Current and Future Prospects of Japan's Nuclear Fuel Cycle Policies: Issues and Challenges

The Royal Society Workshop
"Building proliferation resistance into the nuclear fuel cycle"
June 10-11, 2010

by
Dr. Tatsujiro Suzuki
Vice Chairman, Japan Atomic Energy Commission (JAEC)
tatsujiro.suzuki@cao.go.jp

The views expressed here are of the author's and not necessarily reflects JAEC's views.

CONTENTS

- Introduction
- Current status of Japan's nuclear energy and fuel cycle activities
- Japan's policies on proliferation resistance and transparency of nuclear fuel cycle
- Issues and Challenges
  - Short to mid-term (up to 2025)
  - Long term (beyond 2025)
- Conclusion

Introduction

- Origin of Nuclear Energy Policy in Japan -

- Basic Atomic Energy Law (1955)
  - Article *2: "The research, development and utilization of nuclear energy shall be limited to peaceful purposes, shall aim at ensuring safety, and shall be performed independently under democratic administration, and the results obtained shall be made public so as to actively contribute to international cooperation."*
- JAEC's Long Term Plan for utilization of atomic energy (1956)
  - "*Reprocessing should be conducted within Japan* as much as possible"
  - "Considering its high uranium resource efficiency, Fast Breeder Reactor (FBR) is considered to be the best reactor type suited for Japan. And thus *the main goal of the research & development program is to develop domestic FBR*"

JAEC's Framework for Nuclear Energy Policy (2005) and METI's "Nuclear Power Nation Plan (2006)"

Three Main Goals

- Maintain nuclear power's share in total power production at 30~40% or more by 2030 and beyond
- Steady progress in nuclear fuel recycling program (as Japan's basic policy considering various factors)
- Commercialization of FBR by 2050 and Demonstration FBR by 2025 and the study on 2nd reprocessing plant will start around 2010

Nuclear Fuel Cycle Policy under the current Framework(2005)

- "… We have reached the conclusion that our basic policy is, .. to reprocess spent fuel and to effectively use the recovered plutonium and uranium, while ensuring safety, nuclear non-proliferation, environmental protection, and paying due attention to economic viability" (p.33)
- "Reprocessing of spent fuel is basically to be conducted within the country in view of securing the autonomy of nuclear fuel cycle activities."(p.33)
- "Study on the measures to be taken for spent fuel stored at such interim storage facilities and spent MOX fuel from LWRs will start in around 2010, in response to the operations of the Rokkasho reprocessing plant, progress of research and development of FBRs and reprocessing technologies, international movement of nuclear non-proliferation, etc."(p.34)
- "Since there are uncertain factors …, we expect that the Government, research and development institutions and operating entities will independently and/or collectively pursue surveys and research concerning direct disposal of spent fuel…, which enables flexible considerations …" (p.34)

Source: JAEC, "Framework for Nuclear Energy Policy," Oct. 2005, http://www.aec.go.jp/jicst/NC/tyoki/taikou/kettei/eng_ver.pdf

JAEC: “Strategy for Growth” (2010)

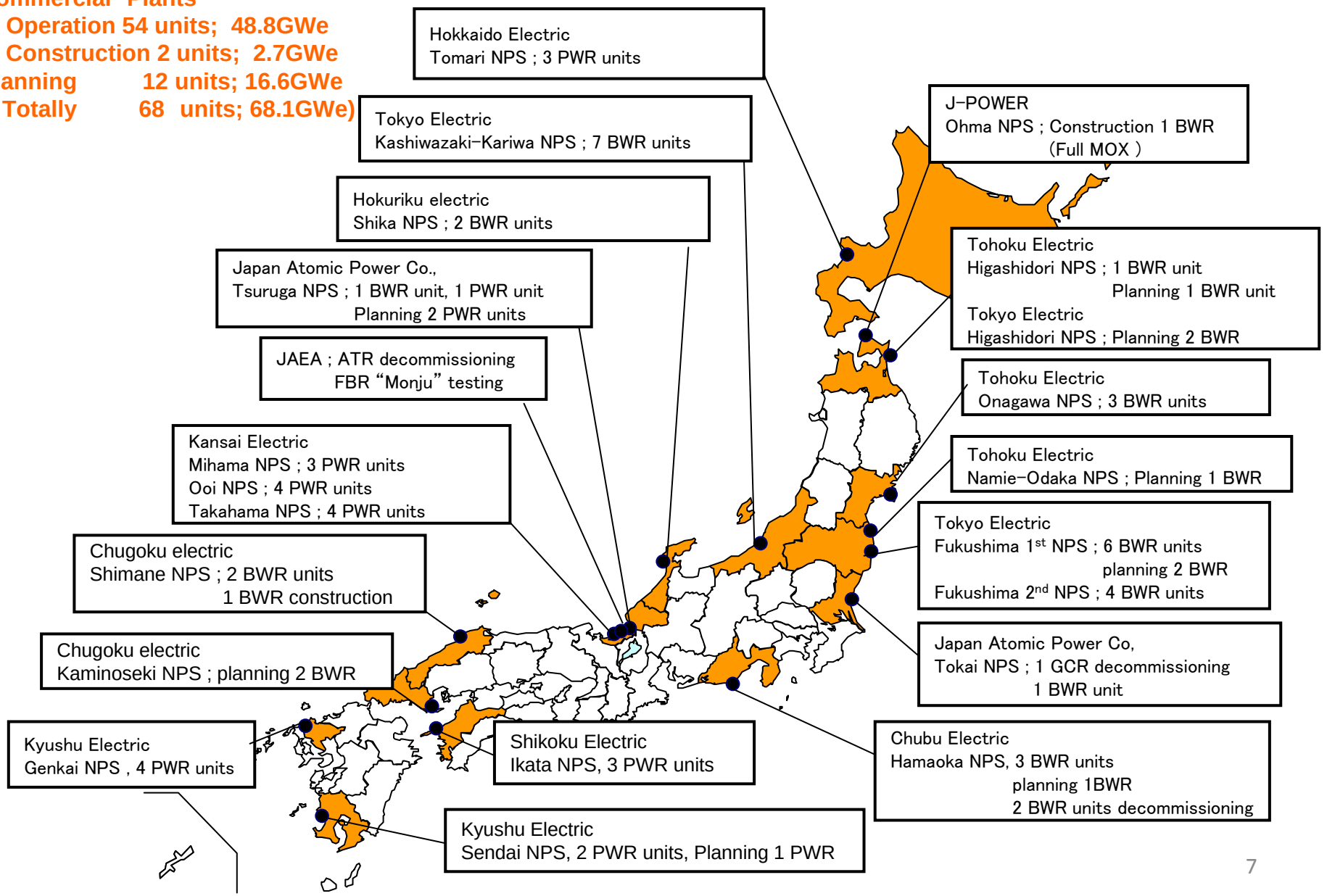
Recommendation on Nuclear Fuel Cycle

- Make steady progress in establishing nuclear fuel cycle, including interim storage of spent fuel, reprocessing operation and final disposal of HLW
  - Secure spent fuel storage capacity for amount of spent fuel beyond reprocessing capability
  - Given uncertainty in reprocessing operation, spent fuel storage capacity should be expanded flexibly onsite as well as off-site.

