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Japan's Options and Strategies on Nuclear Energy and Fuel Cycle post Fukushima

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1. Nuclear Energy / Fuel Cycle Policy Trends and Development

(1) Review of the nuclear power development in Japan so far

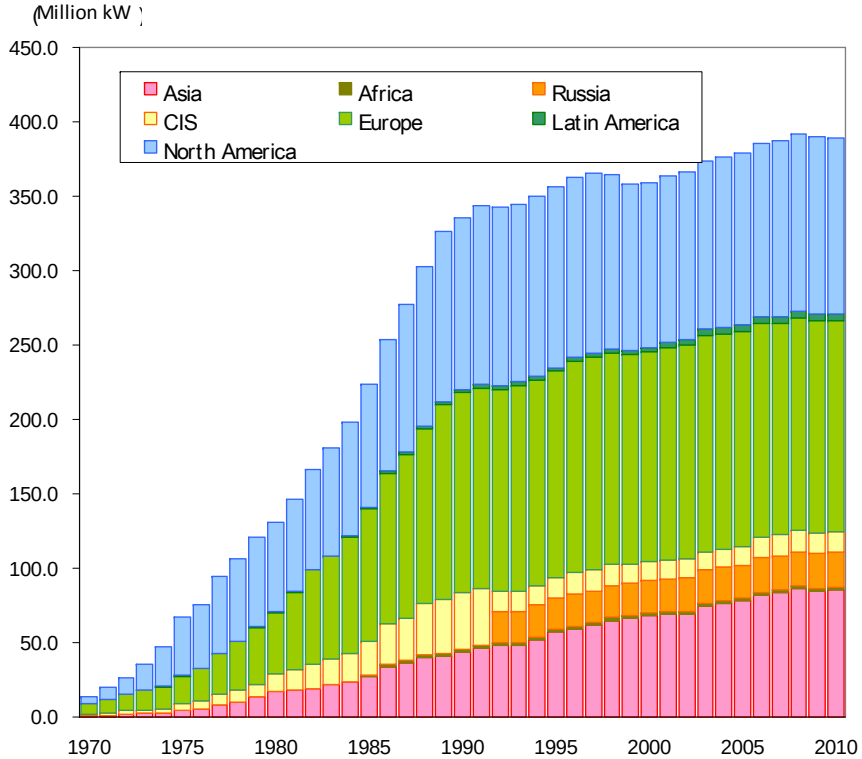
(2) Nuclear Energy National Plan of 2006 – Major Issues –

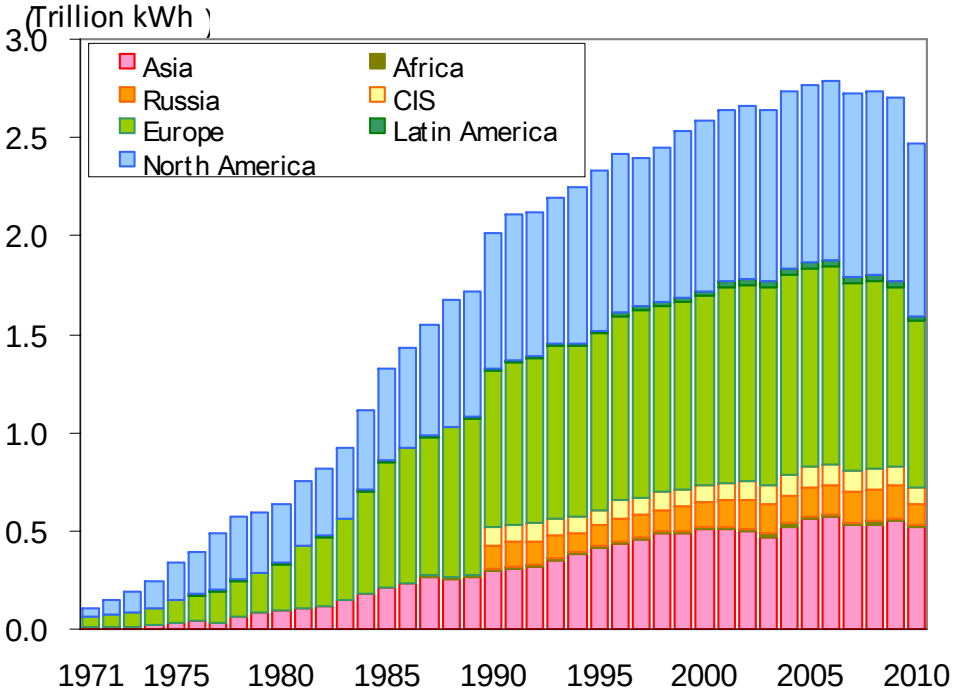
1(1) Review of the nuclear power development in Japan so far (1/4)

