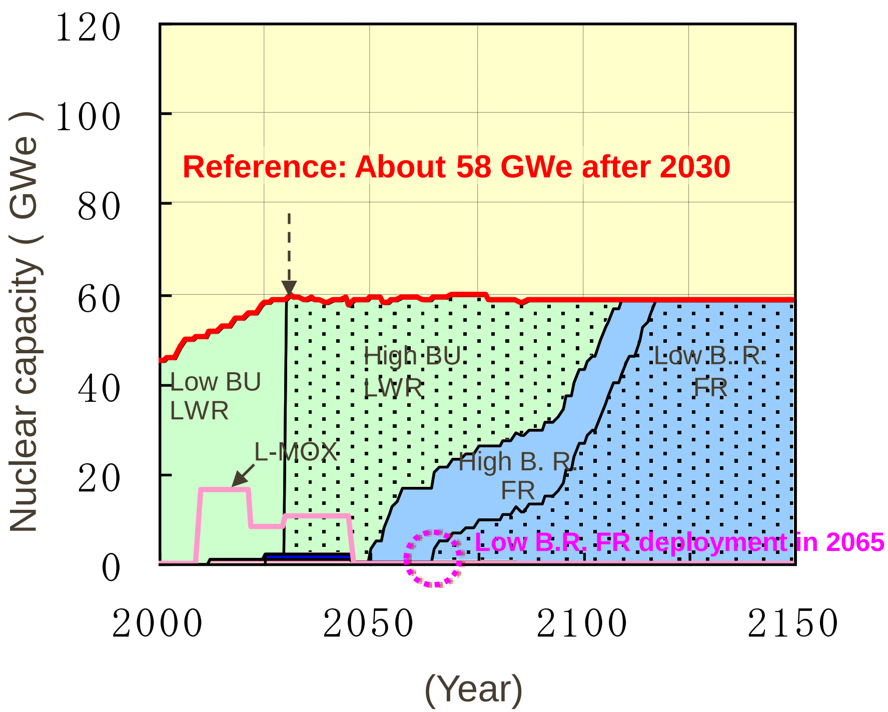
- 45 % electrification rate at 2100 year

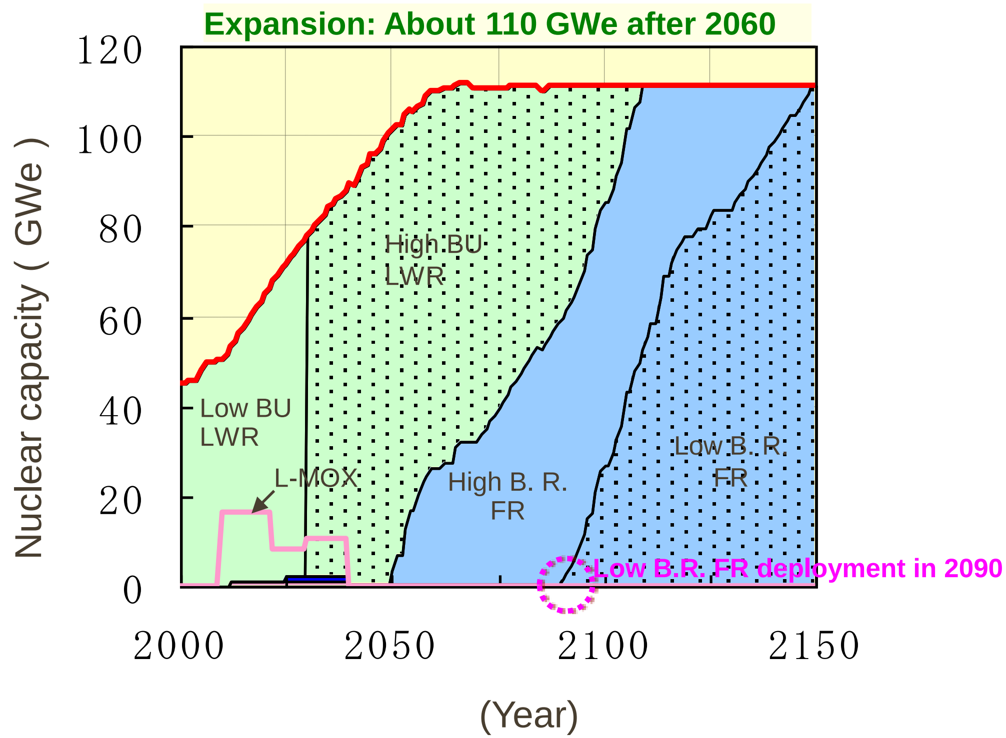
- Reference Case: 58 GWe is used as the nuclear capacity in Japan
- Expansion Case: 110 GWe is used for the nuclear energy use with consideration of large shift from fossil to electricity in energy demand, broader use of hydrogen, and other global warming countermeasures
- FRs are deployed in 2050 in Reference Case, and in 2040 in Expansion Case

Major assumptions for the facility characteristics in the Scenario Study

Items		Outline of characteristics
Nuclear Power Plant Capacity (previous slide)		58 GWe (Reference Case) 110GWe (Nuclear energy use expansion Case)
Reactor Systems	LWR	- 2029: Burnup 40,000MWd/t、 Load Factor80% 2030 - :Burnup 60,000MWd/t、 Load Factor90% LWR-MOX: 2010-2045 (About 30 yrs, keeping with Pu balance)
	FR	Breeding core (B.R. =1.2), Break-even Core type (B.R. =1.03) Replace all LWR to FBR after FR deployment **in 2050 (or 2040)**
Fuel Cycle Systems	Ex-core Time Period	LWR: 4 years, FR: 5 years
	Loss Factor	LWR (Uranium Conversion: 0.5%; Fabrication: 0.1%; Reprocessing: U-0.4%, Pu-0.5%, MA-0.1%) FR (Fabrication: 0.1%, Reprocessing: U/Pu/Am/Cm-0.1%, Np-10%)
	Other	RRP (Rokkasho Reprocessing Plant): plan in Sept. 2007 FR Reprocessing: Demonstration Plant: 20 tHM/year, 2030 in Operation LWR cycle: Recovered uranium usage, MA recovery starts from the 2nd reprocessing plant MA burning in FR (upper limit 5%) Plant lifetime: 60years for reactors, 40years for fuel cycle facilities
Assumptions used in the Analysis		● Transition from LWR cycle to FR cycle for a given transition period with keeping Pu balance ● Upper limit of Pu-f storage in RRP: 20 ton Pu-f ● Average load factor of the 2nd Rep. (LWR) : Over 80 %