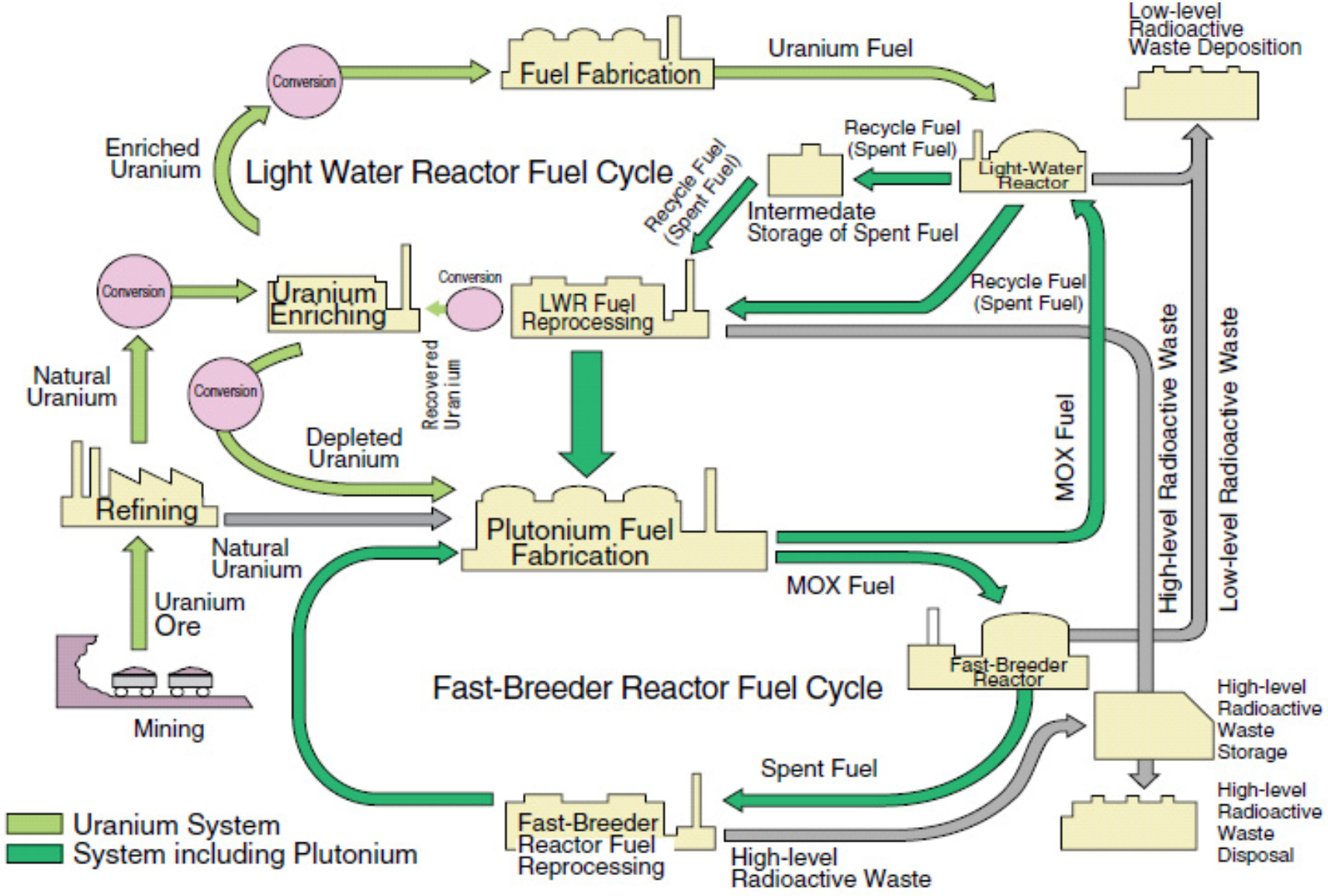
Source: JAEC, “Nuclear Energy Strategy for Growth,” May 2010 (in Japanese)
http://www.aec.go.jp/jicst/NC/about/kettei/kettei100525.pdf

Nuclear Power Plants in Japan (as of March 2010)

Commercial Plants
In Operation 54 units; 48.8GWe
In Construction 2 units; 2.7GWe
Planning 12 units; 16.6GWe
(Totally 68 units; 68.1GWe)



Japan's Long Term Vision
FBR and Closed Nuclear Fuel Cycle



Status of Japan's Pu Programs

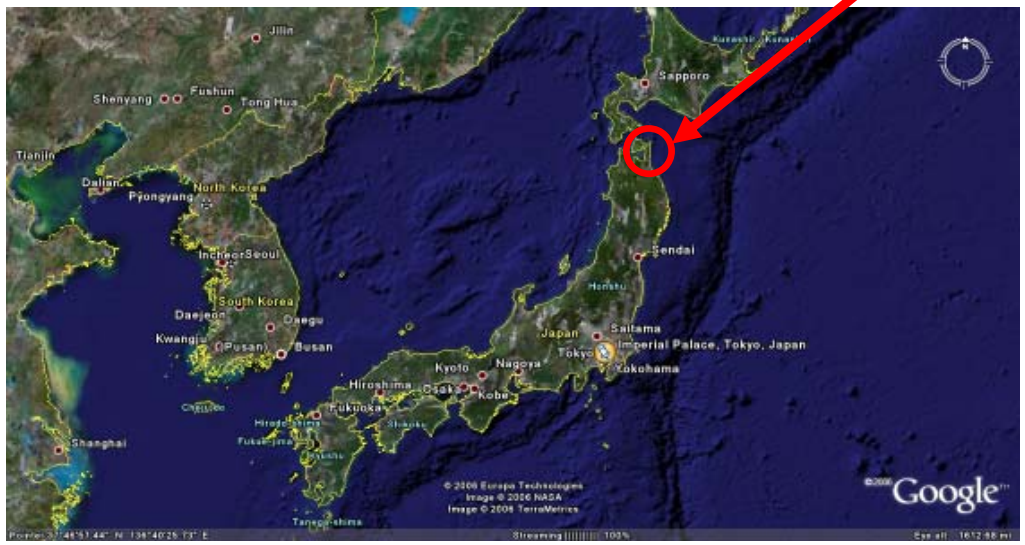
- Rokkasho reprocessing plant
  - Due to difficulties of vitrification process, the plant will not operate at least until October, 2010.
  - Securing spent fuel storage is urgent task for some utilities
- MOX recycling program
  - Kyushu and Shikoku have started loading MOX fuels. Chubu and Kansai will start loading MOX fuels in this year.
  - J-MOX plant will start operation in March 2016.
  - JAEC instructed utilities to revise their plutonium programs.

Rokkasho Reprocessing Operation

- Active testing started on March 31, 2006
- **425 tons** of SF have been reprocessed (by FY2009)
  - Recovered Spent Fuel: 3,165 tU
  - Recovered and Separated Pu-fissile: 2.3 tPuf
    (as MOX Powder)
- Active testing is now on hold
  - Vitrification component has been failure, and is now under repair
  - Additional examination, including Cold Mock-up Test, is now carrying out at Tokai R&D facility

Rokkasho Reprocessing Plant

- Owner : JNFL (Japan Nuclear Fuel Ltd.)
- Capacity; 800 (tU/yr)
- SF Storage capacity: 3,000tU
- Active testing started March.31, 2006.
- Through testing period, it reprocessed 425 tons of spent fuel.
- Currently testing is in the final phase but operation is stopped due to technical problems of vitrification process.
- Commercial operation: now postponed to October, 2010



Cost Estimates of Rokkasho Project (40-year life time cost)

Category	Items	¥ billion
Reprocessing	Construction (¥2,140 billion) , O&M cost (800t × 40 yrs), Decommissioning (¥1,550 billion)	11,000
HLW storage & transportation	From Europe (including HLW swapped for LLW equivalent)	870
HLW disposal	Only vitrified waste Including internal transportation	2,740
TRU disposal	Both From Europe and From Rokkasho	810
MOX fuel fabrication		1,190
Total		16,610

Report of Study Group on Cost Estimate for Nuclear Fuel Cycle (METI, 2004)

Cost Comparison of Fuel Cycle Options by JAEC (¥/kWh, 2004)

	Scenario1 (Current Policy)	**Scenario 2** (Stop reprocessing after Rokkasho)	**Scenario 3** (Cancel Rokkasho, Direct disposal)	**Scenario 4** (Interim storage then decide)
Power Gen. Cost	5.2	5.0~5.1	4.5~4.7	4.7~4.8
Cost due to Policy Change*	-	-	0.9~1.5	0.9~1.5
Total Cost	5.2	5.0~5.1	5.4~6.2	5.6~6.3

*Assumes that all nuclear power plants would be shut down due to shortage of spent fuel storage capacity and have to be replaced with fossil-fueled power plants.