Trends of the Capacity / Generation from 1970-2010

- At the end of 1970s, the total number of reactor in Japan was 20 and the capacity was 14.786 GW.
- In 1980s, the number of reactors under construction decreased in the world, but in Japan, it was a period of "Renaissance", continued boom.
- At the end of 1980s, 36 reactors of 29.114GW was in operation in Japan.

30 GW in 20 years = one of the fastest progress in the world



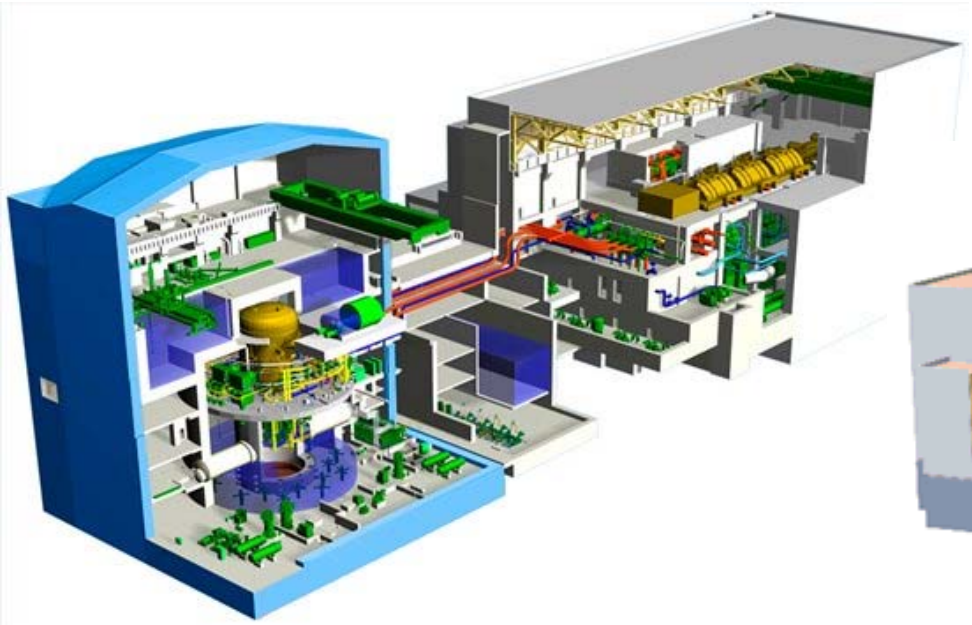


1(1) Review of the nuclear power development in Japan so far (2/4)

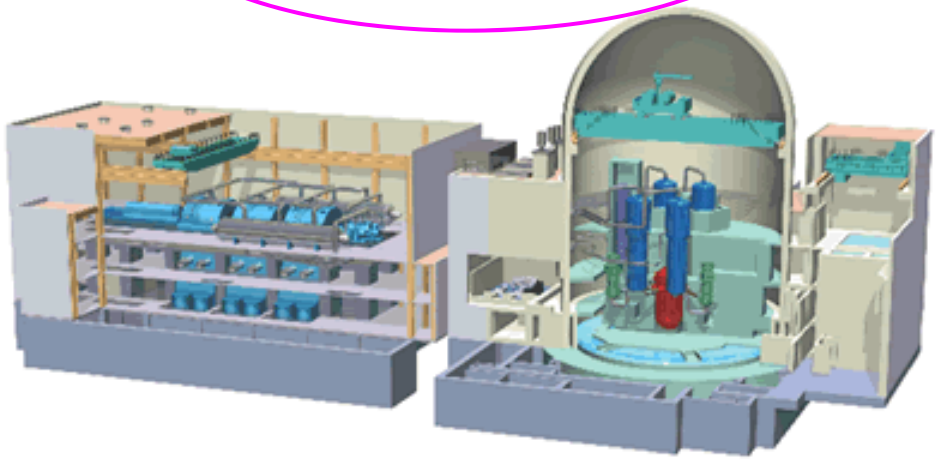
Progress in 1980s

- Plant vendors and the Electric Power Utilities have jointly developed the Advanced, Standardized type of LWRs based on the initial type introduced from overseas as a national project.
  - Advanced BWR: GE, Hitachi and Toshiba
  - Advanced PWR: Westinghouse and Mitsubishi