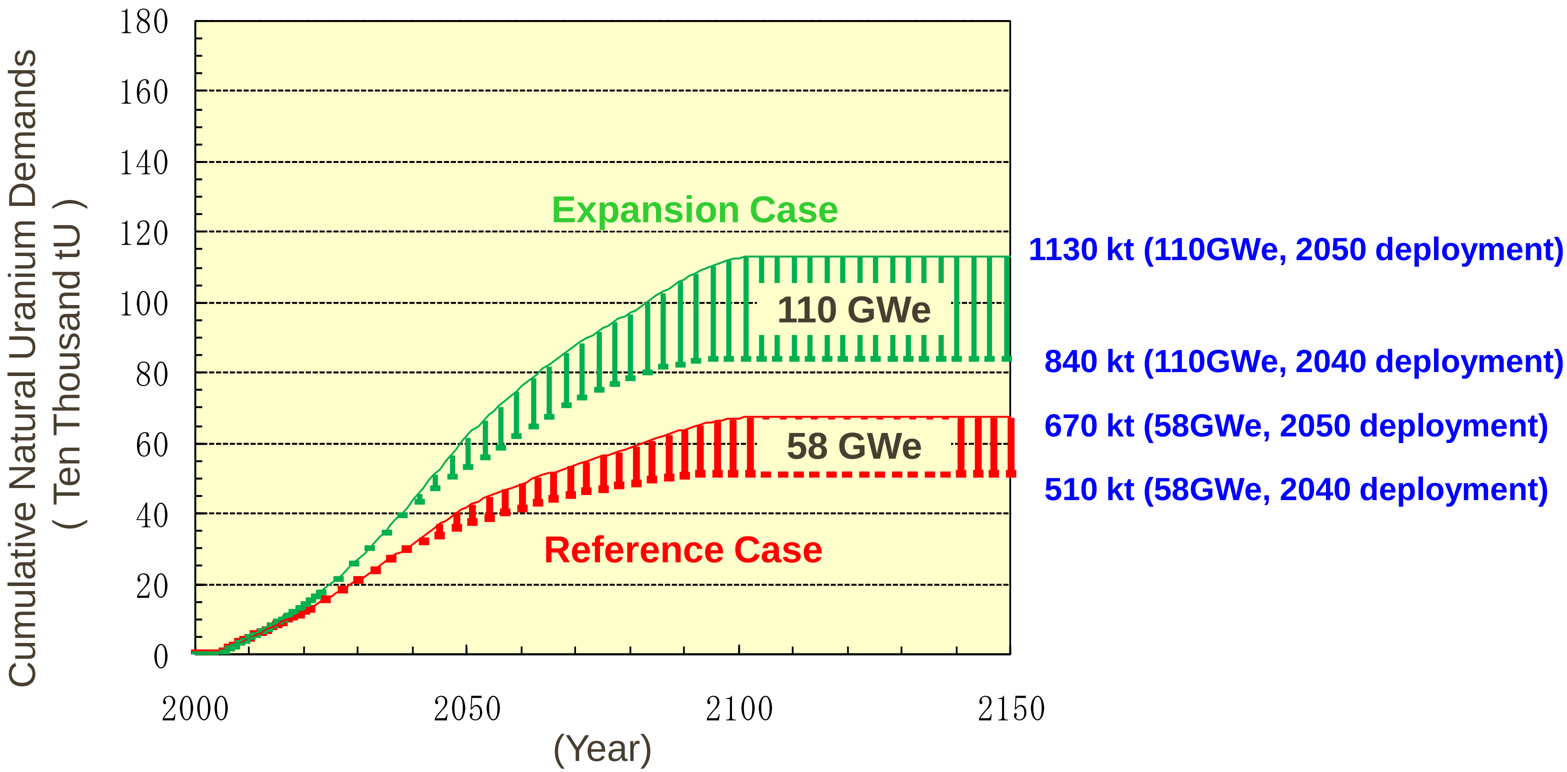
Nuclear Power Plant Scenarios (Nuclear Power Plant Capacities)





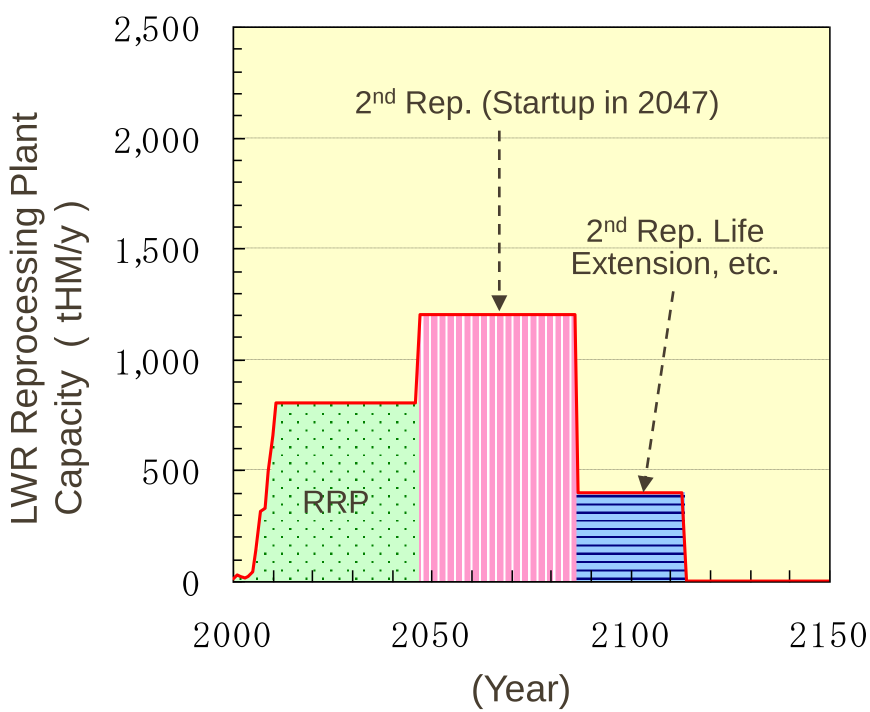
- Total nuclear power capacities are about 58 GWe after 2030 in Reference Case and about 110 GWe after 2060 in Expansion Case
- Cumulative natural uranium demands are 670 – 760 thousand tons for Reference Case