Reprocessing Fund for Rokkasho

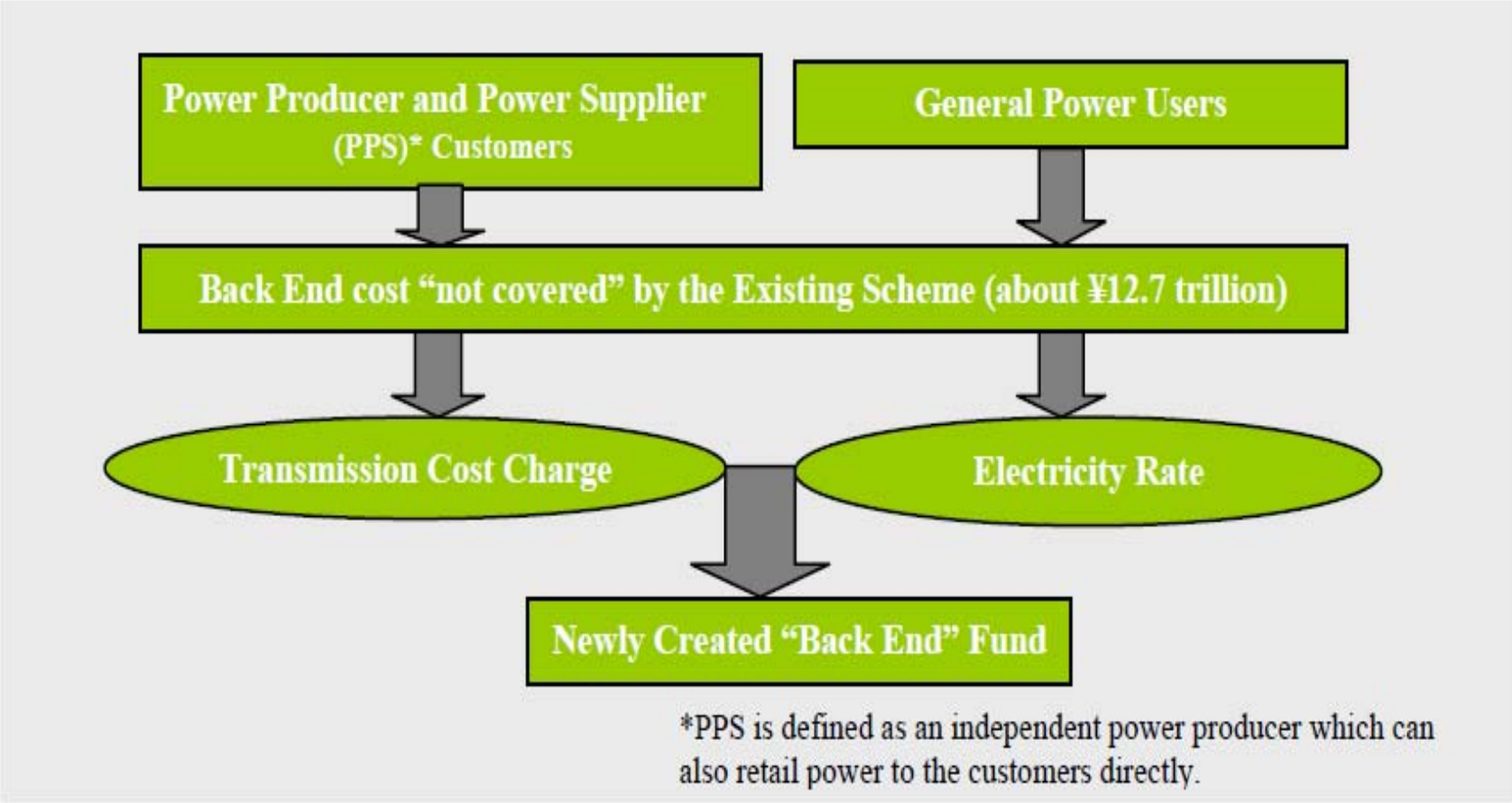


Figure 2.3. Scheme for new reprocessing fund

Source: T. Katsuta and T. Suzuki, "Japan's plutonium and spent fuel management challenges," International Panel on Fissile Materials (IPFM) Research Report, No. 2, September 2006. http://www.fissilematerials.org/ipfm/site_down/rr02.pdf

Progress of MOX fuel program

Electric company		Start	Local Gov't Consent	Licensing Application	License Approved	Note
Hokkaido	Tomari	～FY2015	**OK**	**OK**	Underway	
Tohoku	Onagawa-3	～FY2015	**OK**	**OK**	**OK**	
Tokyo	Fukushima I-3	～FY2015	Canceled	OK	OK	**Restart Local Gov's consent process**
	Kasiwazaki-Kariwa-3	～FY2015	Canceled	OK	OK	**Local consent cancelled**
Chubu	Hamaoka-3	2010	**OK**	**OK**	**OK**	No local consent system
Hokuriku	Shika	～FY2015	---	---	---	
Kansai	Takahama-3	2010	**OK**	**OK**	**OK**	
	Takahama-4	2011	**OK**	**OK**	**OK**	
	Ooi -1, 2	～FY2015	———	———	———	
Chugoku	Shimane-2	～2015	**OK**	**OK**	**OK**	
Shikoku	Ikata-3	**2010**	OK	OK	OK	**Already Start**
Kyusyu	Genkai-3	**2009**	OK	OK	OK	**Already start**
JAPC	Tsuruga-2	～FY2015	———	———	———	Under negotiation
	Tokai-2	～FY2015	———	———	———	
J-Power	Oma	FY2013	**OK**	**OK**	**OK**	Start Construction

MOX fuel fabrication

- J-MOX plant is designed to consume all plutonium from Rokkasho with capacity of 130 ton HM/year and its construction cost is ¥190 billion.
- It has been finished safety review, and will start construction by Oct. 2010, and will start commercial operation by March 2016.
- It is located next to Rokkasho reprocessing plant and MOX powder will be transferred through underground tunnel.

Policies to enhance proliferation resistance and transparency of Japan's nuclear fuel cycle

- Safeguards related Technological Developments
  - Co-extraction process for Tokai reprocessing plant (1977)
  - HSP (Hexapartite Safeguards Project) for enrichment
  - LASCAR（Large Scale Reprocessing Plant Safeguards）for Rokkasho reprocessing plant
  - Safeguards by Design
  - Clean Laboratory for Environmental Analysis and Research (CLEAR)
  - Remote monitoring technologies for enhanced transparency
- R&D on proliferation resistance for advanced nuclear fuel cycle with GENIV, INPRO

Policies to enhance proliferation resistance and transparency of Japan's nuclear fuel cycle

- Improving transparency of Japan's plutonium programs
  - "No plutonium surplus" policy introduced in 1991
- Voluntary disclosure of plutonium stockpile by the government
  - Guidelines for Management of Plutonium (INFCIRC/549) since 1997

JAEC's "No Pu surplus policy"

- In August 2003, JAEC announced its new guideline for plutonium management
- Utilities are expected to submit **its plutonium usage plan annually *before* separation of plutonium**.
- Its plan should include the information on:

  (1) current plutonium stock

  (2) planned usage of plutonium (name of power plant, or site, insertion period)

  (3) amount of reprocessing (during that year)

  (4) usage of plutonium (during that year)

  (5) MOX contract plan and fabrication amount (during that year).

Plutonium Stockpile in Japan (2008)

	2007 (kg)	2008 (kg)
Stock in Japan (Pu total)		
Reprocessing Plants	3,407	4,384
MOX Fuel Plant	3,962	3,620
Stored at Reactors	1,352	1,692
Sub-total (Pu fissile)	8,721(6,019)	9,696 (6,625)
Stocks in Europe (Pu fissile)		
UK	11,332	11,380
France	13,886	13,832
Sub-total :Put[est]*(Puf)	36,538*(25,218)	36,899*(25,212)
Total [est]*(Puf)	45,259*(31,237)	46,595*(31,837)

Source: Japan Atomic Energy Commission (2008,2009)

Date: March 15, 2010

Plans for the Utilization of Plutonium to be Recovered at the Rokkasho Reprocessing Plant (RRP), FY2010

The Federation of Electric Power Companies of Japan

The above plans shall be updated and detailed as future progress is made in the pluthermal program, such as the start of operation of the Rokkasho MOX fuel fabrication plant, etc..

