Nuclear Fuel Cycle Policy Options in Japan after the Fukushima Accident

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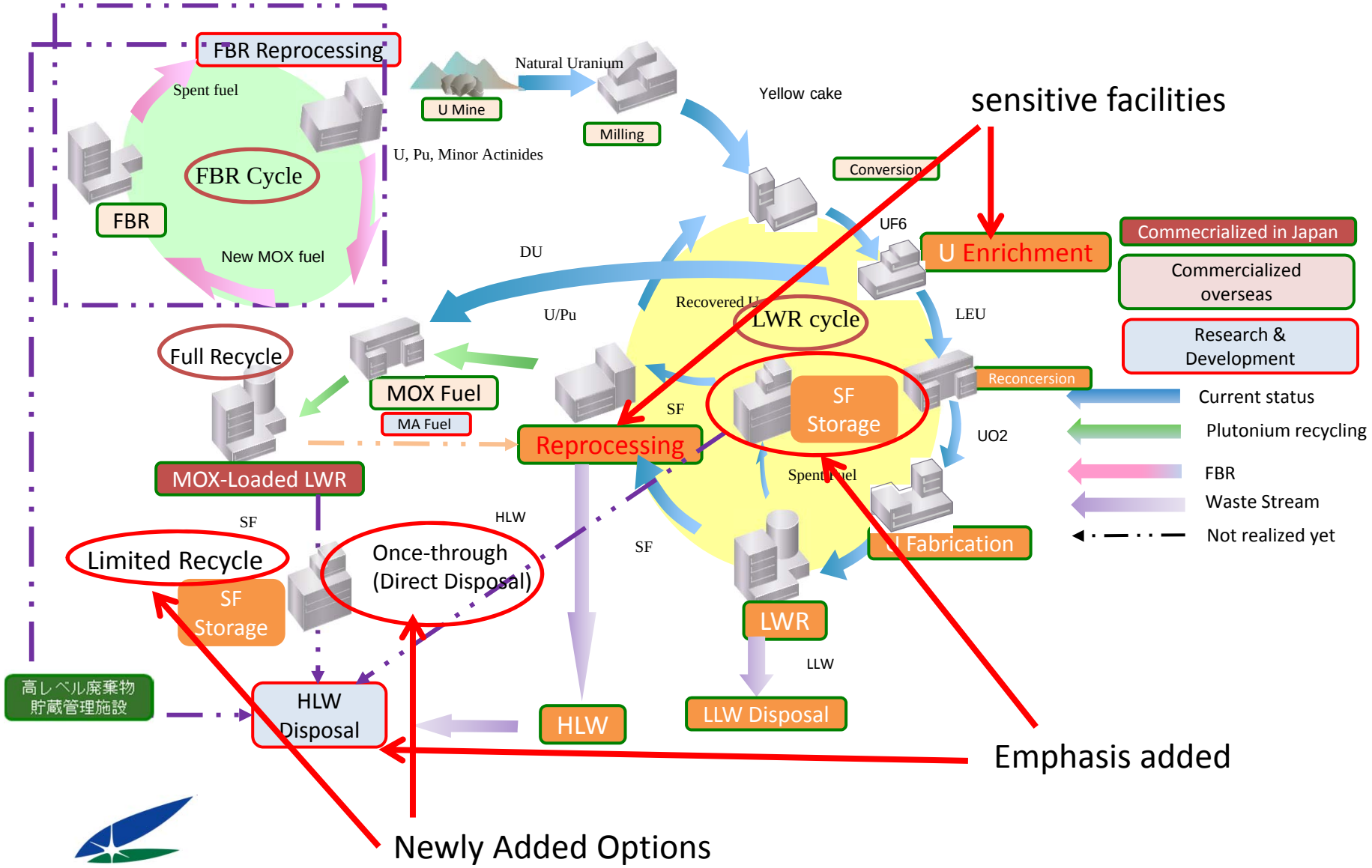
Note: The views expressed here are of my own and do not necessarily reflect those of the JAEC nor the government.