Cumulative Natural Uranium Demands

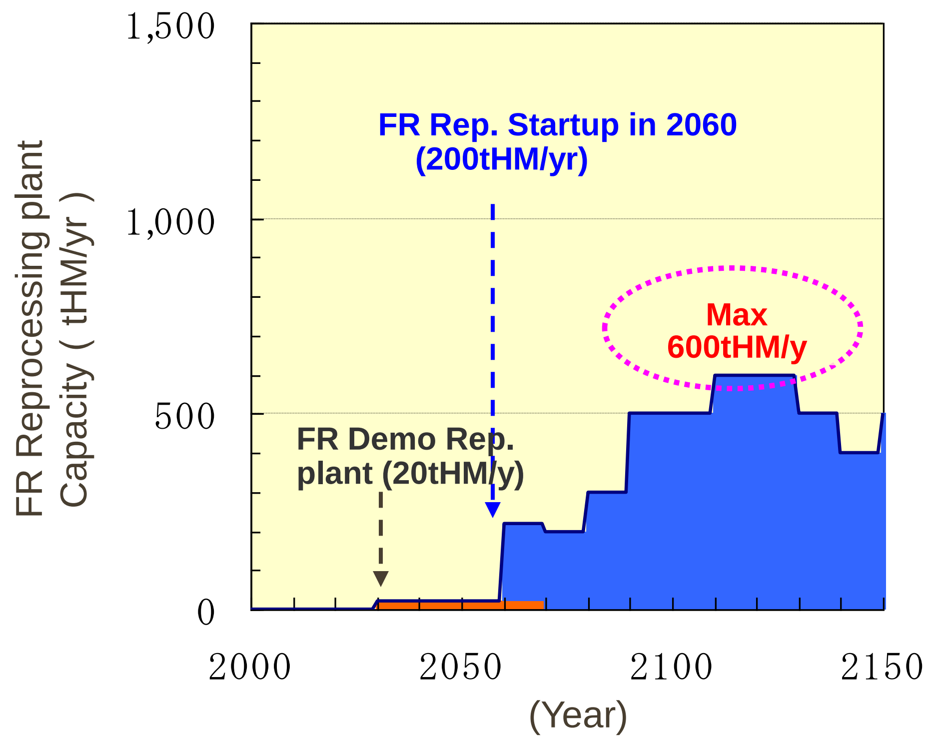


- If FRs are deployed in 2040, cumulative natural uranium demands will be changed 670 to 510 thousand tU for 58 GWe Reference Case and 1130 to 840 thousand tU for 110 GWe Expansion Case

Capacity of Reprocessing Plant



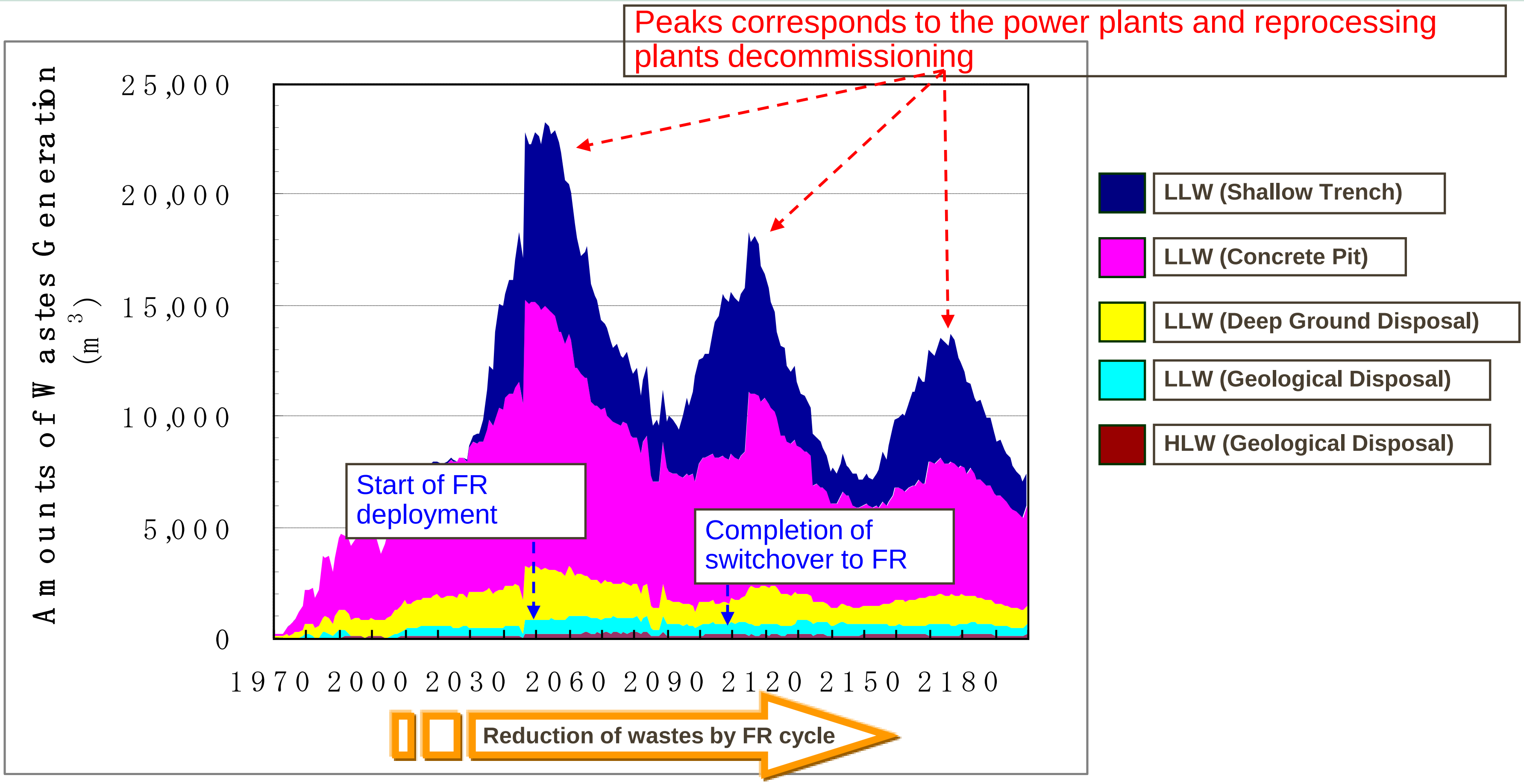
LWR Reprocessing Plant Capacity
(58GWe, FR deployment in 2050)



FR Reprocessing Plant Capacity
(58GWe, FR deployment in 2050)

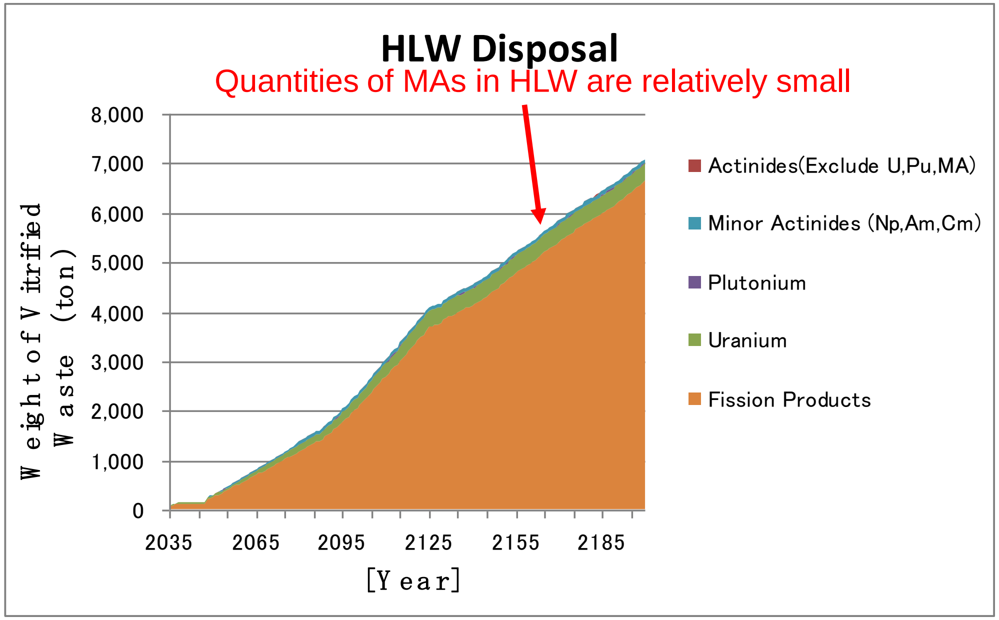
- Total capacity of commercial reprocessing plant will reach 1000 tHM/y before the completion of switchover to FR cycle, it will be around 500 – 600 tHM/y after FR deployment