Standardized Domestic Reactors since 1990s



ABWR – conceptual design
Source: GE Hitachi Nuclear Energy



APWR – conceptual design
Source: Mitsubishi Heavy Industries

1(1) Review of the nuclear power development in Japan so far (3/4): Why nuclear ?

- Scarcity of Energy Resources
  - High import dependence
  - High Middle East dependence

-> Since the oil crises in the 1970s Japan has diversified energy sources

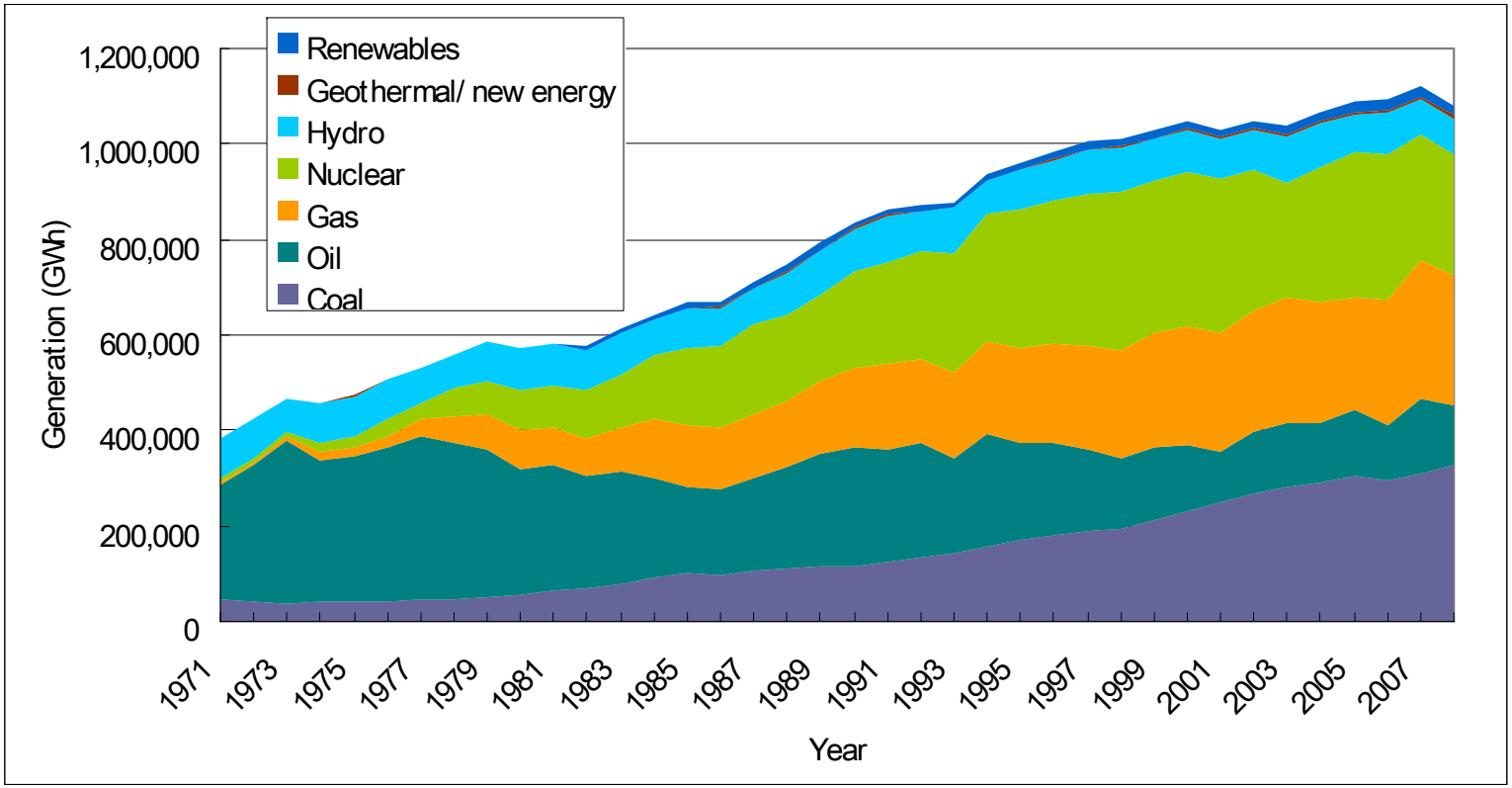
- Optimal Combination of Power Sources
  - Power source diversification based on the best use of the characteristics of each power source