Owner	Amount of reprocessing	Amount of plutonium			Purpose of use (used as LWR fuel)		
	Amount of spent fuel to be reprocessed in FY2010 (tU)	Amount of plutonium expected to be retained by the end of FY2009 (tPuf)	Amount of plutonium expected to be recovered in FY2010 (tPuf)	Amount of plutonium expected to be retained by the end of FY2010 (tPuf)	Place to be used	Estimated annual usage (tPuf per year)	Timing of the start of utilization and estimate of the period required for utilization
Hokkaido EPCo	14	0.1	0.0	0.1	Tomari Power Station Unit 3	0.2	After FY 2015 for a period equivalent to 0.4 years
Tohoku EPCo	—	0.1	0.0	0.1	Onagawa Nuclear Power Station Unit 3	0.2	After FY 2015 for a period equivalent to 0.5 years
Tokyo EPCo	13	0.7	0.1	0.9	Three to four Tokyo EPCo units including Fukushima Daiichi Nuclear Power Station Unit 3, based on continued efforts by Tokyo EPCo to regain public trust from local communities at sites	0.9 – 1.6	After FY 2015 for a period equivalent to 0.6-1.0 years
Chubu EPCo	—	0.2	0.0	0.2	Hamaoka Nuclear Power Station Unit 4	0.4	After FY 2015 for a period equivalent to 0.5 years
Hokuriku EPCo	—	0.0	0.0	0.0	Shika Nuclear Power Station	0.1	After FY 2015 for a period equivalent to 0.1 years
Kansai EPCo	—	0.6	0.1	0.7	Takahama Power Station Units 3 and 4; one or two units at Ohi Power Station	1.1 – 1.4	After FY 2015 for a period equivalent to 0.5-0.6 years
Chugoku EPCo	17	0.1	0.0	0.1	Shimane Nuclear Power Station Unit 2	0.2	After FY 2015 for a period equivalent to 0.5 years
Shikoku EPCo	18	0.1	0.0	0.2	Ikata Power Station Unit 3	0.4	After FY 2015 for a period equivalent to 0.4 years
Kyushu EPCo	—	0.3	0.1	0.4	Genkai Nuclear Power Station Unit 3	0.4	After FY 2015 for a period equivalent to 0.9 years
Japan Atomic Power Company (JAPC)	18	0.1	0.0	0.2	Tsuruga Power Station Unit 2; Tokai Daini Power Station	0.5	After FY 2015 for a period Equivalent to 0.3 years
Subtotal	80	2.3	0.5	2.8		4.4 – 5.4	
Electric Power Development Company (J-Power)		Amount to be transferred from other utilities			Ohma Nuclear Power Station	1.1	
Total	80	2.3	0.5	2.8		5.5 – 6.5	

Issues and Challenges(1)

Short to mid-term (~2025)

- Rokkasho and spent fuel management
  - Startup of Rokkasho with adequate spent fuel storage capacity is critically important to avoid unnecessary shutdown of nuclear power plants
- Pu stockpile management and nuclear security
  - Managing and control of increasing Pu stockpile is a challenge for nuclear security

Spent Fuel Management

Current Status

- Total storage capacity at NPP site in Japan is 19,420 tons
  - 12,840tU in storage
- Rokkasho has 3,000 tons of storage capacity
  - 2,740tU in storage
- 900～1,000 tons/yr of SF is generated
  - Only 7 years left, if not start commercial operation of Rokkasho Reprocessing plant

Countermeasures

- Mutsu Off-site storage facility (3,000 tons) will start storage on 2012.
- At Genkai NPP, the storage capacity will be increased about 400 tU by 2015.
- At Hamaoka NPP, on-site storage facility (700 tons) is announced along with new BWR (replacing old two reactors)

Three types of spent fuel storage capacity

At-reactor storage

Storage capacity: 19,420 tU/17 sites

On-site dry cask storage is not allowed by local governments (Fukushima-1 & Tokai-2 was allowed).

Rokkasho reprocessing plant

Storage capacity:**3,000tU**
(storage **2,740 tU** as of March 2010)
Construction cost: ¥2.14Trillion

Mutsu Interim storage site

Dry Cask storage type
Capacity : totally 5,000 tU
1st 3,000 tU, add 2,000tU in future
Operation: July 2012
(Status : Permitted)
Construction cost: ¥0.1Trillion
(including dry casks)

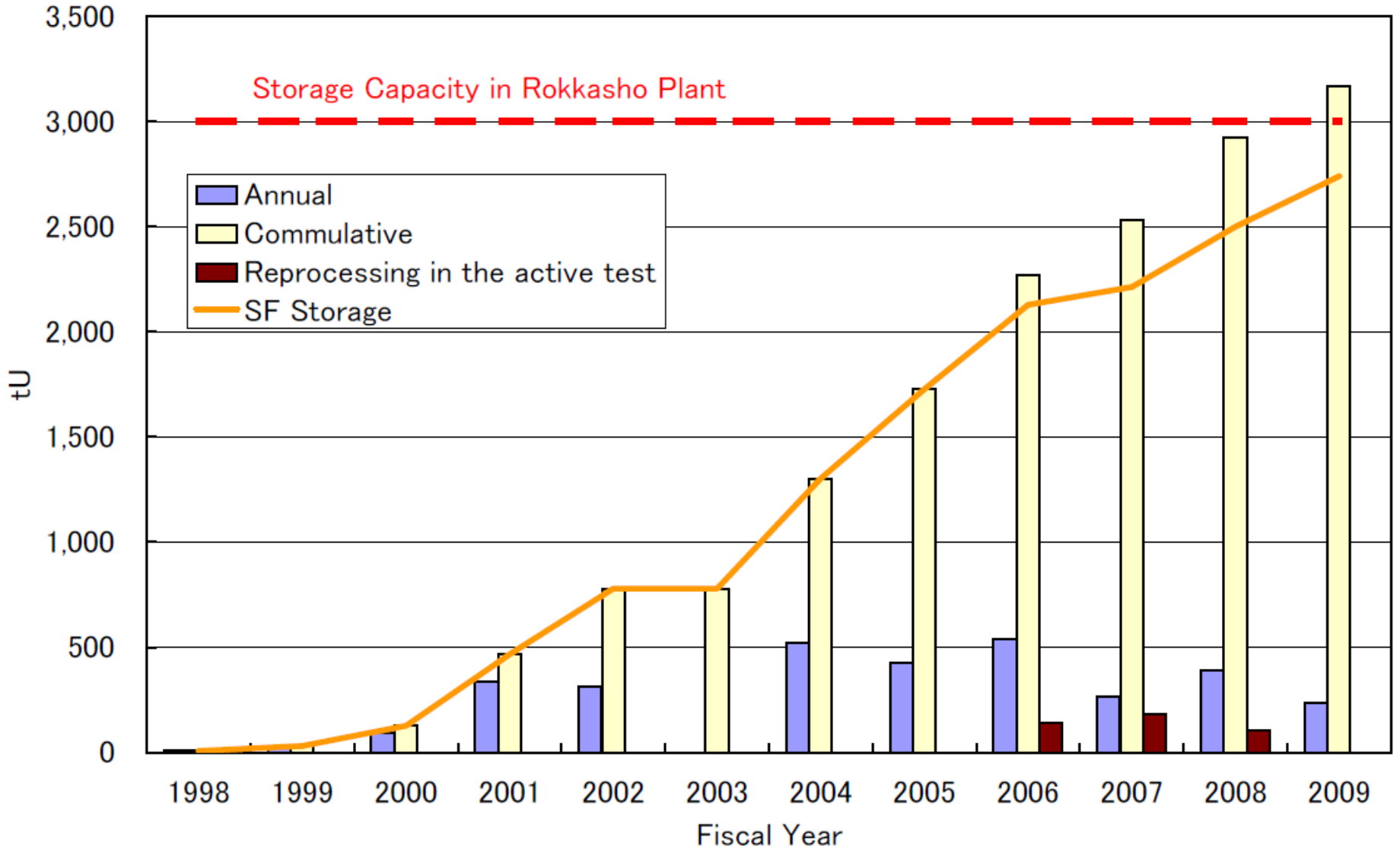
Amount of Spent Fuel at Each Site [tU]