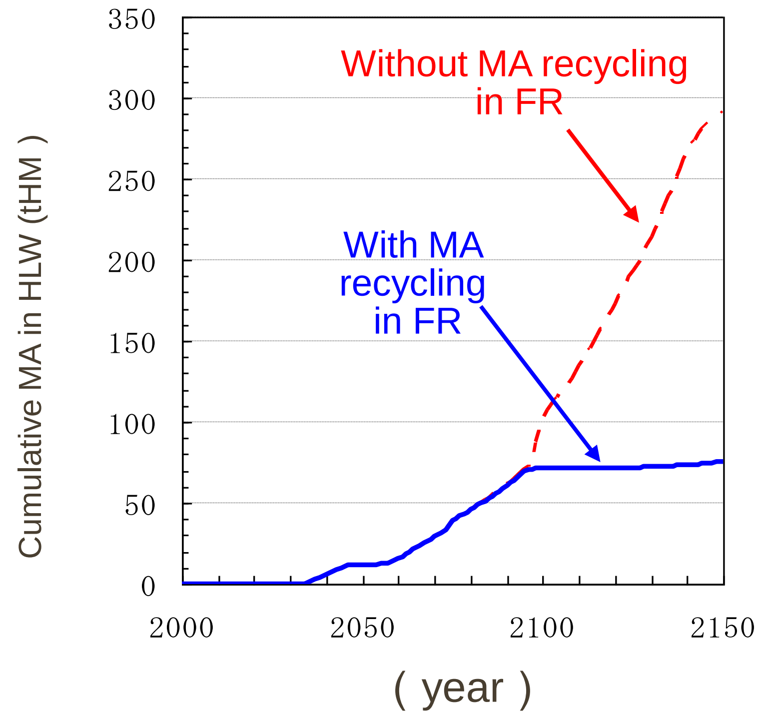
Effects of FR Deployment on Wastes Generation



- Radioactive waste generated from nuclear energy system in Japan will be reduced by deploying FR cycle with actinides (heat emitters) recycling and compact facilities.

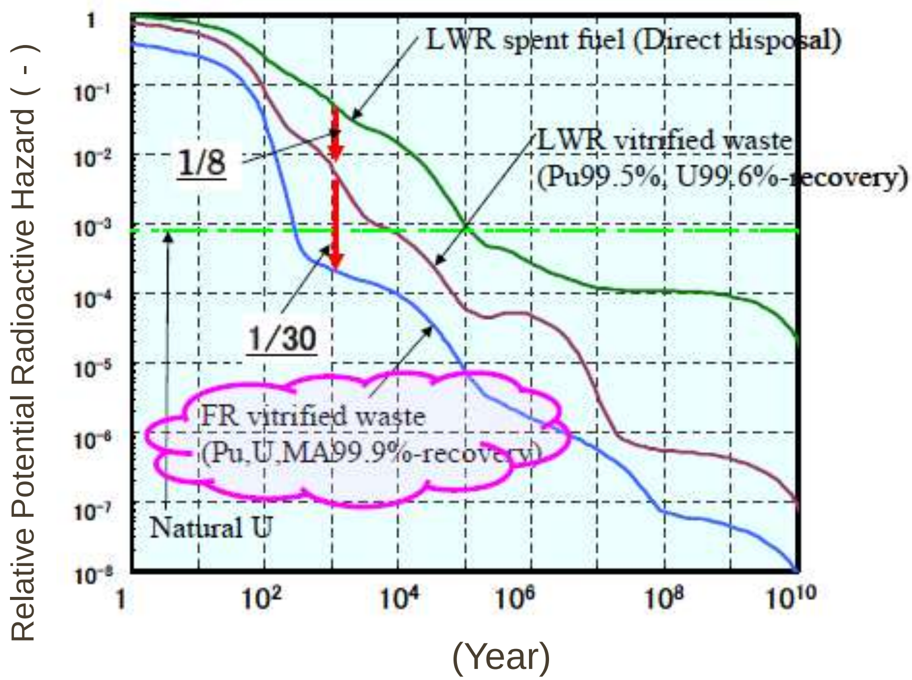
MAs Contained in the HLWs from Various Nuclear Fuel Cycle Schemes





- The quantities of actinides contained in HLW are relatively small compared to the total weight of fission products in HLW.
- Reducing the MA quantities in HLW is important from the viewpoint of their heat emissions, radioactivity, etc.
- If MAs are recycled in FR, the quantity of MAs in HLW is still below 100t in 2150 which is 1/3 or less compared to no MA recycling.

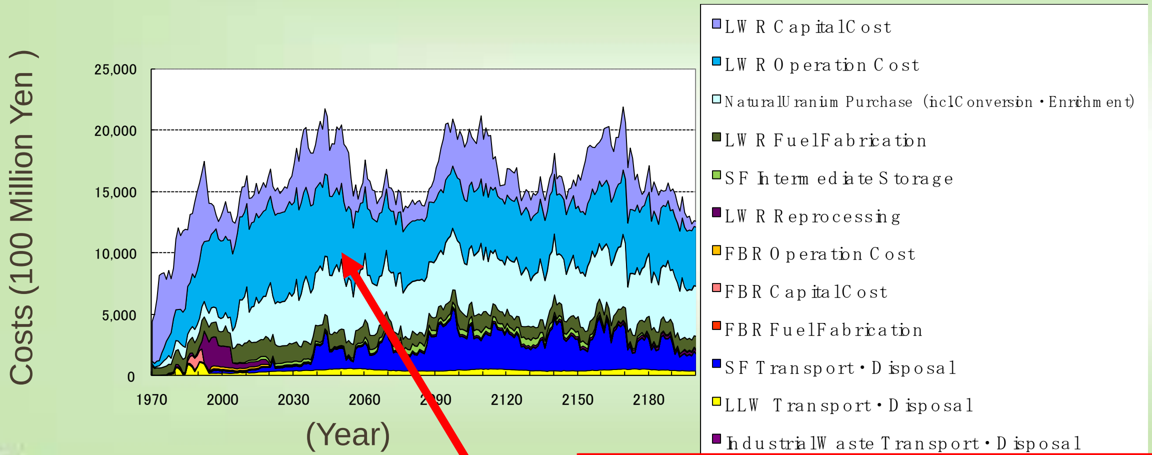
Effects of FR Deployment on Wastes Generation