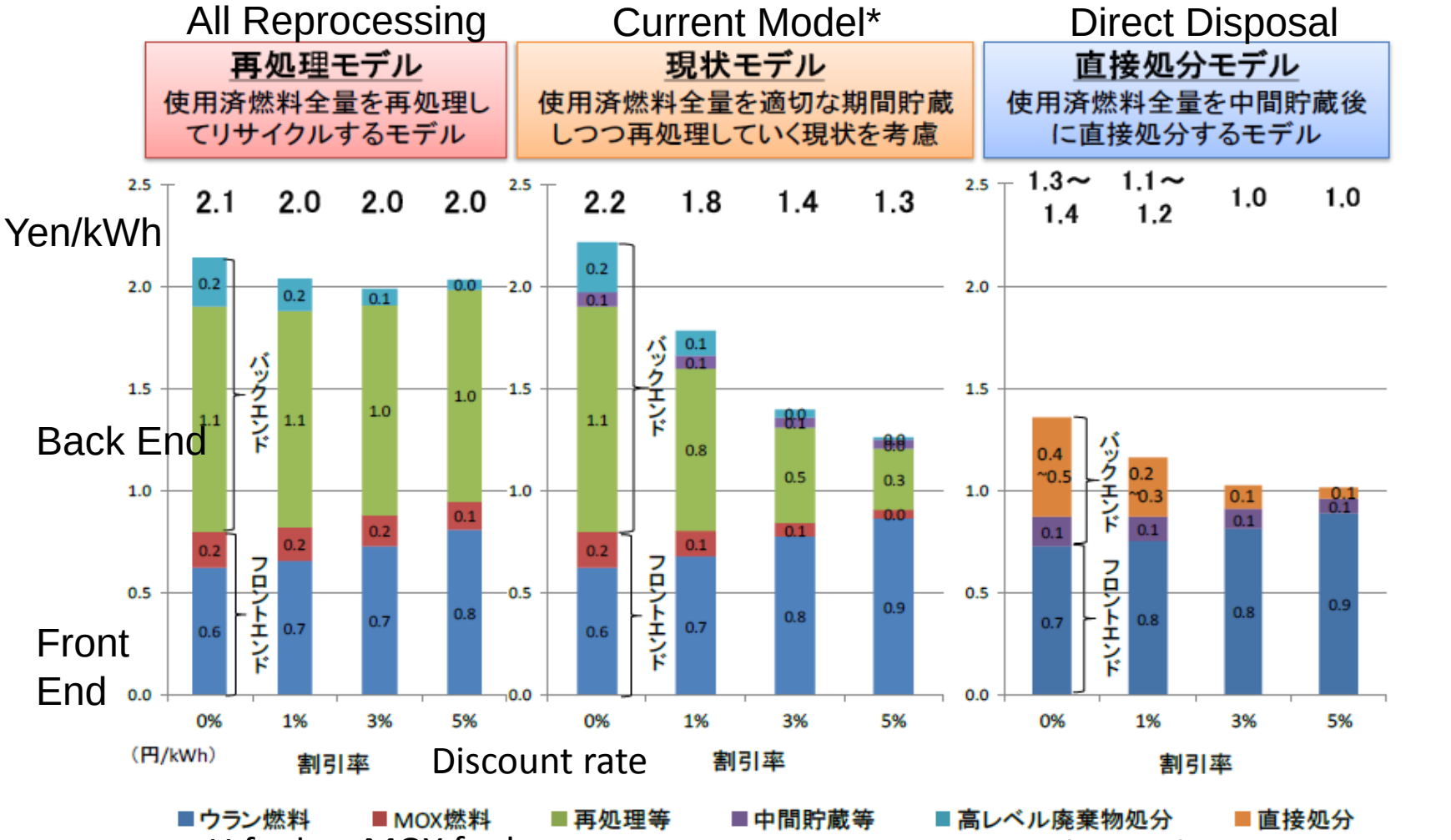
Nuclear Fuel Cycle Technology Options



Major Findings of JAEC subcommittee on nuclear power and fuel cycle (12/06/05)

- For the next 20~30 years, “MOX recycling” and “Once-through” fuel cycle are the only commercially available options.
  - “Once-through” is more desirable from economic and nuclear proliferation/security standpoints, but “MOX recycling” is more desirable from resource efficiency standpoint.
  - No significant difference in terms of safety and waste management.

Source: Chairman’s report on Subcommittee on nuclear power and fuel cycle technologies, June 5, 2012. (in Japanese) http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-1.pdf



（図　１７）核燃料サイクル費用の比較

（再処理モデルと現状モデルと直接処分モデル）

*50% immediate reprocessing and 50% reprocessing after long term storage

Source: National Policy Unit, Energy and Environmental Council, Cost etc. Verification Committee.
http://www.npu.go.jp/policy/policy09/pdf/20111221/siryo3.pdf

Fuel Cycle Economics in Variation of Options (Summary)

～3 Fuel Cycle Options～	～4 Nuclear Share Options～
1. Total reprocessing	1. Nuclear share: 35 % (Installed capacity: 50 GW)
2. Mixed option	2. Nuclear share: 20 % (Installed capacity: 30 GW)
3. Total disposal	3. Nuclear share: 15 % (Installed capacity: 20 GW)
	4. Nuclear share: 0 %

○For all nuclear share option, **total expense of F.C. option 3 is less than the other F.C. options**.

○As for F.C. option 3, SF stored in Aomori pref. may have to be sent back and under the worst case, **nuclear power operation could be suspended if new SF storage capacity is not available**.

