Peaceful Nuclear Energy Use and Japanese Effort for Nuclear Nonproliferation

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The University of Tokyo (UT)
Ⅰ Status of Nuclear Energy Use in Japan
Ⅱ Japan’s Efforts to Ensure Compatibility between Peaceful Nuclear Energy Use and Nuclear Non-Proliferation
Ⅲ Responsibilities of States which pursue Nuclear Energy Option and Japan’s Contribution
I Status of Nuclear Energy Use in Japan
Japan’s Current Nuclear Energy Development

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

Tokai Plutonium Fuel Development Center (JAEA)
April 1988: Start of the operation

Light-water reactor 55 Units (50 GWe)

Prototype FBR “MONJU” (JAEA)
Plant operation has been suspended since December 1995
System start-up test is expected to start in 2009

Rokkasho Reprocessing Plant (JNFL)
under final commissioning test
Start of the operation is expected in 2009
Japan has the lowest energy self-sufficiency ratio among industrialized countries.

After the oil crisis in early 1970’s, Japan has shifted power source from oil to other sources such as nuclear energy.

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**Energy Self-Sufficiency of Major Countries <2004>**

- **Italy**: 120%
- **Japan**: (148%)
- **Germany**: 139%
- **France**: 120%
- **US**: 87%
- **UK**: 61%
- **Canada**: (96%) (148%)
- **Japan's food self-sufficiency ratio**: 87%

**Change in Share of Power Source**

**Before the Oil Crisis (1973)**
- **Oil**: 73%
- **LNG**: 26%
- **Coal**: 25%
- **Nuclear Energy**: 10%
- **Renewable, New energy etc**: 10%
- **Water Pump**: 1%

**Now (2004)**
- **Oil**: 10%
- **LNG**: 28%
- **Coal**: 25%
- **Nuclear Energy**: 28%
- **Renewable, New energy etc**: 16%
- **Water Pump**: 1%

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Overview of Japan’s Nuclear Energy Policy

Basic Goals of the Framework for Nuclear Energy Policy

(a) Continuing to meet at least 30 to 40% of electricity supply even after 2030 by nuclear power generation,
(b) Further promoting the nuclear fuel cycle, and
(c) Aiming at commercializing practical FBR cycle in 2050.

- Japan adopts closed fuel cycle as its basic policy
- Rokkasho Reprocessing Plant is now in final stage in preoperational test
- Construction of J-MOX fabrication plant starts from groundbreaking.
- Centrifuge enrichment is in operation, new centrifuge is under development.
- Proven track record of plutonium utilization through fuel cycle is essential for showing a good success path of waste management to public
Status of Nuclear Power Plants in Japan

- 55 commercial nuclear power plants (BWRs and PWRs) are in operation (including those under reinforcement work).
- 2 plants are under construction.

<table>
<thead>
<tr>
<th>Power Plant</th>
<th>Location</th>
<th>Status</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomari</td>
<td>Kashiwazaki Kariwa</td>
<td>In Operation</td>
<td>4</td>
</tr>
<tr>
<td>Shimane</td>
<td></td>
<td>Under Construction</td>
<td>1</td>
</tr>
<tr>
<td>Tsuruga</td>
<td></td>
<td>Preparing for Construction</td>
<td>1</td>
</tr>
<tr>
<td>Mihama</td>
<td></td>
<td>In Operation</td>
<td>4</td>
</tr>
<tr>
<td>Ohi</td>
<td></td>
<td>Under Construction</td>
<td>1</td>
</tr>
<tr>
<td>Takahama</td>
<td></td>
<td>Preparing for Construction</td>
<td>2</td>
</tr>
<tr>
<td>Genkai</td>
<td></td>
<td>In Operation</td>
<td>4</td>
</tr>
<tr>
<td>Sendai</td>
<td></td>
<td>Under Construction</td>
<td>1</td>
</tr>
<tr>
<td>Ikata</td>
<td></td>
<td>Preparing for Construction</td>
<td>2</td>
</tr>
<tr>
<td>Fukuoka</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tokai</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hamaoka</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higashidori (Tohoku Electric)</td>
<td>In Operation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Higashidori (Tokyo Electric)</td>
<td>Under Construction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Onagawa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onagawa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sendai</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tokai</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hamaoka</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A: ABWR/APWR