- Potential radioactive hazard of HLW (vitrified wastes) will be reduced when actinides are recycled in FR cycle.
- MA recycling in FR reduces the potential radiological hazard by more than factor of 10 after 1,000 years from HLW disposal

Effects of FR Deployment on Power Generation Cost

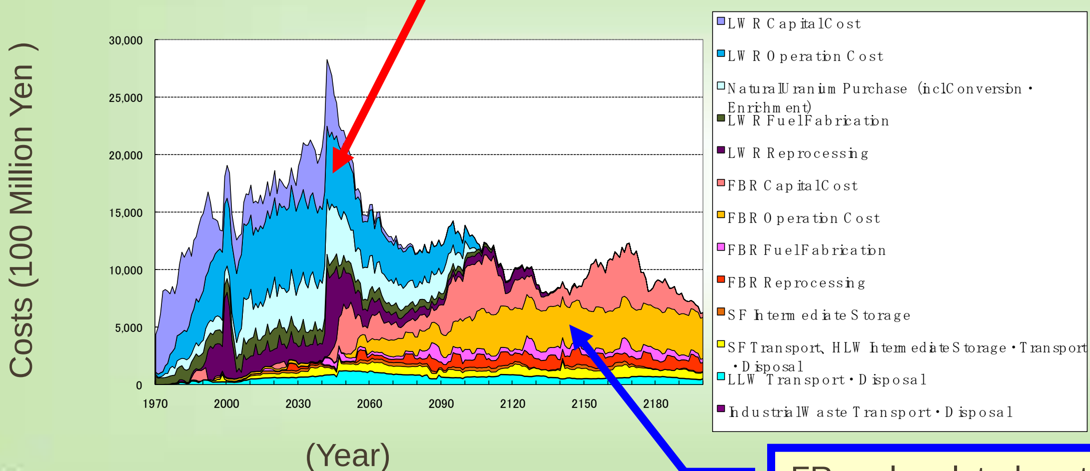
Power generation cost without FR deployment (Once-through case)



- The SF direct disposal cost is generated though the reprocessing cost decreases in the once-through case (The construction cost of Rokkasho reprocessing plant is included).

LWR cycle related costs (blue, green, violet, etc.)

Power generation cost with recycling in FR (FR recycling case)



- Although there will be cost-up in the short-term because of the cost of the 2nd reprocessing plant, etc., the power generation cost of FR recycling case will be kept low compared to that of once-through case when FR cycle facilities with innovative technology are deployed.

FR cycle related costs (red, orange, etc.)

Summary of Japanese Nuclear Fuel Cycle Strategy

1. Nuclear power generation continues to meet at least 30 to 40% of electricity supply even after 2030.
2. Commercial FRs will be deployed in around 2050 to secure Japanese energy supply and to reduce the environment burden.
3. All LWRs can be replaced by FRs within ca. 60 years.
4. The second reprocessing plant (for LWR reprocessing) will start up in 2047.
5. The required max. reprocessing plant capacities are: 1,200 tonU/y for LWRs, and the 600 tonHM/y for FRs.
6. Timing of termination of Pu recycling in LWRs is 2045. The operation period of Pu recycling in LWRs is about 35 years.
7. If MAs from LWR and FR spent fuels are recovered and recycled in FR cycle, the cumulative amount of MA disposed as HLW can be reduced to about 1/3 or less compared to no MA recycling scenario (ex. once-through).
8. MA recycling leads to a large reduction of potential radioactive hazard of HLWs.
9. Deployment of FR and fuel cycle systems with innovative technologies can lead the reduction of waste generation and power generation cost in a long run.

Related Materials

Dynamic Characteristic Analysis methodology Corresponds to FR Deployment Scenarios

Input Data

Each facilities

- Capacity
- Construction and Decommissioning time
- Lead/lag time
- Unit of waste generation
- Construction cost
- Processing unit price, etc.

Reactor

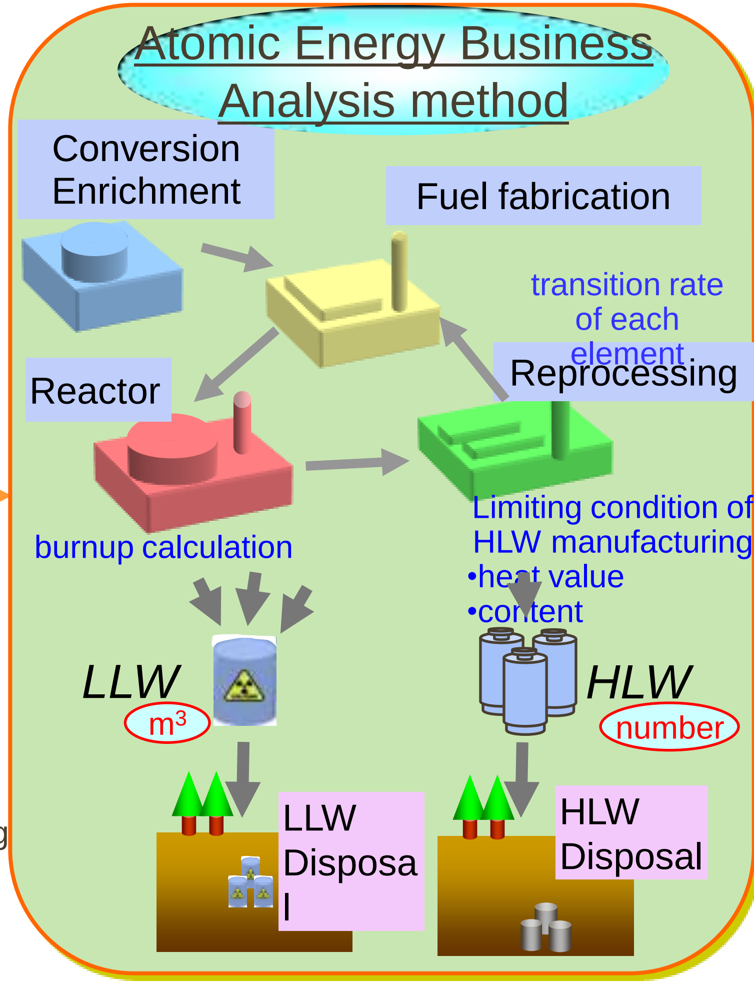
- Burnup condition

Fuel fabrication plant

- Restriction and manufacturing condition

Reprocessing plant

- Transition rate of each element
- Limiting condition of HLW manufacturing



Output

Each facilities

- Nuclear material composition
- Amount of waste generation
- Utilized capacity
- Capital cost, Operation cost, etc.

Total of all facilities

- Total amount of waste generation
- Total Cost
- Total electric generating capacity, etc..