Total Expense of Fuel Cycle (Unit: trillion yen) <Discount rate: 0 %>

	F.C. Option 1 Total reprocessing	F.C. Option 2 Coexistence of reprocessing/disposal	F.C. Option 3 Total disposal
Nuclear Share Option I: 35 %	18.4	17.3～18.4	13.9～14.8
Nuclear Share Option II: 20 %	15.4	15.3～15.4	12.0～12.8
Nuclear Share Option III: 15 %	14.4	14.4	10.9～11.6
Nuclear Share Option IV: 0 %	—	—	8.1～8.7

Ref. : http://www.aec.go.jp/jicst/NC/tyoki/hatukaku/siryo/siryo15/index.htm
16 May 2012 Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle, etc., Material No. 1-1, No. 1-2, No. 1-3, No. 1-4 (Japanese)

Assessment of Nuclear Fuel Cycle Policy Options by Subcommittee (June, 2012)

- "All reprocessing" option: Most desirable when nuclear power will expand or stay as it is
- "Co-existing of reprocessing/direct disposal" option : Most desirable when future of nuclear energy is uncertain
- "All direct disposal" option: Most desirable when nuclear energy will be phased out

Source: Chairman's report on Subcommittee on nuclear power and fuel cycle technologies, June 5, 2012. (in Japanese) http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-1.pdf

JAEC's Decision on Nuclear Fuel Cycle Policy Options (2012/06/21)

- As recommended by the technical subcommittee, regardless of the policy choice, it is vital to build a system ready to cope with future policy changes

http://www.aec.go.jp/jicst/NC/about/kettei/kettei120621_2.pdf

Basic Policy for FY 2014 Nuclear Energy Budget
(2013/07/17)

- On nuclear fuel cycle policy, there are measures which are necessary regardless of future of nuclear energy policy. Parties should promote such measures with increased flexibility as JAEC decision on June 21, 2013.
- Especially, government should take more active leadership in expanding storage capacity of spent fuel, measures to enable direct disposal and final disposal of high-level radioactive waste.
- Especially, on plutonium management, principle of "no plutonium surplus policy" should be strictly followed, with enhanced transparency and more persuasive programs than the current measures.

http://www.aec.go.jp/jicst/NC/about/kettei/kettei130717.pdf

Energy Basic Plan (Draft)
2014/02/25

- We reduce dependence on nuclear energy as much as possible by expanding renewable energy, energy efficiency and more efficient fossil power plants.
- We continue to use nuclear energy as an important base-load energy source to support stable energy supply
- Under this basic policy, considering the constraints of energy resource situations, we maintain the necessary level of nuclear power from the viewpoints of energy supply stability, cost reduction, climate change, human resources to maintain the safety.
- We make steady progress without delay in the following area:

① Comprehensive and enhanced measures to deal with spent nuclear fuel
  - Strengthen measures for final disposal of HLW
  - Expansion of spent fuel storage capacity
  - R&D on alternative options including direct disposal and reduction of toxicity/volume of radioactive waste

② Making progress in nuclear fuel cycle
  - Promote nuclear fuel cycle while gaining understanding of local communities and international communities. Mid-long term flexibility should be maintained.
  - Under the principle of peaceful use of nuclear energy, we will manage plutonium appropriately while assuring the principle of "no plutonium surplus policy" with careful consideration of plutonium supply and demand.

http://www.enecho.meti.go.jp/topics/kihonkeikaku/140225_1.pdf

Three types of spent fuel storage capacity

(As of September 2013, total of 17,335 tons are in storage)

At-reactor storage

Storage capacity: 20,640 tU/17 sites (as of Sept. 2013, 14,340tons ~70% full)

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

If Rokkasho was cancelled...