- Carbon Dioxide Reductions
  - Nuclear as “Zero emission” source

Even after Fukushima accident, these drivers to develop nuclear still exist.

1(1) Review of the nuclear power development in Japan so far (4/4): Diversified energy sources

- Well diversified power portfolio – coal, gas, hydro and nuclear
- Increased self-sufficiency ratio (though it is still low)



Trend of the generation by fuel from 1971 to 2009 in Japan

Source: Energy Balances of OECD Countries, IEA

1(2) Nuclear Energy National Plan of 2006 – Major Issues –

Policy Package – Repeated and stressed, constant since the 1st long-term plan in 1956

- Smooth proceeding of new nuclear construction plans by reducing investment risk
- Appropriate use of existing plants by dealing with maintenance of aging reactors
- Promotion of nuclear fuel cycle
  - reprocessing, fabricating of uranium-plutonium mixed oxide fuel (MOX)
  - developing a fast breeder reactors in the future
- Active support to private companies advancing to international nuclear markets
- Joint development on next-generation light water reactor by public and private sector, as well as technical and human resources development

What should we do with this National Plan after Fukushima ?

2. Current Status of Nuclear Power Generation and the Spent Fuel Stockpiles

(1) Overview of the global/domestic fuel cycle industries

(2) Nuclear power operation status after March 11

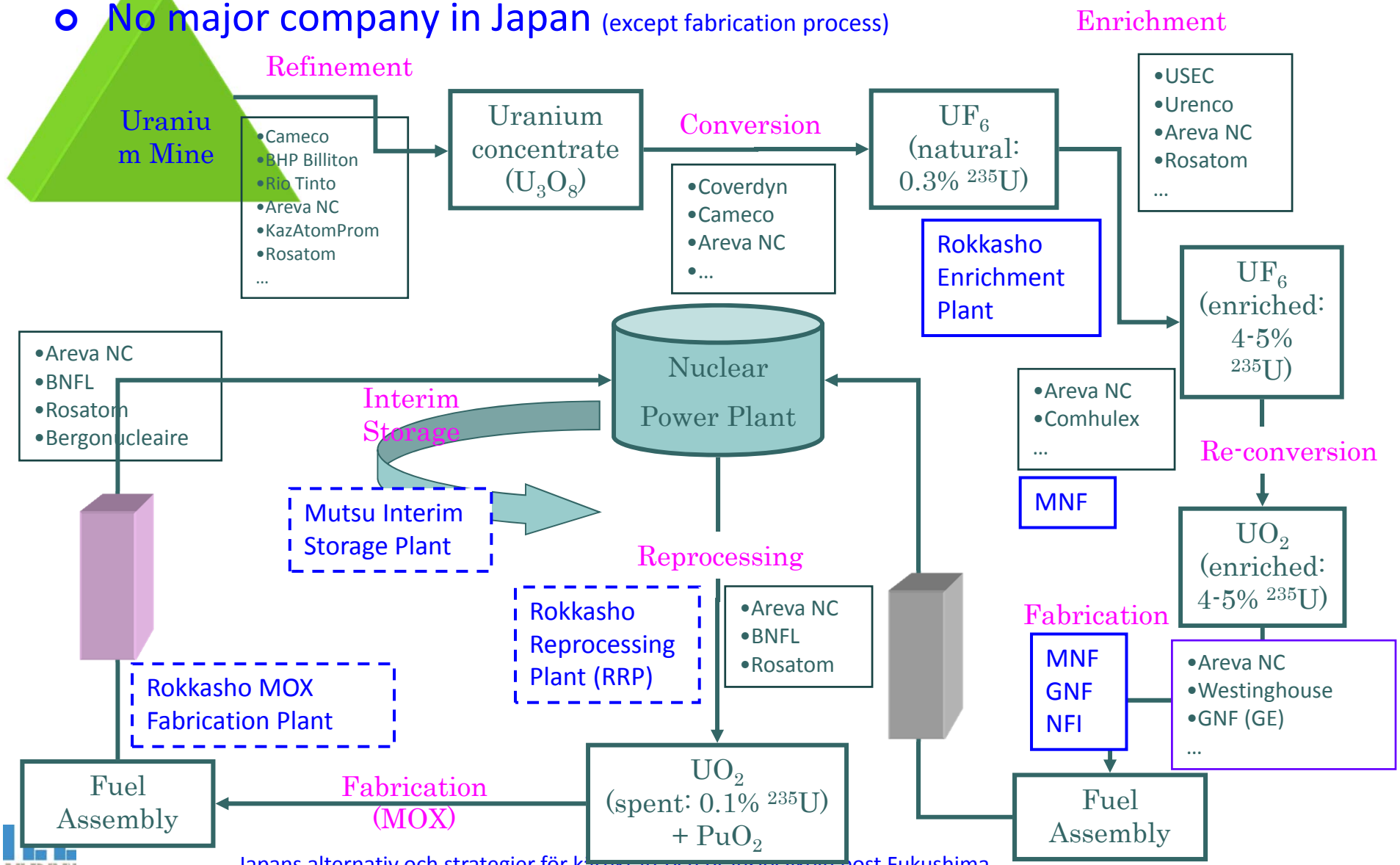
(3) Spent Fuel Stockpiles

(4) Status of the fuel cycle facilities

(5) FBR – Monju toward Commercialization

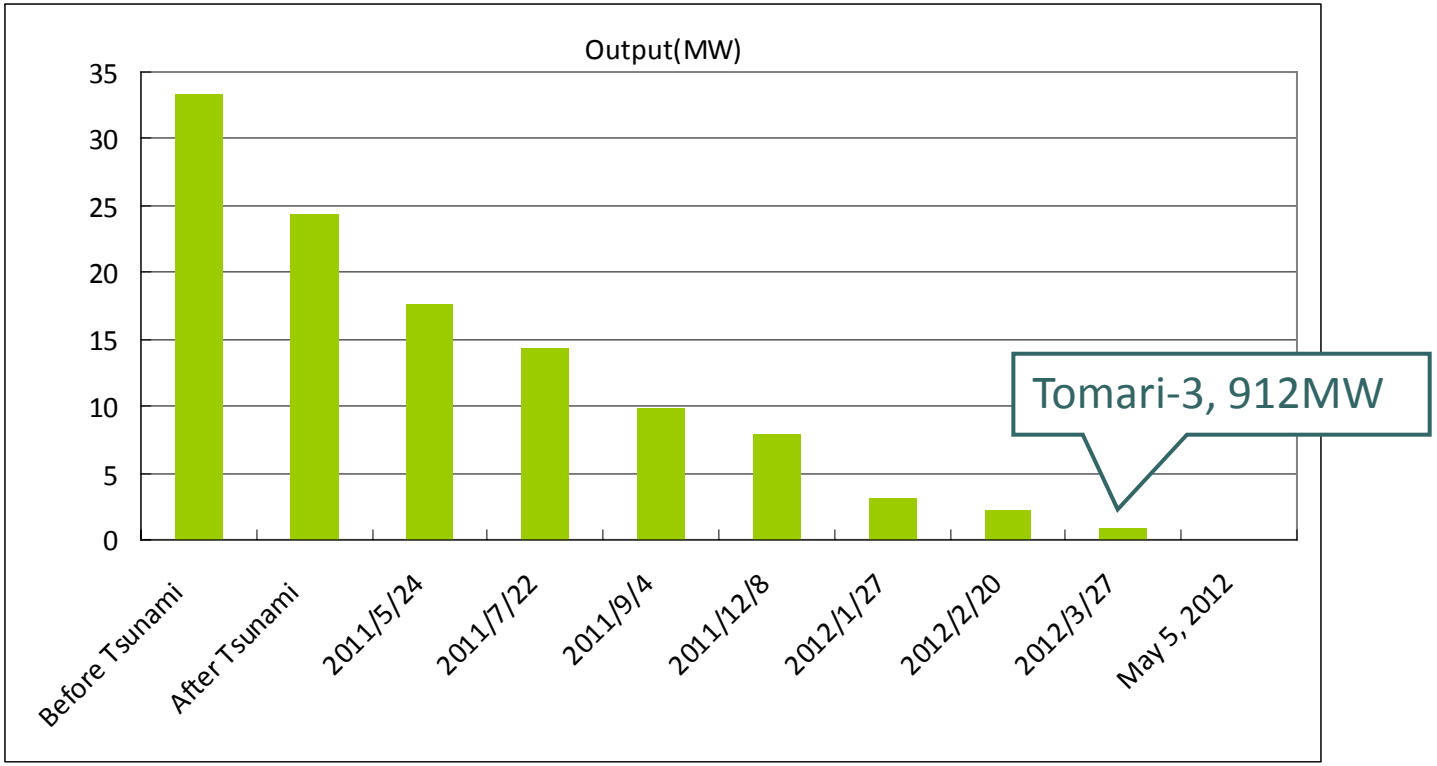
2(1) Overview of the global / domestic fuel cycle facilities