- Almost all nuclear facilities in Japan are included in the analysis
- Flexible simulation is possible (object-oriented design.)

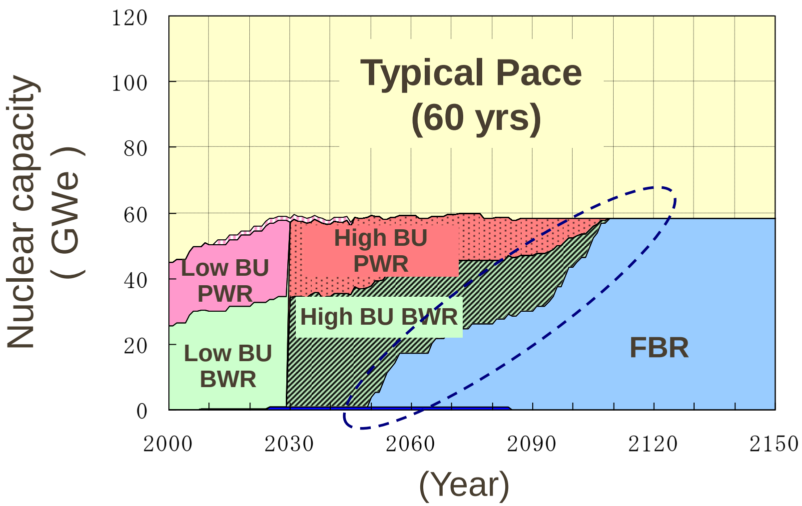
Analysis Cases and common assumptions in the scenario analysis

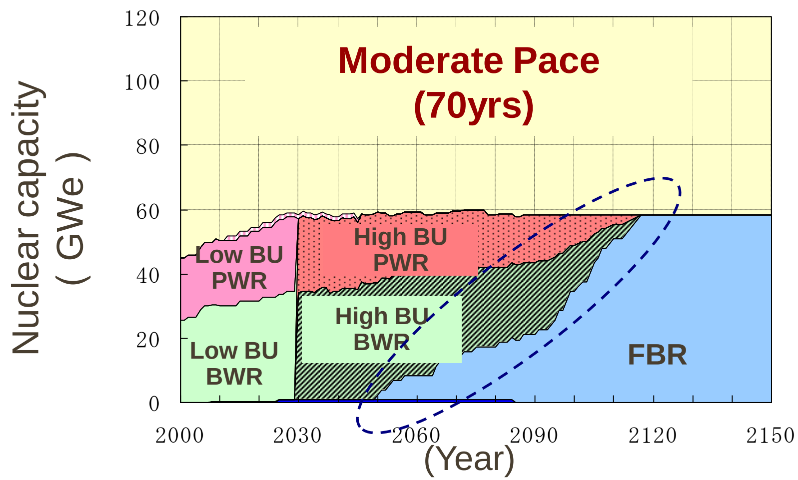
Cases	Nuclear Power Generation Capacity		Timing of FR Deployment		Pace of FR Deployment	
	58GWe	110GWe	2040	2050	Typical	Moderate
Reference	○			○	○	
Nuclear Energy Expansion Use		○		○	○	
Early FR Deployment	○		○		○	
Moderate FR Deployment Pace	○			○		○
Notes	*1 : Typical pace(60 years). Replace all LWR to FBR after FBR deployment *2 : Moderate pace. 1st FBR deployment by each electric companies trace past results. Replacing all LWR with FBR after 10 years from FBR deployment.					

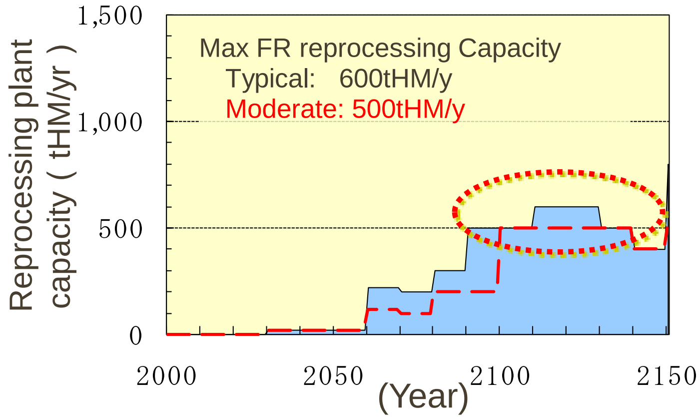
Assumptions in the analysis

- Transition from LWR cycle to FBR cycle for given transition period with keeping Pu balance.
- Upper limit of Puf storage in RRP : 20 ton Puf
- Average load factor in 2nd Rep. (LWR) : Over 80 %

Effects of the Transition Pace to FR







- Max FR reprocessing capacity will decrease from 600 tHM/y to 500 tHM/y if the "moderate pace"is selected as the transition pace.
- Moreover, The capacity during 21st century will not reach 500 tHM/y.