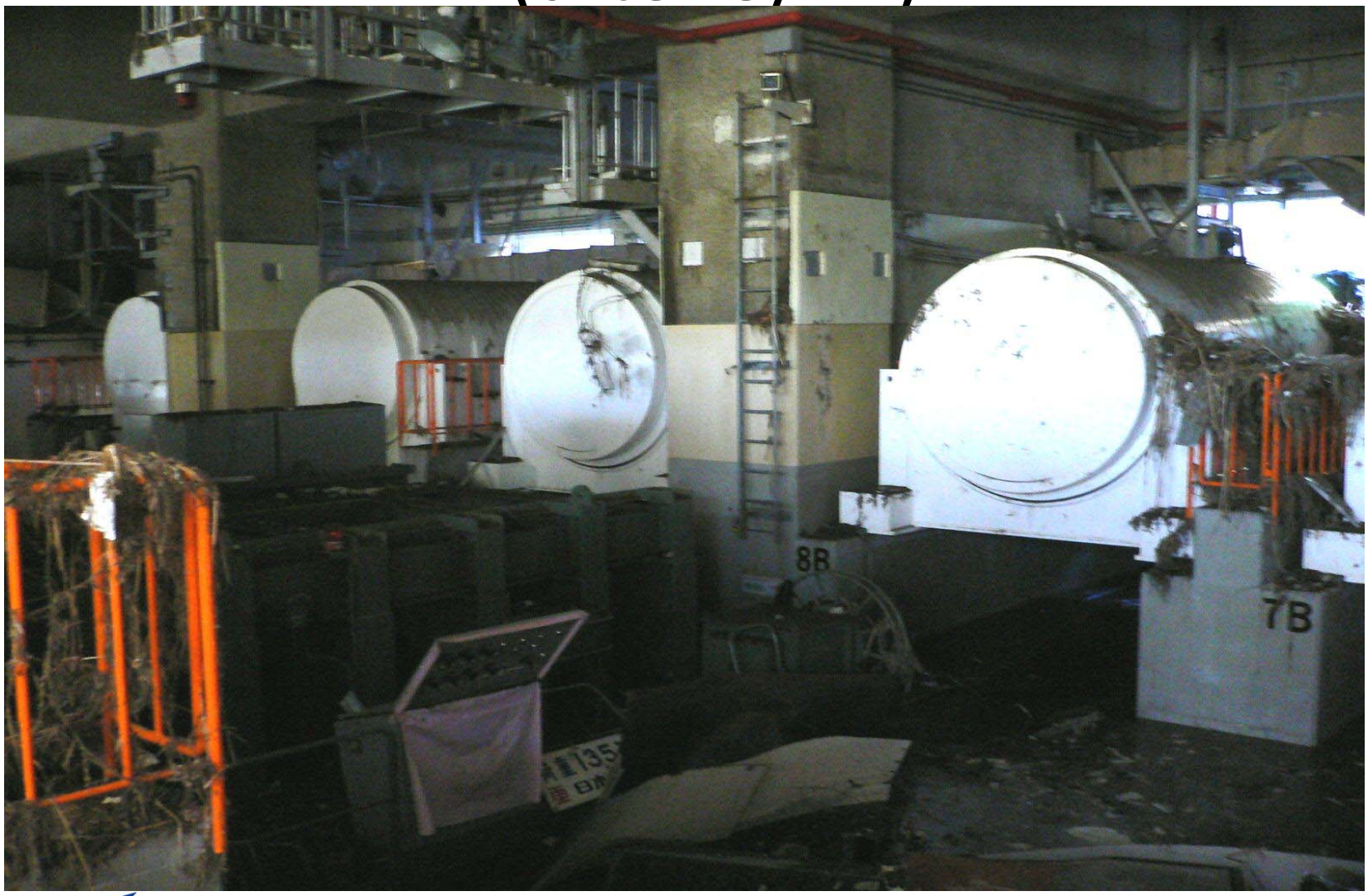
Rokkasho reprocessing plant

Storage capacity:**3,000tU**
(storage **2,945 tU** as of Sept. 2013)
Construction cost: ¥2.14Trillion
Commission date: not known

Mutsu Interim storage site

Dry Cask storage type
Capacity : totally 5,000 tU
1st 3,000 tU, add 2,000tU in future
Operation March 2015 (postponed)
(Status : under construction)
Construction cost: ¥0.1Trillion
(including dry casks)

Dry Cask Storage at Fukushima Daiichi (after 3/11)



http://photo.tepco.co.jp/library/110909_2/110909_69.jpg

JAEC's "No Pu surplus policy"

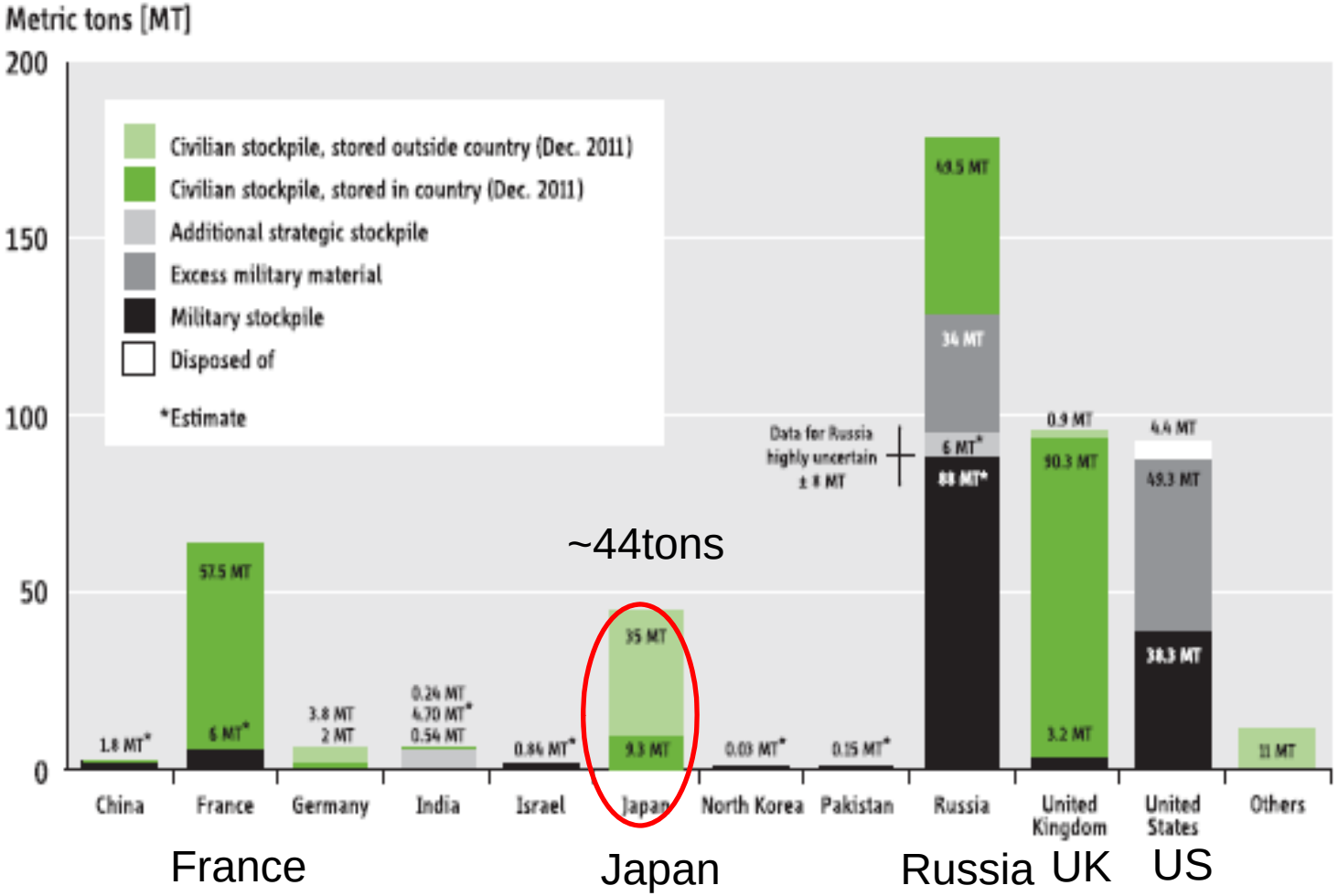
- Since 1991, Japan stick to a principle of "no plutonium surplus policy" , i.e. Japan does not have any plutonium which does not have specific purposes to use.
- In August 2003, JAEC announced its new guideline for plutonium management preparing for commissioning of the first commercial reprocessing plant.
  - Utilities are expected to submit **its plutonium usage plan annually *before* separation of plutonium**.