- PWR In Operation: 23 Units
- BWR In Operation: 32 Units
- PWR Under Construction: 1 Unit
- BWR Under Construction: 1 Unit
- PWR Preparing for Construction: 2 Units
- BWR Preparing for Construction: 2 Units
Three Fundamental Problems in Direct Disposal Option

- **Formation of plutonium mines → Increase in proliferation concerns**
  - More than 8,000 tons of Pu as spent fuels will be buried by 2100
  - 100 years later, access becomes easier, and plutonium properties become more attractive for weapon use

- **Extremely low uranium utilization efficiency (≤1%)**

- **Need for larger HLW repository space due to larger volume and larger heat load of waste packages**
Japan’s Fundamental Strategy for Nuclear Fuel Cycle
Effective Utilization of Energy Resource

Current LWR fuel cycle
- LEUO₂ fuel
- Spent fuel
- Interim Storage Facility
- MOX fuel
- MOX fuel plant
- U, Pu
- Reprocessing plant
- HLW
- HLW repository
- Industrial and social infrastructure
- Technical expertise

Future FR fuel cycle
- U/Pu/MA fuel
- Fast Reactor (FR)
- Spent fuel
- Fuel cycle plant
- MA-free HLW
- HLW repository
Excess plutonium is fed to LWR-MOX before FR procurement.

In case FR systems are commercially procured from 2050, it will take 50-60 years at least for total replacement.
<table>
<thead>
<tr>
<th>Owner</th>
<th>Amount of spent fuel to be reprocessed (GW)</th>
<th>Amount of plutonium expected to be allocated (Pu)</th>
<th>Place to be used</th>
<th>Amount to be used (Estimated annual usage in Pu per year)</th>
<th>Purpose of Use (as LWR fuel)</th>
<th>Timing of the start of utilization and estimate of the period required for utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hokkaido EPCo</td>
<td>67</td>
<td>0.0</td>
<td>Tenari Nuclear Station</td>
<td>0.2</td>
<td>From FY 2012 or later for a period equivalent to 0.5 years</td>
<td></td>
</tr>
<tr>
<td>Tohoku EPCo</td>
<td>67</td>
<td>0.1</td>
<td>Onagawa Nuclear Power Station</td>
<td>0.2</td>
<td>From FY 2012 or later for a period equivalent to 0.5 years</td>
<td></td>
</tr>
<tr>
<td>Tokyo EPCo</td>
<td>67</td>
<td>0.5</td>
<td>Three to four Tokyo EPCo units, based on continued efforts by Tokyo EPCo to regain public trust from local communities at sites</td>
<td>0.9 - 1.6</td>
<td>From FY 2012 or later for a period equivalent to 0.3-0.6 years</td>
<td></td>
</tr>
<tr>
<td>Chubu EPCo</td>
<td>130</td>
<td>0.1</td>
<td>Hamaoka Nuclear Power Station Unit 4</td>
<td>0.4</td>
<td>From FY 2012 or later for a period equivalent to 0.3 years</td>
<td></td>
</tr>
<tr>
<td>Hekuriku EPCo</td>
<td>130</td>
<td>0.0</td>
<td>Shika Nuclear Power Station</td>
<td>0.1</td>
<td>From FY 2012 or later for a period equivalent to 0.2 years</td>
<td></td>
</tr>
<tr>
<td>Kansai EPCo</td>
<td>130</td>
<td>0.4</td>
<td>Units 3 and 4 at Takahama Power Station and one or two units at Ohi Power Station</td>
<td>1.1 - 1.4</td>
<td>From FY 2012 or later for a period equivalent to 0.3-0.4 years</td>
<td></td>
</tr>
<tr>
<td>Chugoku EPCo</td>
<td>130</td>
<td>0.1</td>
<td>Shimane Nuclear Power Station Unit 2</td>
<td>0.2</td>
<td>From FY 2012 or later for a period equivalent to 0.5 years</td>
<td></td>
</tr>
<tr>
<td>Shikoku EPCo</td>
<td>130</td>
<td>0.1</td>
<td>Ikata Nuclear Power Station Unit 3</td>
<td>0.4</td>
<td>From FY 2012 or later for a period equivalent to 0.3 years</td>
<td></td>
</tr>
<tr>
<td>Kyushu EPCo</td>
<td>15</td>
<td>0.2</td>
<td>Genkai Nuclear Power Station Unit 3</td>
<td>0.4</td>
<td>From FY 2012 or later for a period equivalent to 0.5 years</td>
<td></td>
</tr>
<tr>
<td>Japan Atomic Power Company (JAPC)</td>
<td>15</td>
<td>0.1</td>
<td>Tsuruga Power Station Unit 2 and Tokai Daiichi Power Station</td>
<td>0.5</td>
<td>From FY 2012 or later for a period equivalent to 0.2 years</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>273</td>
<td>1.8</td>
<td></td>
<td>5.5 - 6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric Power Development Company (EPDC)</td>
<td>258</td>
<td>0.1</td>
<td></td>
<td>4.4 - 5.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These plans shall be updated in more detail as future progress is made in the Phothermal Program, such as the start of fuel fabrication at Rokkasho MOX fuel plant, etc.