Basic Japanese Policy Related to FR Cycle Research and Development

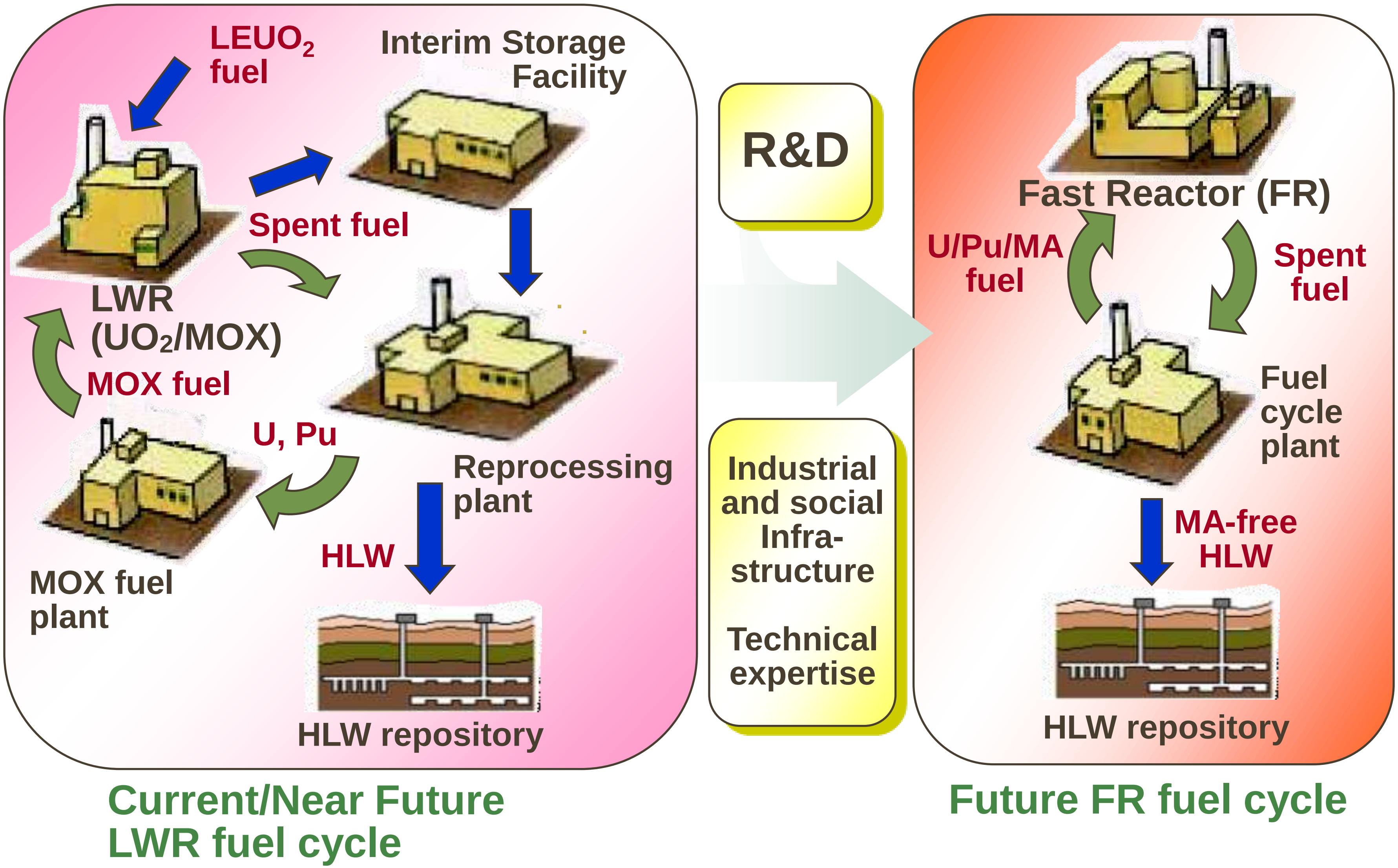
- **Framework for Nuclear Energy Policy by Atomic Energy Commission (AEC) of Japan (Oct. 2005)**
  - It is necessary to promote R&D toward commercialization of FR cycle technology, which can enable long-term energy security and reduction in radio-toxicity of radioactive waste.
  - A Feasibility Study on Commercialized FR Cycle Systems aims to establish the FR cycle technological scheme by around 2015.
  - Development of FR cycle aims at its commercial introduction around 2050.

- **Science and Technology Basic Plan by Council for Science and Technology Policy (Mar. 2006)**
  - FR cycle technology was selected as one of the key technologies of national importance.

- **Report on Nuclear Energy Policy of MEXT (Jul. 2006) and METI (Aug. 2006)**
  - A council was set up to investigate demonstration processes of FR cycle technology by MEXT, METI, JAEA, electric utilities and plant vendors.
  - Development of a demonstration FR aims at its introduction by around 2025.

- **"Basic Policy on Research and Development of Fast Reactor Cycle Technologies over the Next Decade" was decided by AEC (Dec. 2006)**

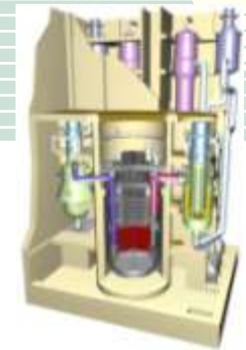
Japan's Basic Strategy for Nuclear Fuel Cycle



History of Fast Reactor Development in Japan

JSFR

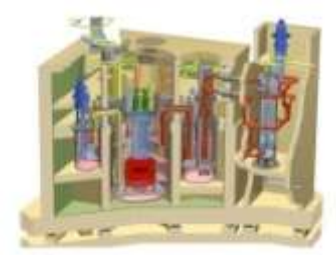
Demonstration / Commercialization



Innovative Technology for Economics and Reliability

DFBR

Design for Demonstration



- **Design Study of Demonstration Reactor**
- **Development of Element Technologies**