But, Japan now has 44 tons (35 tons in Europe, 9 tons in Japan) of stockpile.

"Plutonium stockpile should be reduced regardless of fuel cycle options chosen in the future"

(Statement in JAEC Subcommittee on Nuclear Power/Nuclear Fuel cycle technologies)
http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-1.pdf (in Japanese)

Global Civilian Plutonium Stockpile (2011)
- Reprocessing has international security implications -



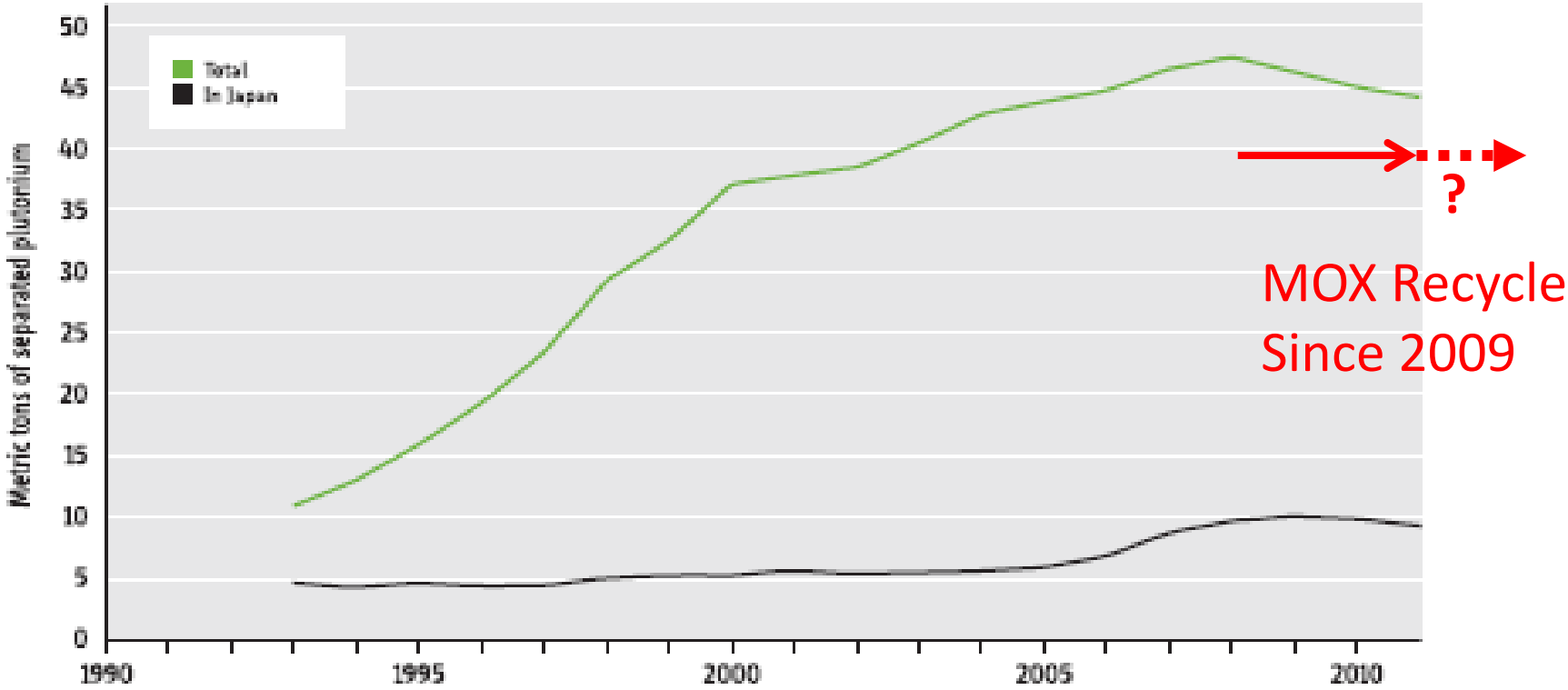
Source: International Panel on Fissile Material (IPFM), Global Fissile Material Report 2013, http://fissilematerials.org/library/gfmr13.pdf