(As of the end of September 2009)

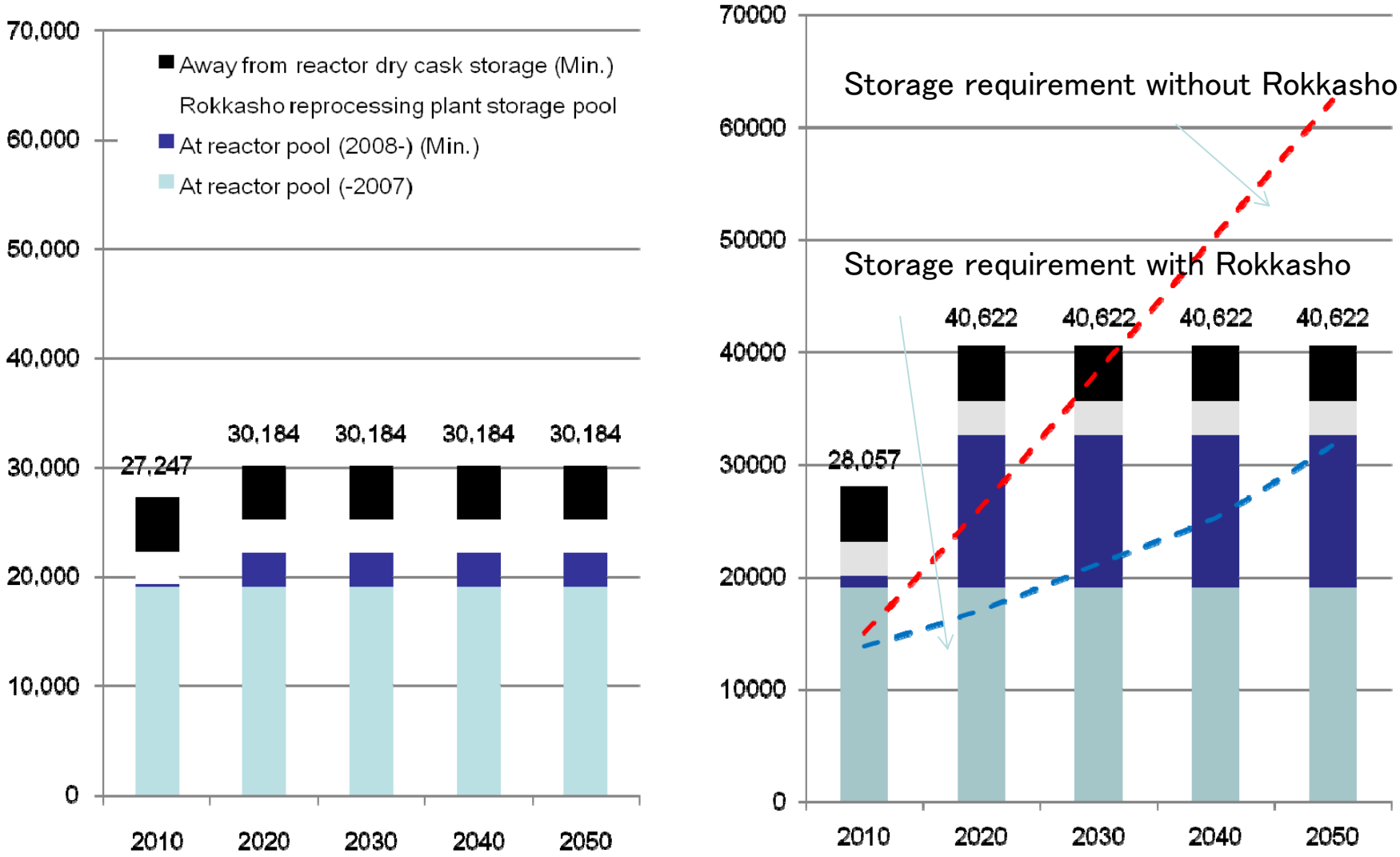
Utilities	Plants		Number of unit	1 Full Core	Annual discharge	Amount of spent fuel	Effective storage capacity
Hokkaido	Tomari	PWR	2	100	30	340	420
Tohoku	Onagawa	BWR	3	260	60	360	790
	Higashidori	BWR	1	130	30	30	230
Tokyo	Fukushima I	BWR	6	580	140	1,720	2,100
	Fukushima II	BWR	4	520	120	1,030	1,360
	Kashiwazaki -Kariwa	BWR	7	960	240	2,140	2,910
Chubu	Hamaoka	BWR	3	410	100	1,080	1,740
Hokuriku	Sika	BWR	2	210	50	110	690
Kansai	Mihama	PWR	3	160	50	320	620
	Takahama	PWR	4	290	100	1,120	1,630
	Ooi	PWR	4	360	110	1,250	1,900
Chugoku	Shimane	BWR	2	170	40	370	600
Shikoku	Ikata	PWR	3	170	60	540	930
Kyusyu	Genkai	PWR	4	270	100	740	1,060
	Sendai	PWR	2	140	50	810	1,140
JAPC	Tsuruga	BWR/ PWR	2	140	40	540	860
	Tokai-II	BWR	1	130	30	350	440
Total			**53**	**5,000**	**1,340**	**12,840**	**19,420**

Effective storage capacity = Storage capacity - (1 Full core + Annual discharge)

Transportation Volume to Rokkasho Reprocessing Plant SF Pool



Estimation of spent fuel storage capacity until the next fifty years [tU]



Source: T.Katsuta and T. Suzuki, “Japan’s plutonium and spent fuel management challenges,” International Panel on Fissile Materials (IPFM) meeting, October 2008.