*1 "Amount of reprocessing" is based on JNFL's reprocessing program.

*2 "Amount of plutonium" represents the estimated amount of plutonium to be allocated from reprocessing at JNFL's RRP in FY2005 and FY2006. Recovered plutonium is to be allocated to the utilities in proportion to the amount of fissile plutonium contained in the spent fuel they have delivered to RRP. Therefore, plutonium will also be allocated to the utilities whose spent fuel is not actually reprocessed in FY2005 and FY2006. However, plutonium will eventually be allocated in proportion to the amount of fissile plutonium contained in the spent fuel contracted for reprocessing by each utility.

*3 In addition to use as LWR fuel, some plutonium may be transferred to JAEA for R&D purposes. Specific amounts of plutonium to be transferred by each utility will be made public once such amounts have been determined.

*4 The amount of plutonium is described as the amount of fissile plutonium (Pu). (Total amount of plutonium may not add up owing to rounding to the first decimal place.)

*5 "Estimated annual usage" represents the average annual amount of plutonium contained in MOX fuel to be loaded into power reactors according to each utility's Phothermal program. In some cases, the estimate may include plutonium recovered from overseas reprocessing.

*6 "Timing of the start of utilization" is stated as from FY2012 or later, when the Rokkasho MOX fuel fabrication plant, to be constructed adjacent to RRP, is scheduled to begin operation. Until then, plutonium will be stored at RRP in the form of uranium-plutonium mixed oxide powder.

*7 "Estimate of the period required for utilization" is "amount of plutonium" divided by the "estimated annual usage." (It does not necessarily reflect the actual period of use, because some plutonium is expected to be transferred to EPDC and JAEA, and in some cases the "amount to be used" may include the use of the plutonium recovered from overseas reprocessing.)

*8 The specific amount to be transferred to EPDC by the utilities will be made public once it has been determined.
FBR Development Strategy in Japan

- Verification of operation reliability
- Establish sodium handling and innovative technology

**Basic research**
- Experimental reactor "Joyo"
- Plutonium Fuel Production Facility

**Experiment reactor "Monju"**
- Restart up in 2008 FY is expected

**Demonstration Phase**
Around 2025
- Demonstration reactor comes true for verification of economical competitiveness

**Fast Reactor Cycle Technology Development (FaCT) Project**
2006
- FaCT Project
  - Study on conceptual design
  - Development of innovative technology

1999
- Feasibility Study (FS) on Commercialized Fast Reactor Cycle Systems
- Verification of operation reliability
- Establish sodium handling and innovative technology

**Feasibility Study**
- R&D on feasibility of candidate concepts
- Clarification on candidate concepts

**Before 2050**
- Development of commercialized FBR

**Commercialized FBR**

**Commercialized fuel cycle facility**
Development of FR Cycle Technology toward Commercialization

- **2005**: Feasibility Study
- **2010**: FaCT Project (2010)
- **2025**: Conceptual Designs of Commercial and Demonstration FR Cycle Facilities
- **2050**: Commercialization of FR Cycle

**Main Concept of FR Cycle Tech.**
- Sodium-cooled FR
- Advanced Aqueous Reprocessing
- Simplified Pelletizing Fuel Fabrication

**Fuel Cycle (Reprocessing + Fuel Fabrication)**
- Advanced Aqueous + Simplified Pelletizing
- Advanced Aqueous + Vibration Packing
- Metal Electro-refining + Injection Casting
- Oxide Electro-winning + Vibration Packing

**Design, Construction of Demo Facility**

**Operation of Demo. Facility**

- Validation of Reliability and Economy
J NFL “J-MOX” in Rokkasho

- History
  - April 2005: Agreement with local gov., First Application for Safety Review
  - November 2008: Groundbreaking