Performed during the 1990s
Power : 1,600MWt / 660MWe
Temperature : 550ºC

Monju

Prototype

- **Demonstration of Reliable Operation**
- **Establishment of Sodium Handling**

Initial Criticality in 1994
Power : 714MWt / 280MWe
Temperature : 529ºC

Joyo

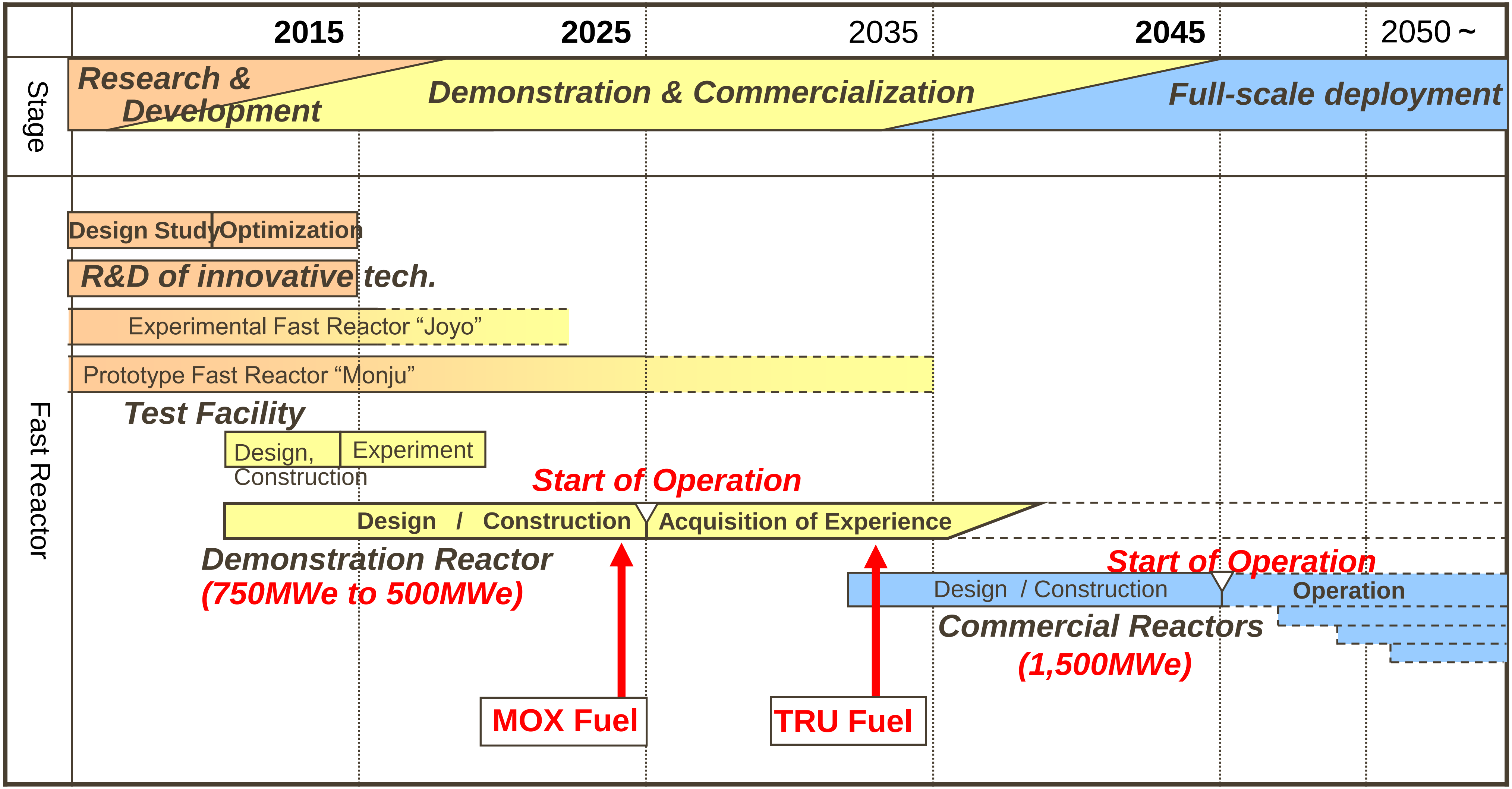
Experi-mental

- **Confirmation of FR Basic Technologies**
- **Verification of Safe and Stable Operation**

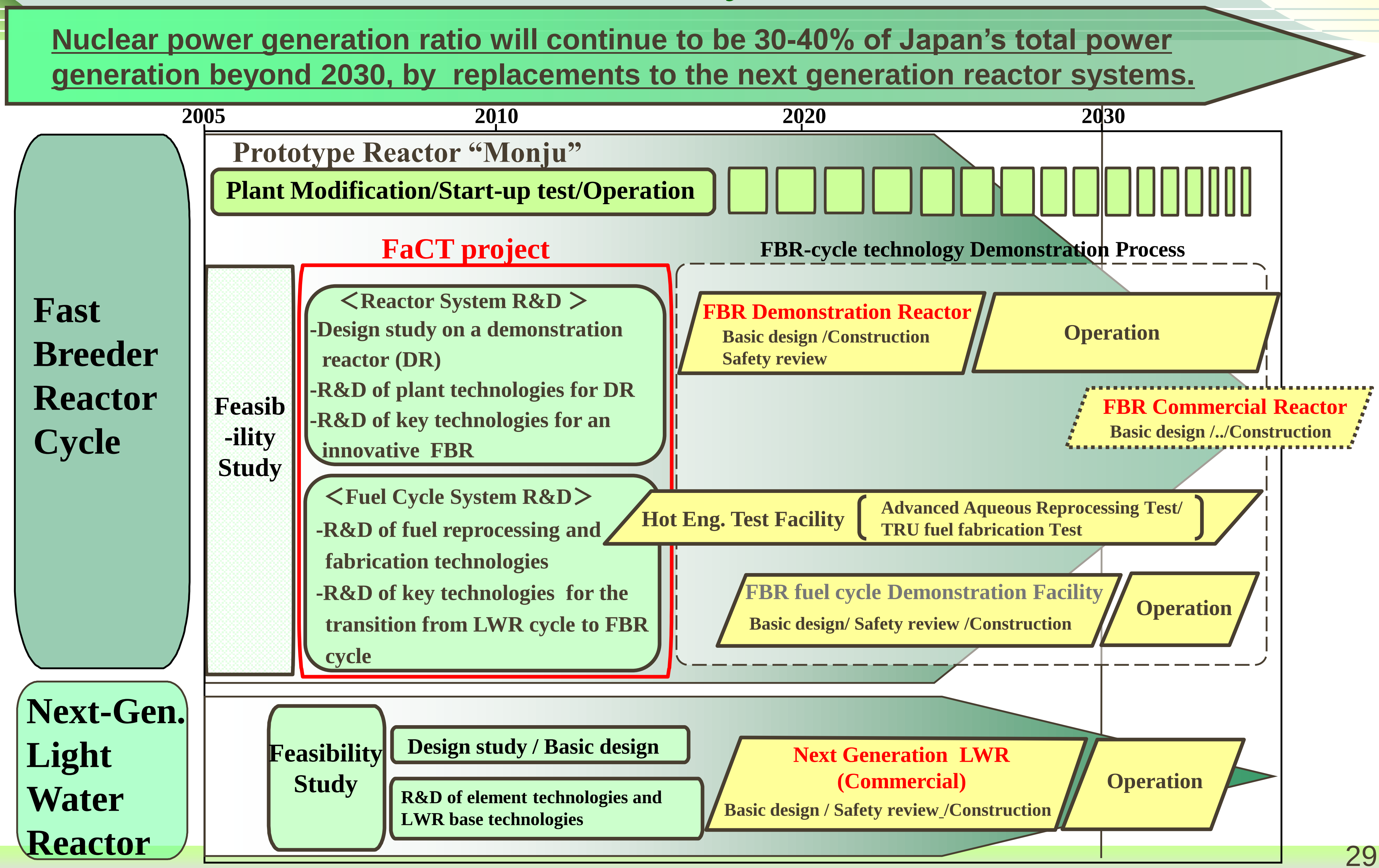
Initial Criticality in 1977
Power : 50MWt → 100MWt → 140MWt (Mk-III Core)
Temperature : 435ºC → 500ºC → 500ºC

System Development as Electricity Generation

R&D Roadmap toward Commercialization



Roadmap for Next Generation Reactors and Related Fuel Cycle



Development Targets of FaCT Project

Safety and Reliability

SR-1	Ensuring safety equal to future LWR and related fuel cycle facilities
SR-2	Ensuring reliability equal to future LWR and related fuel cycle facilities

Sustainability

Environment Protection

EP-1	Radioactive influence through normal operation no more than future LWR cycle
EP-2	Emission control of environment transfer substances which can restrict in safety limits

Waste Management

WM-1	Reduction of an amount of radioactive waste compared with future LWR cycle
WM-2	Improvement of waste managementability equal to or more than future LWR cycle
WM-3	Reduction of radio-toxicity compared with future LWR cycle

Efficient Utilization of Nuclear Fuel Resources

UR-1	Breeding ratio to enable transition to fast reactor, and its flexibility

Economical Competitiveness

EC-1	Electric generation cost which can match other power plants
EC-2	Investment risks no more than future LWR cycle
EC-3	External costs no more than future LWR cycle

Nuclear Non-Proliferation

NP-1	Adoption of institutional measures and application of technical features which can enhance non-proliferation
NP-2	System design of physical protection and its development

3S (Safety, Safeguards, and Security)

1. **Safety (nuclear safety)**
   - ✓ Regulatory framework, measures to strengthen earthquake-resistance
2. **Safeguards (safeguards, nuclear non-proliferation)**
   - ✓ Comprehensive Safeguards Agreement
   - ✓ Additional Protocol
3. **Security (physical protection, nuclear security)**
   - ✓ Countermeasures against nuclear terrorism