Spent fuel storage Inflexibilities

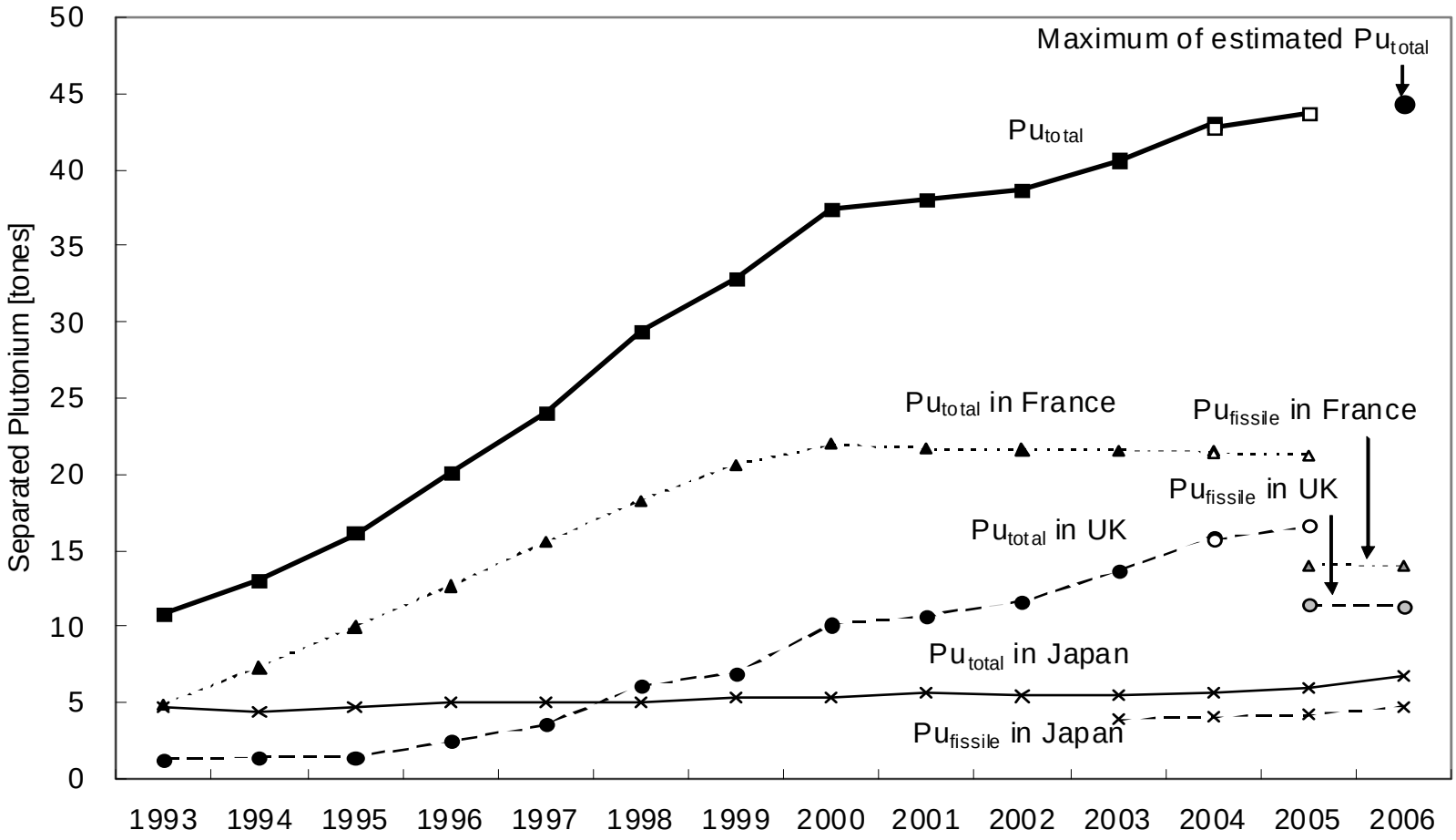
- Although total spent fuel storage capacity is large enough to store spent fuel up to mid-2020s, inflexibilities of spent fuel storage management make situation more complex:
  - No transfer of spent fuel between utilities is allowed.
  - Storage pool at Rokkasho plant (3,000tU) is divided into two sections; 1,500tU of PWR spent fuel, 1,500tU of BWR.
  - Mutsu interim storage facility (5,000 tU) owned by only two utilities; TEPCO (4,000tU), and JAPCO (1,000tU).

- Local mayors and governor of Aomori demand that the recycling program continue in order to guarantee that spent fuel will be removed from the site within 50 years.

Pu stockpile and MOX recycling Program

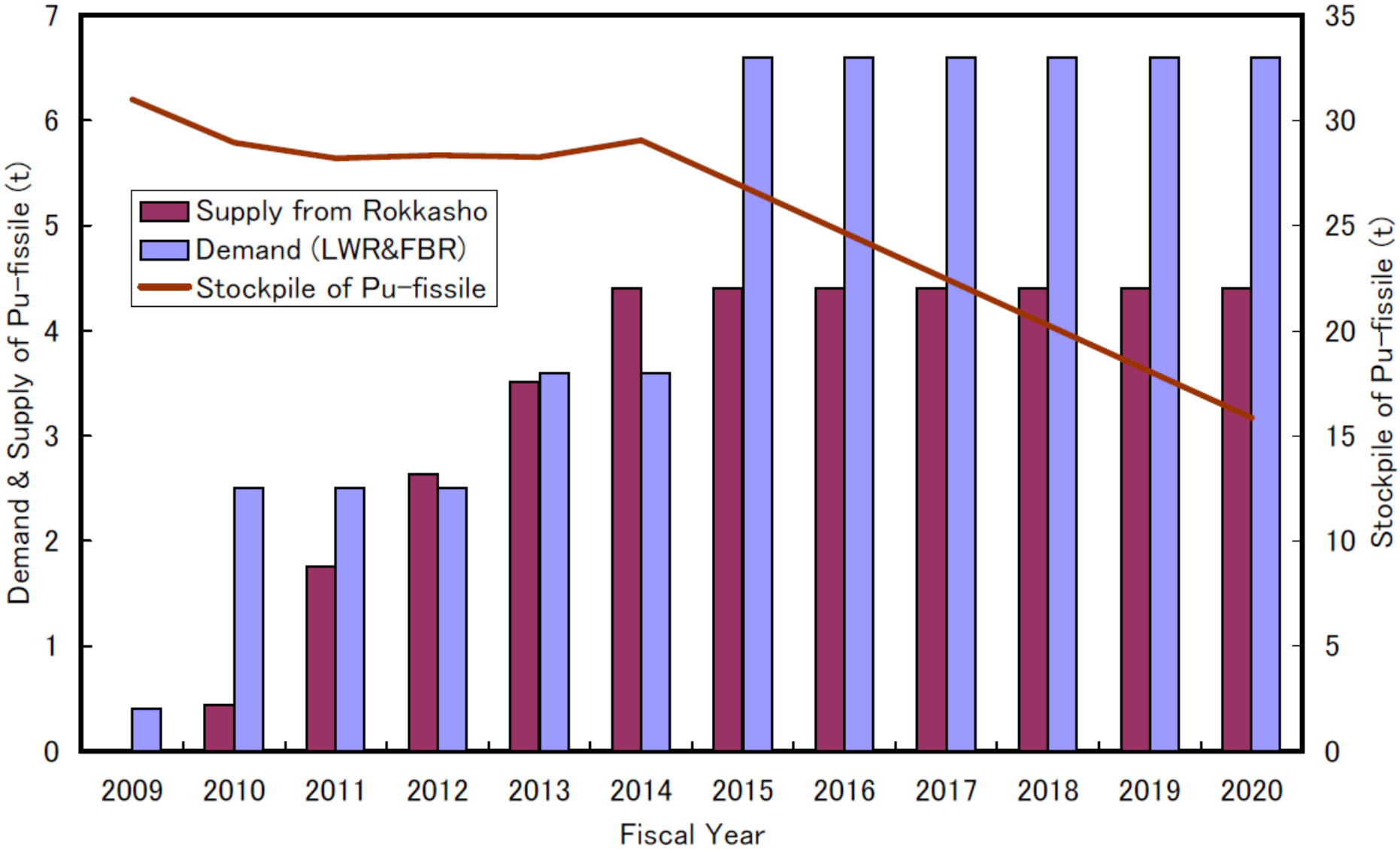
- Total of **31.8 tons** of **Pu fissile** is in stock owned by Japan (as of end of 2008)
  - 27.8 tPuf (18.8 t in France, 11.4 t in UK) in Europe
  - 6.6 tPuf in Japan (4.3 t by JAEA, 2.3 t by JNFL)
- From Rokkasho, about **4.4 tPuf/y** will be generated.
- **About 6 tPuf/y** will be consumed by LWRs and **0.6 tPuf/y** will be consumed by Fast Reactors
  - Japan use MOX fuels in 16 to 18 nuclear power stations by FY2015. Only 2 units (Genkai-3 & Ikata-3) have just started using MOX fuels. A few unit will using MOX fuels in this year.
  - It will take at least **14 years** to consume all stockpile.