Plutonium Stockpile in Japan (as of the end of 2012)

	2012 (kg)	2011 (kg)
Stock in Japan (Pu total)		
Reprocessing Plants	4,363	4,364
MOX Fuel Plant	3,364	3,363
Stored at Reactors	1,568	1,568
Sub-total (Pu fissile)	9,295(6,315)	9,295 (6,316)
Stocks in Europe (Pu total)		
UK	17,052	17,028
France	17,895	17,931
Sub-total :Pu total(Pu fissile)	34,946 (23,277)	34,959(23,308)
Total (Pu fissile)	44,241(29,592)	44,254(29,624)

Source: Japan Atomic Energy Commission (2013, 2012) http://www.aec.go.jp/jicst/NC/sitemap/pdf/130911e.pdf

Japan's Plutonium Stockpile



Source: International Panel on Fissile Material (IPFM), Global Fissile Material Report 2013, http://fissilematerials.org/library/gfmr13.pdf

Pu Use Plan for Rokkasho (FY2010)

	Pu stock (End of FY 2009)	Pu recovered (FY2010)	Pu stock (End of FY2010)	Reactors for Pu use	Pu use per year	Planned period
Hokkaido	72kgfis	0	72kgfis	Tomari#3	0.2tonfis/y	FY2015~
Tohoku	78	0	78	Onagawa#3	0.2	FY2015~
TEPCO	748	0	748	3～4 unit include Fukushima-1#3 (planned)	0.9~1.6	FY2015~
Chubu	182	0	18	Hamaoka#4	0.4	FY2015~
Hokuriku	9	0	9	Shika #1	0.1	FY2015~
Kansai	556	0	556	Takahama#3,4 1～2 unit in Ohi	1.1~1.4	FY2015~
Chugoku	84	0	84	Shimane#2	0.2	FY2015~
Shikoku	133	0	133	Ikata #3	0.4	FY2015~
Kyushu	315	0	315	Genkai #3	0.4	FY2015~
JAPCO	140	0	140	Tsuruga#2. Tokai#2	0.5	FY2015~
J-Power	(purchase from others)			Ohma	1.1	NA
Total	2,317	0	2,317	--	5.5~6.5	--

Source: Federation of Electric Power Cos, Sept. 17, 2010, http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2010/siryo51/siryo1.pdf

Current Status of Rokkasho and Monju

- Rokkasho reprocessing plant (800 tons/y) is now under licensing process. JNFL plans to start operation from October 2014.
  - It plans to reprocess 880 tons in three years once it starts operation, which could produce about 8 tons of Pu (total) in three years.
  - Safety licensing process may take one to two years.
- Monju is also under safety examination under the new regulatory standards. JAEA plans to use Monju for transmutation R&D in addition to demonstrating FBR prototype reactor.

Current status of LWRs and Plutonium recycling in Japan

- Currently no nuclear power plants (out of 48) are operating.
- Utilities applied 17 nuclear power plants (12 PWRs, 5 BWRs). BWRs are required to install new systems such as filtered venting systems.
- Among 17 units, 7 units are for plutonium recycling and 2.3 tons of Pu(fissile) per year will be used. In addition, if Oma goes on line, additional 1.1 tons per year will be used.

Second Meeting of the Japan-United States Bilateral Commission on Civil Nuclear Cooperation

（2013/11/4）

- “On nuclear security, Japan and the United States committed to continue to strengthen the nuclear security posture of both countries and to fundamentally reduce the threat that terrorists could acquire nuclear material. Key steps towards these goals include the following:
  - Reducing the quantities and attractiveness of weapons-usable nuclear material;”

http://www.mofa.go.jp/mofaj/files/000018671.pdf

http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2013/siryo41/siryo2-2.pdf

A Proposal for Plutonium Use Policy - personal opinion (2013/03/26)

1. Demand comes first: Reprocessing should take place only when plutonium demand(use) is specified. In order to achieve this goal, spent fuel storage capacity must be expanded.
2. Stockpile reduction: Matching demand/supply is not good enough. Existing stockpile should be reduced before further reprocessing.
3. Flexible plan: Current Pu use plan (MOX recycling in 16~18 units) is no longer certain. Other options (Pu ownership transfer, disposition as waste etc.) need to be pursued. With minimizing cost, transportation and time required to dispose.