- Outline of “J-MOX”
  - Fuel product: MOX fuel for BWR and PWR
  - Capacity: 130t-HM/year, 100t-MOX production
  - Nearly 300 operating employees
  - Expect start of operation: June, 2015

- Technology transfer from JAEA/JNC
  - Safe of Pu handling
  - Nuclear Material Control and Accountancy (MCA)
  - MOX fuel fabrication
RFS (Recyclable-Fuel Storage Company) was established in November 2005
Groundbreaking in Spring 2008

Target:
Beginning of Operation in July 2012

http://www.rfsco.co.jp/
## Fast breeder reactors cycle system

### Objectives of Research and Development of the Fast Breeder Reactor Cycle

<table>
<thead>
<tr>
<th>Category</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Reducing the risk smaller enough than that in daily life of the public</td>
</tr>
<tr>
<td>Economic performance</td>
<td>Ensuring that power generation cost is competitive enough against other major power sources in the commercial stage</td>
</tr>
<tr>
<td>Reduction of environmental impact</td>
<td>Achieving the reduction of the final disposal waste and the rationalization of radioactive waste disposal sites</td>
</tr>
<tr>
<td>Effective use of resources</td>
<td>Ensuring the breeding performance that allows a smooth transition from the LWR cycle to the FBR cycle</td>
</tr>
<tr>
<td>Nuclear proliferation resistance</td>
<td>Plutonium must not exist as a single unit in the process. Design must be made to restrain the accessibility using low decontamination TRU fuel.</td>
</tr>
</tbody>
</table>

Source: “Policy on Research and Development of the Fast Breeder Reactor Cycle”  
Strategy for Economical Improvement of Sodium-cooled FRs

- Simplified R/V Structure
- Simplified Piping System
- Increase of System Temperature (550 °C)
- Horizontal Seismic Isolation System
- BOP Rationalization
- Reduction of Plant Construction Period

- Shortening of Piping System
- Reduction of Loop Number
- Compacted Reactor Vessel
- Integrated Components

With Innovative Technologies

With Scale Merits

With Standardization and Skilled Technologies

Plant Construction Cost (x 10^6 JPY/ren/kWe)

- LWR 1 GWe
- DFR Design (670 MWe)
- Monju (280 MWe)

(Converted to 1000 MWe)

Target in Feasibility Study

Estimated Cost around 2030

(1500 ~ 1700 MWe Commercialized LWRs)

Large-scaled FRs (1500 MWe x 2)
Nuclear Fuel Cycle and Geological Disposal
Research and Development Facilities

Horonobe Underground Research Center
- Research on the deep geological environment
- Improving the reliability of disposal technologies
- Development of advanced safety assessment methods

Tokai R&D Center
- Improving the reliability of disposal technologies
- Development of advanced safety assessment methods

Tono Geoscience Center
- Research on the deep geological environment

Mizunami Underground Research Laboratory (Mizunami City, Gifu)

Horonobe Underground Research Laboratory (Horonobe-cho, Hokkaido)

Crystalline rock (Granite)
Fresh water
Hard rock

Sedimentary rock (Mudstone)
Saline water
Soft rock
Milestones in the HLW Disposal Program

**JAEA’s R&D activities**

- **Second Progress Report (’99)**
  - Technical reliability
- **First Progress Report (’92)**
  - Technical feasibility
- **H17 Report (’05)**
- **Start of research at QUALITY (’99)**
- **Start of research at ENTRY (’93)**
- **Start of Mizunami URL Project (’96)**
- **Start of Horonobe URL Project (’01)**

**Geoscientific study at Kamaishi Mine (’88~’98)**

**Geoscientific study at Tono Mine (’86~’03)**

- **Start of R&D Program**

**Long-term Program for Research, Development, and Utilization of Nuclear Energy**

**Internation Program for Research on Nuclear Energy**

**Implementation**

- **NUMO: Commencement of Open Solicitation (Dec. ’02)**
- **Construction & Operation of Repositotory**
- **Selection of Disposal Site**
- **NSC†: The Basic Policy for Safety Regulations for HLW (1st Report )(’00)**
- **Establishment of NUMO as an Implementing Organization (’00)**
- **“Specified Radioactive Waste Final Disposal Act” (’00)**