Japan's Plutonium Stockpile



Source: From T. Katsuta and T. Suzuki,ibid., Based on data published by the Japan Atomic Energy Commission,
The Current Situation of Plutonium Management in Japan

Plutonium Balance up to 2020



Issues and Challenges(2)

Short to mid-term (~2025)

- Proliferation resistance and MNA
  - In addition to technical means, institutional arrangements are necessary to enhance proliferation resistance of nuclear fuel cycle
  - Japan is, in principle, supporting the MNA and proposed IAEA standy nuclear fuel system
  - Universality, transparency and economic viability are key principles for MNA

Japan's Proposal for IAEA Standby Arrangement System of Nuclear Fuel Supply (2006)

- Member countries voluntarily notify IAEA
  - Nuclear fuel supply capacity (uranium, reserve, conversion, enrichment, fuel fabrication)
    - Level 1: only domestic production capacity
    - Level 2: has export capacity
    - Level 3: has excess (reserve) capacity
- IAEA can play as an administer of information and play intermediary role for emergency fuel arrangements

http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2006/kettei/speech060921_2.pdf

Japan-US Joint Statement (2009)

- *"The GOJ and the USG intend to work together and with other countries to explore ways to enhance a new framework for civil nuclear cooperation, including assurances of fuel supply, so that countries can access peaceful nuclear power without increasing the risks of proliferation, and agree that cradle-to grave nuclear fuel management could be one important element of the framework."*
- *"The GOJ and the USG intend to expand nuclear nonproliferation, safeguards, and security cooperation that may include areas such as nuclear measurement and detection technologies, nuclear forensics, human resource development, training and infrastructure assistance for countries interested in nuclear energy, and coordination of our respective Member State support programs to IAEA safeguards."*

Source: "Japan-U.S. Joint Statement toward a World without Nuclear Weapons", November 2009,

http://www.mofa.go.jp/region/n-america/us/pv0911/nuclear.pdf

Japan's National Statement at Nuclear Security Summit (2010)

- Japan's Contributions to the Strengthening of Nuclear Security
  - (A) Establishment of Integrated Support Center for Strengthening of Nuclear Security in Asia
  - (B) Development of Technology related to Measurement and Detection of Nuclear Material and Nuclear Forensics based on International Cooperation
  - (C) Contributions to IAEA Nuclear Security Programs
  - (D) Hosting of a WINS Conference

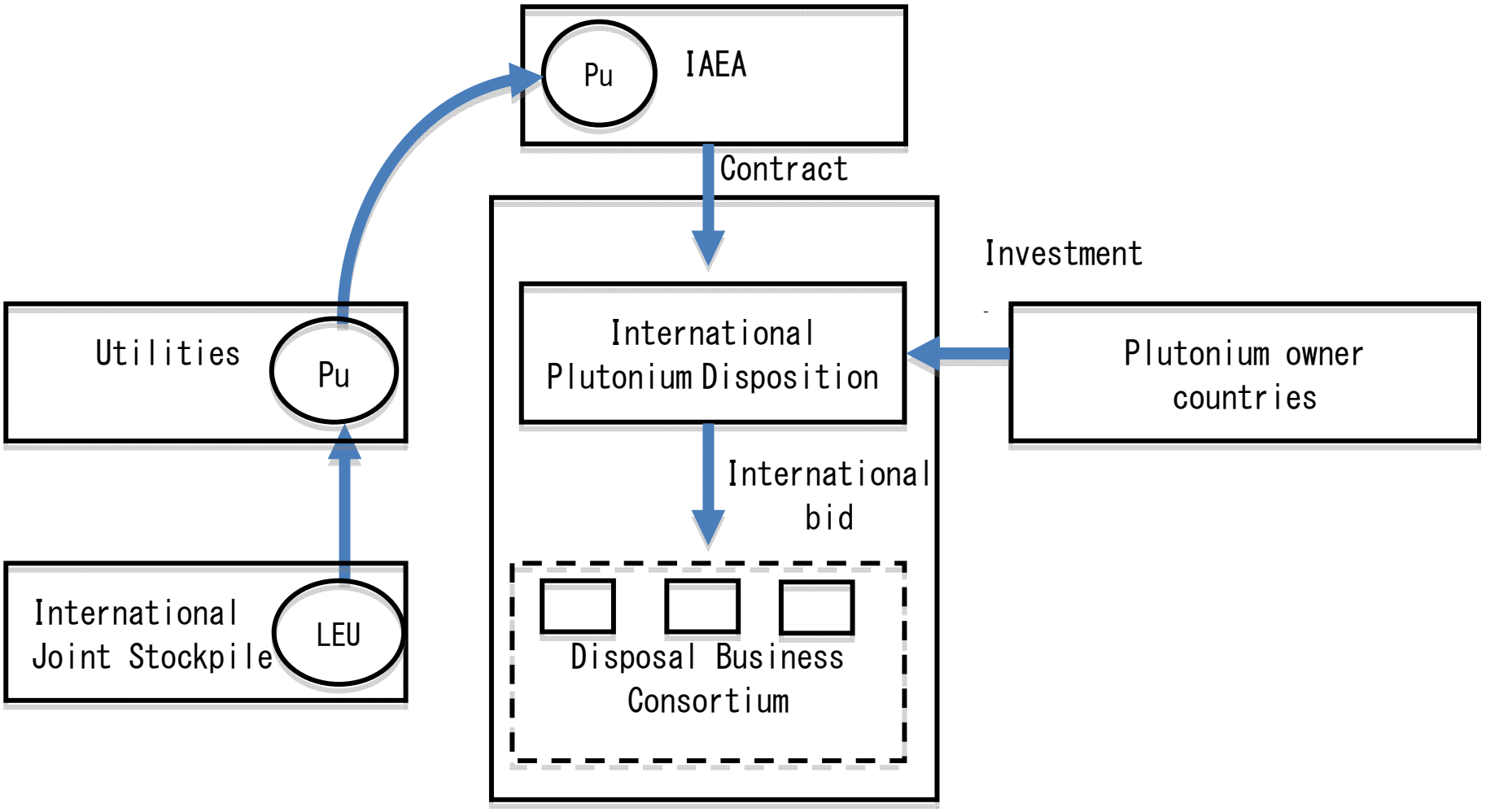
Source:http://www.mofa.go.jp/policy/un/disarmament/arms/nuclear_security/2010/national_statement.html

NPT 2010 Review Conference
Final Draft Document

Action 58: continue to discuss further, in a non-discriminatory and transparent manner under the auspices of IAEA or regional fora, the development of multilateral approaches to the nuclear fuel cycle, including the possibilities to create mechanisms for assurance of nuclear fuel supply, as well as possible schemes dealing with the back-end of the fuel cycle without affecting rights under the Treaty and without prejudice to national fuel cycle policies, while tackling the technical, legal and economic complexities surrounding these issues, including in this regard the requirement of IAEA full scope safeguards;

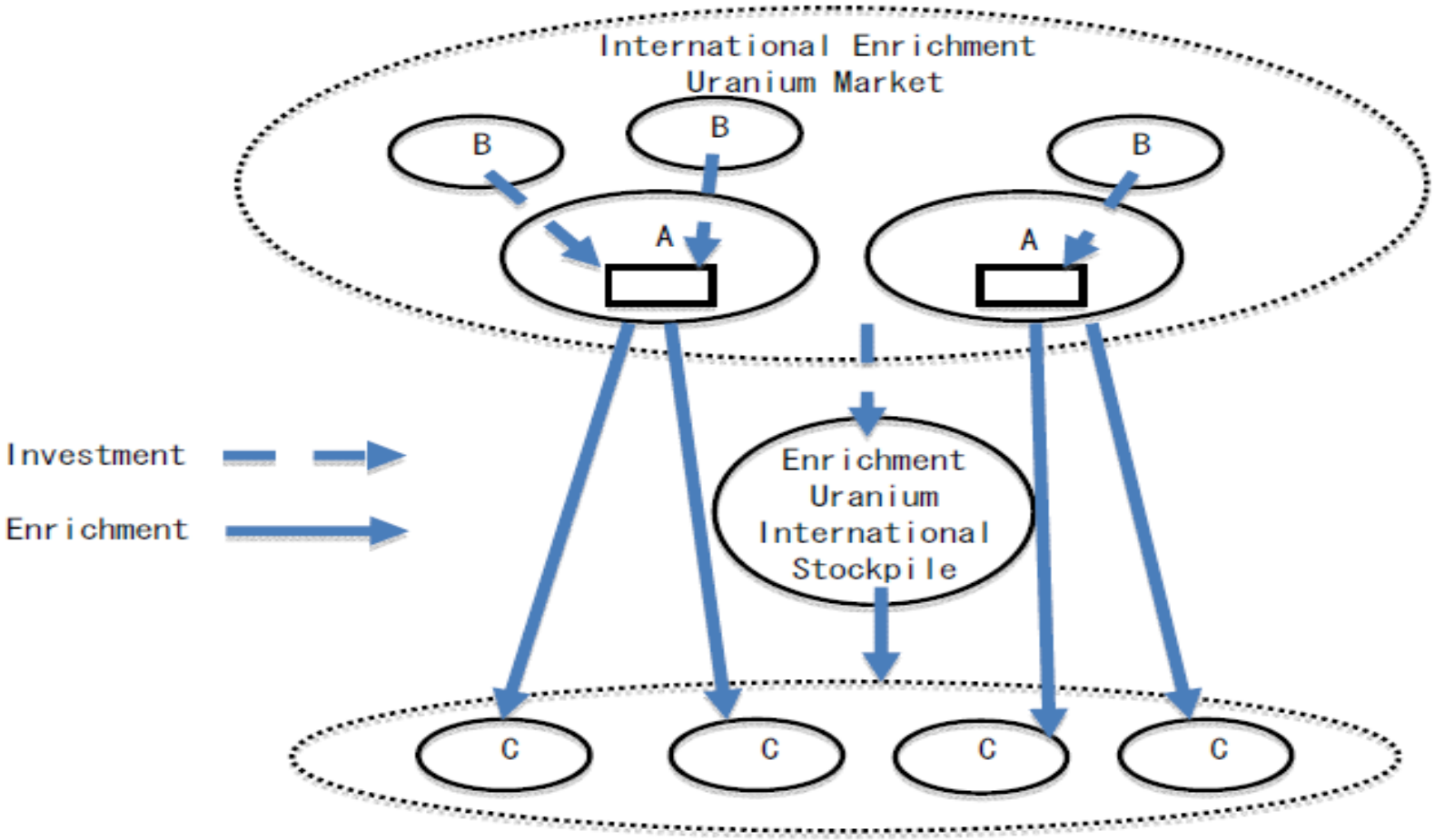
http://www.reachingcriticalwill.org/legal/npt/revcon2010/DraftFinalDocument.pdf