REFERENCE

安全性：ライフサイクルでの被ばくリスク(2/3)

Life cycle analysis of exposure risk

核燃料サイクルの主要工程毎の被ばく量概算値について

核燃料サイクル工程	操業後500年間にわたるヨーロッパの一般公衆の集団被ばく線量 解析値 (manSv/GWe-year)		作業従事者の集団被ばく線量 (manSv/GWe-year)	
	ワンスルー	リサイクル	ワンスルー	リサイクル
採掘、精錬	1	0.79 (1)	0.7	0.55 (1)
転換、濃縮	0 (2)	0 (2)	0.02	0.016
燃料成形加工	0.0009 (4)	0.0007 (3)	0.00657 (5)	0.0941 (3)
発電	0.65 (6)	0.65 (6)	2.7 (7)	2.7 (7)
再処理、ガラス固化、中間貯蔵	0	1.534 (8)	0	0.012 (9)
合計	1.65	2.97	3.43	3.37

Once-through Recycle Once-through Recycle

U mine

Reprocessing

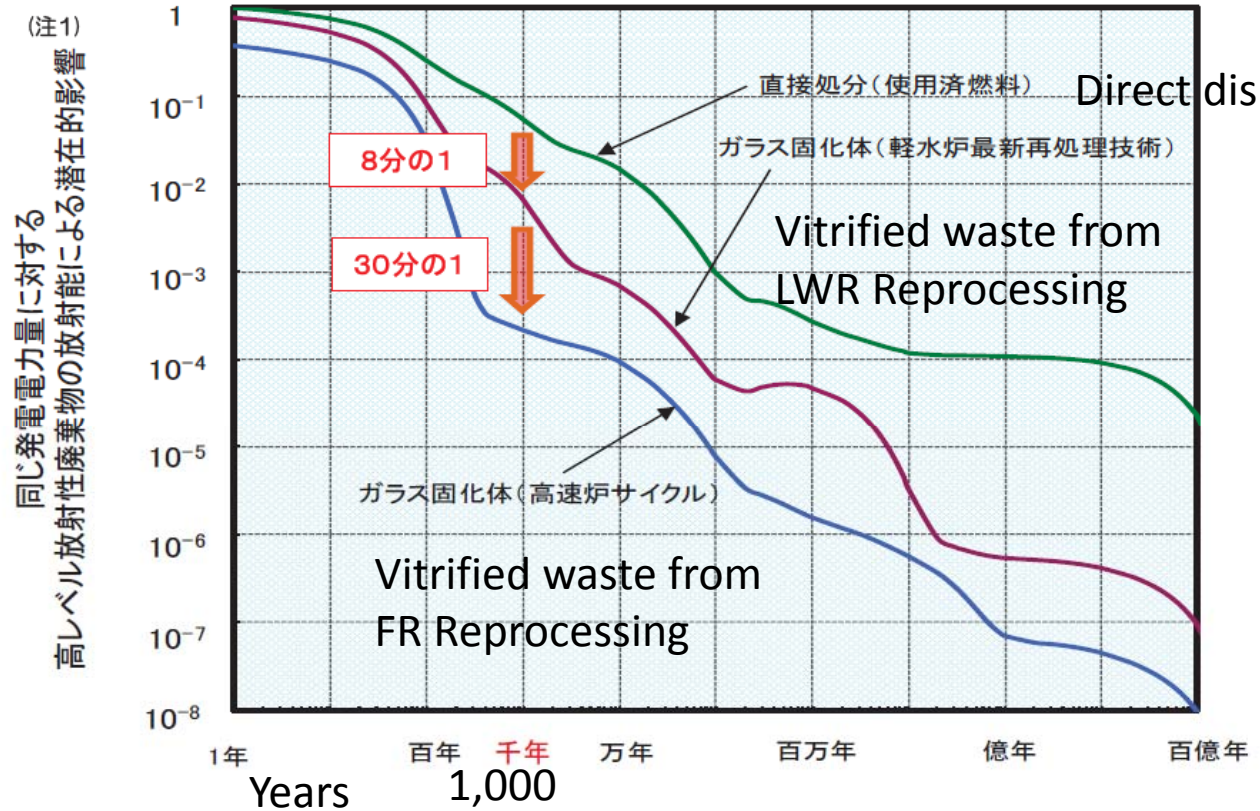
注釈
(1) 天然ウラン必要量に基づいて算出、作業従事者の線量はUNSCEAR88による
(2) 燃料成形加工による影響に合算した
(3) UO_2とMOX燃料の重量(21.1t、5.5t)で重み付けして算出
(4) 一般公衆：解析結果：Romans 3.21×10^{-4}、 Melox 2.51×10^{-3}
(5) 作業従事者：Romans 6.57×10^{-3}、 Melox 4.3×10^{-1}
(6) 一般公衆：海岸 0.54、 内陸 0.65
(7) 作業従事者：フランス 900MW(e)プラントの平均
(8) 一般公衆：サイトを特定しない一般的な評価
(9) 作業従事者：La Hagueにおけるデータ

出典：
・OECD/NEA, "Trends in the Nuclear Fuel Cycle: Economic, Environmental and Social Aspects" (2001).
参考文献：
・UNSCEAR88, United Nations Scientific Committee on the Effects of Atomic Radiation(UNSCEAR): "Sources, Effects and Risks of Ionizing Radiation, 1988, Report to the General Assembly, with annexes", United Nations, New York, 1988.