† Nuclear Safety Commission
II. Japan’s Efforts to Ensure Compatibility between Peaceful Nuclear Energy Use and Nuclear Non-Proliferation
Japan’s Efforts for the Peaceful Use of Nuclear Energy

Five Key Factors for International Confidence

- **Manifestos** for peaceful use of nuclear energy and total elimination of nuclear weapons
- **Obvious Needs** for nuclear fuel cycle program
- **Transparency** of national nuclear energy program
- **Excellent Records of Compliance** with non-proliferation norms for more than 30 years
- **Active Contribution** to Non-Proliferation
Japan’s Excellent Record of Compliance with Non-Proliferation Norms

Full Compliance with IAEA Safeguards

- 1976: Nuclear Non-Proliferation Treaty
- 1977: Comprehensive Safeguards Agreement
- 1999: Additional Protocol
- 2004: Broader Conclusion → Integrated Safeguards

Integrated Safeguards Approach Handling Plutonium for the JNC-1

- Random interim inspection
- Remote monitoring system
- Providing facility information more frequently
- Human resources for inspection will be decreased by 1/3
- Will not disturb facility operations
"I am pleased to note that the Secretariat was recently able to reach all conclusions needed for the implementation of integrated safeguards in Japan – the State with the largest nuclear programme subject to Agency safeguards."
Integrated Safeguards System for PFPF

Advanced Declaration System

FDFI - Frequent Declaration of Flow and Inventory information

Material Storage Area

PCAS

Material Flow

Pellet Production Process

MAGB

Pellet Production and Fuel Elements Handling Area

FAAS

Assemble Process

C/S

Production Storage Area

C/S

: Approach Element

PCAS

Powder Process

MAGB

Frequent MailBox Declaration

FAAS

NRTA Assessment based on Frequent Declaration

NRTA

Remote Monitoring of Nuclear Material

ERMS

Entire Remote Monitoring System

Limited Frequent Random Inspection

LFRI

Limited Frequent Random Inspection

Safeguards Conclusion
III Responsibilities of States which pursue Nuclear Energy Option and Japan’s Contribution
Two Major Nuclear Trends

Increased Concern about Nuclear Proliferation
- Nuclear black market
- Iran, DPRK
- Nuclear Terrorism

Expansion of Peaceful Use of Nuclear Energy
- Worldwide recognition of nuclear energy’s role

➢ To help sever the link between the two trends
Total Elimination of Nuclear Weapons and Peaceful Use of Nuclear Energy

Importance of dual pursuit of two objectives

Total Elimination of Nuclear Weapons

- Nuclear Disarmament
- Nuclear Non-Proliferation

Peaceful Use of Nuclear Energy
Proliferation Resistance (PR) Strategy of FR Cycle

Example of Proliferation Resistance aspects of the Fuel Cycle

Characteristics
- Highly radioactive
- Radiation dose
- High heating rate
- Low decontamination
- Low grade Pu

From PR&PP
- Hard to access
- Difficult to handle
- Difficult to divert

Key for PR = Unattractive for diversion

We need to prevent nuclear proliferation from Fuel Cycle Technologies.
Proliferation Resistance: Technical Issues

Proliferation Resistance – detection: Based on Institutional system (Extrinsic)

High detection probability by SG and other techniques
- Design information
- Accountability
- C/S
- Detectability of material-diversion / misuse
- Operational transparency
- etc

Proliferation Resistance - technical difficulty and Material type (Intrinsic)

Hard to access / Difficult to handle / Difficult to divert
- Lower Pu Grade (Isotopic Composition)
- High Radiation Dose
- High Heating Rate
- High Neutron Emission Rate
- No pure Pu; Low decontamination (chemical physical property)
A Proposal by Nuclear Nonproliferation Study Committee University of Tokyo

1. The non-proliferation study committee at Tokyo University proposes a cooperative framework in Asia Pacific to meet the goals of 1) assurance of fresh fuel supply, 2) spent fuel management and 3) nuclear non-proliferation.

2. The goal of the regional network of nuclear fuel cycle facilities in Asia Pacific is to promote trust, confidence-building measures, and transparency of peaceful nuclear fuel-cycle programs in Asia Pacific.
Conclusions

- Continuation of Nuclear Fuel Cycle (NFC) policy in Japan
- Challenges in non-proliferation:
  - Application of robust Safeguards for future NFC
  - Application of robust proliferation resistance, effective but economically viable.
- Important to continue studying Internationalization of NFC, MNA etc
Thank you for your attention