A Proposal for International Pu Disposition Program



Source: Japan Cooperative Security Initiative, “Towards Nuclear Disarmament and Non-Proliferation: 10 Proposals from Japan”,http://a-mad.org/download/A-MAD_EN-JPN.pdf

A proposal for Internationalization of Nuclear Fuel Cycle Facilities



Source: Japan Cooperative Security Initiative, “Towards Nuclear Disarmament and Non-Proliferation: 10 Proposals from Japan”,http://a-mad.org/download/A-MAD_EN-JPN.pdf

Issues and Challenges(3)
Long Term (2025 and beyond)

- FBR and its fuel cycle development
  - Plan for the 2nd reprocessing plant is not certain
    - Financing scheme, technology, size and timing
  - Review of Fast Reactor Cycle Development Project (FaCT) and Monju experiences may determine future FBR development
- Alternative advanced reactor and fuel cycle
  - Diversified R&D portfolio is needed to secure backup options for FBR and current fuel cycle
    - Ex. HTGR, 4S reactor, U from seawater, thorium fuel cycle, chemical enrichment process

Japan's FBR and Nuclear Budget

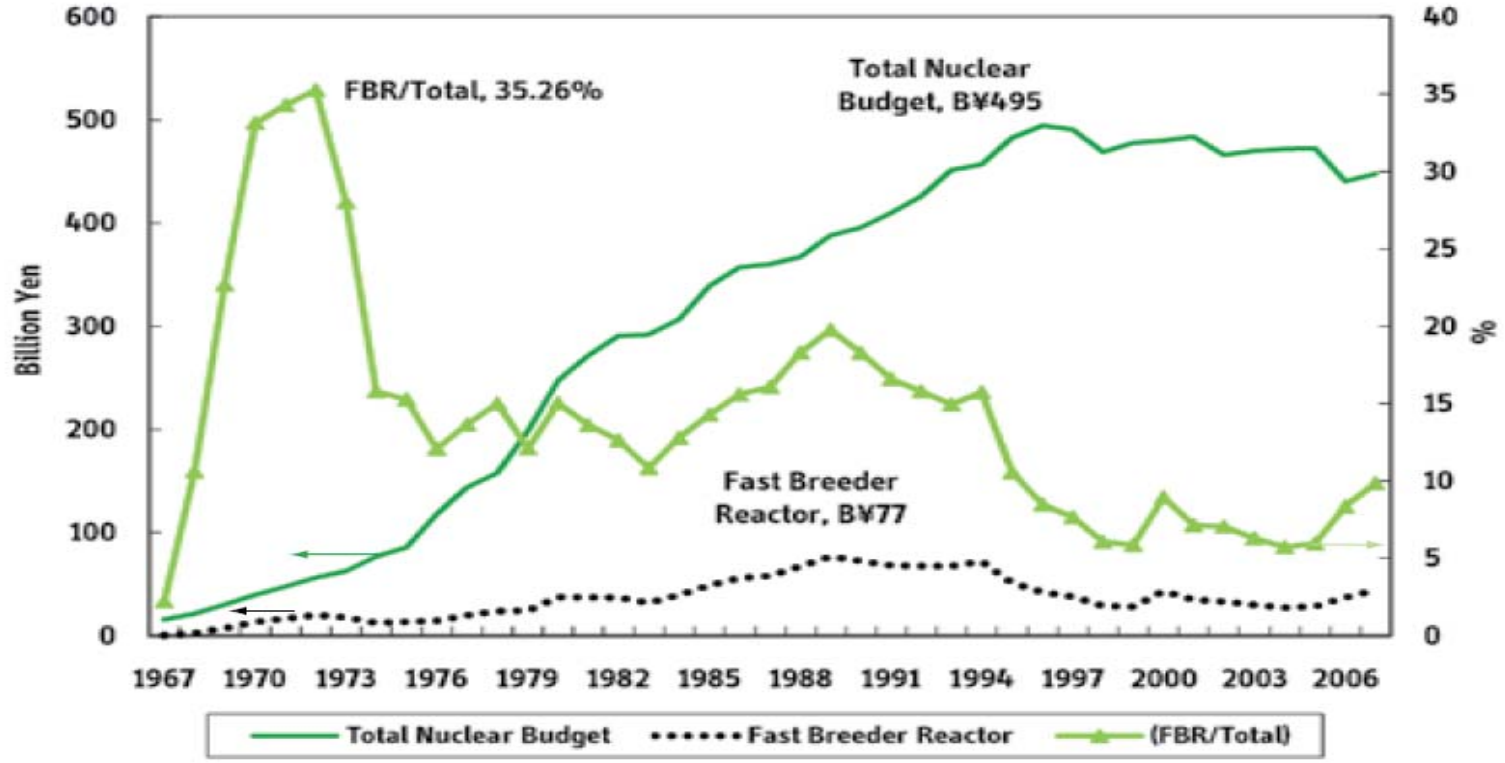


Figure 4.1 History of Japan's R&D budgets for nuclear power and breeder reactors. Peak-year budgets and fast breeder reactor budget percentages are indicated.

Source: T. Cochran et al., "Fast Breeder Reactor Programs: History and Status,"
A research report of the International Panel on Fissile Materials (IPFM) , No. 8, February 2010
http://www.ipfmlibrary.org/rr08.pdf

Policy Assessment of Framework for Nuclear Energy Policy

Recommendations on Energy Utilization (2009)

- Recommendations (13): R&D on technologies whose commercialization goals are not clearly defined by the Framework
  - Important to acquire knowledge on diversified technology options
  - Appropriate level of R&D should be maintained for such technologies as: direct disposal, long term spent fuel storage, thorium utilization, transmutation, uranium from seawater, enhancement of proliferation resistance technologies

Source: Policy Assessment Sub-committee, JAEC, "Evaluation of basic approaches on energy utilization in the framework for nuclear energy policy," June 25, 2009 (in Japanese).

Conclusions

- JAEC is now preparing for deliberation of the next Framework for Nuclear Energy Policy
- Nuclear fuel cycle is one of the main policy issues to be examined
  - Spent fuel management and Rokkasho plant
  - MOX recycling program and FBR
  - Plutonium stockpile and nuclear security
- Japan should pursue its fuel cycle programs not only to satisfy local conditions but also to meet international challenges of nuclear proliferation and nuclear security