2012/3/1 原子力発電・核燃料サイクル技術等検討小委員会（第9回） 27

http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-2.pdf

廃棄物：Potential Hazard of HLW by form 高レベル放射性廃棄物の潜在的有害度（毒性）(2/2)



（注1）高レベル放射性廃棄物と人間との間の障壁は考慮されておらず、高レベル放射性廃棄物の実際の危険性ではなく、潜在的な有害度（経口摂取による年摂取限度で規格化）を示している。使用済燃料取り出し直後の潜在的影響を1とした相対値。

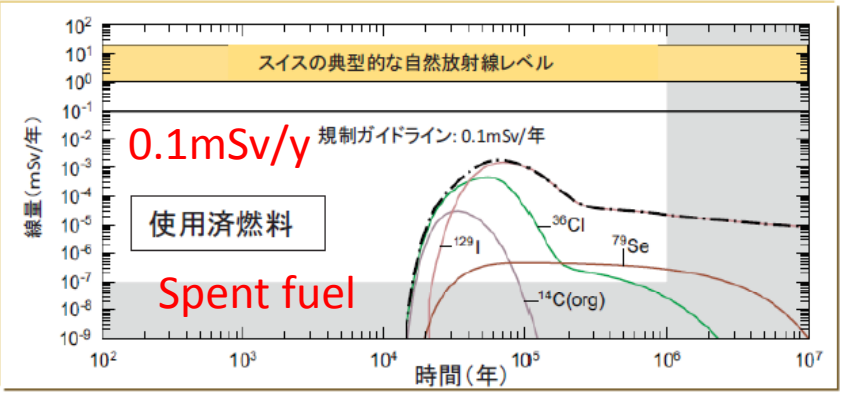
出典：原子力委員会 原子力政策大綱（平成17年）を基に編集

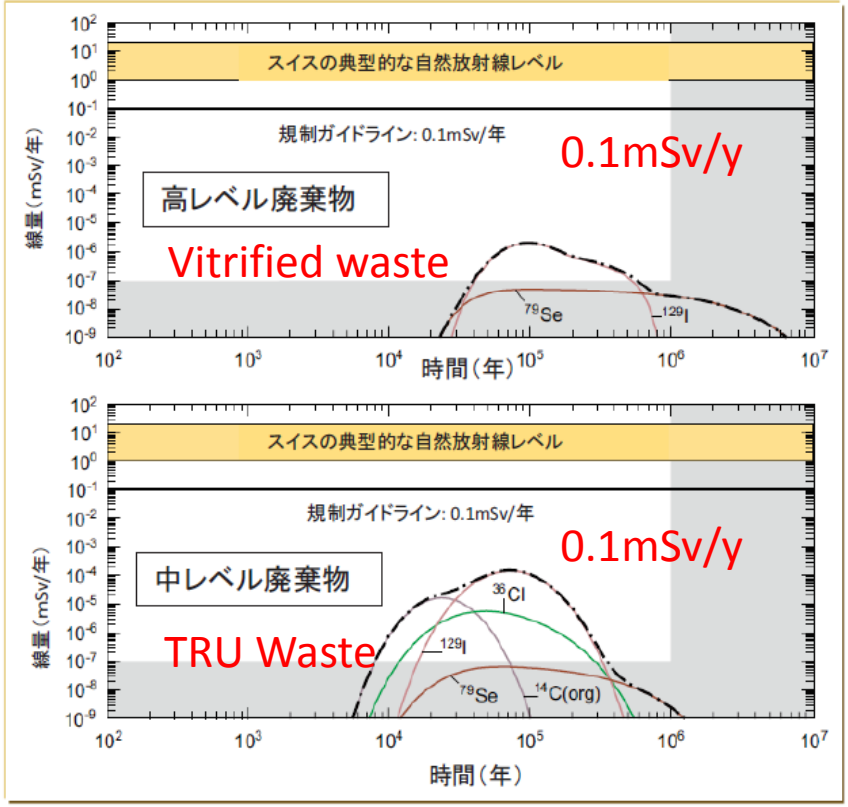
http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-2.pdf

Potential Exposure Risk from HLW
廃棄物：高レベル放射性廃棄物の被ばくリスク(2/2)

"What if" case studies in Switzerland assuming 100 times speed of underground flow

スイスの解析例
"what if"ケースとして、地下水の流量をリファレンスケースの100倍と仮定した場合の放射線量





直接処分の場合（左上図）及び再処理を行った場合（右上＋右下図）のいずれも、廃棄物からの被ばく線量は、諸外国で提案されている安全基準（0.1～0.3mSv/年）に比べて十分低い

出典：Nagra Technical Report NTB 02-05(2002)より事務局作成

http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryo2012/siryo22/siryo1-2.pdf