- Several steps in both front-end and back-end
- No major company in Japan (except fabrication process)



2(2) Nuclear power operation status after March 11

- 36 Plants were in operation just before the earthquake on 11 March 2011.
- 10 plants were shut down directly by the earthquake.
- After the event, restarting of commercial operation has not been permitted yet.



2(3) Spent Fuel Stockpiles (1/3)

Spent fuel storage capacity by type

- At-reactor storage
  - Storage capacity: 20,420 tU/17 sites
  - On-site dry cask storage is not allowed by local governments (Fukushima-1 had been allowed so far and Hamaoka was under negotiation before Fukushima disaster).

- Rokkasho Reprocessing Plant (RRP)
  - Storage capacity:3,000tU (Received 3,258 tU and storage 2,834 tU as of Mar. 2011)

- Interim storage plant
  - Only Mutsu Interim Storage Plant is ongoing in Japan.

2(3) Spent Fuel Stockpiles (2/3)

- Reactor on-site pools are filling up

Company	Station	1 full core (tU)	Annual Discharge (tU)	Effective Stogage Capacity (tU)	Amount of spent fuel (tU)	(%)
Hokkaido	Tomari	170	50	1,000	380	38
Tohoku	Onagawa	260	60	790	420	53
	Higashidori	130	30	440	100	23
	Fukushima- I	580	140	2,100	1,960	93
Tokyo	Fukushima- II	520	120	1,360	1,120	82
	Kashizazaki- Kai	960	230	2,910	2,300	79
Chubu	Hamaoka	410	100	1,740	1,140	66
Hokuriku	Shika	210	50	690	150	22
Kansai	Mihama	160	50	680	390	57
	Takahama	290	100	1,730	1,180	68
	Ohi	360	110	2,020	1,400	69
Chugoku	Shimane	170	40	600	390	65
Shikoku	Ikata	170	50	940	590	63
Kyushu	Genkai	270	90	1,070	830	78
	Sendai	140	50	1,290	870	67
JAPC	Tsuruga	140	40	860	580	67
	Tokai- II	130	30	440	370	84
Total		**5,070**	**1,340**	**20,630**	**14,200**	**69.**

Source : Technical Subcommittee on nuclear power and fuel cycle, AEC, 12 April 2012

2(3) Spent Fuel Stockpiles (3/3)

Strategic positioning of Interim Storage Plants

- About 13,500tU spent fuel assemblies will be generated in 2011-2020 based on the operation plan by the Electric Utilities 2011, while,
- Only 8,000tU spent fuel will be able to reprocess in Rokkasyo even though Rokkasho run as planned.

-> 5,500tU spent fuel assemblies should be kept on-site or in the Interim Storage Plants.

	1997 ~ 2010	2011 ~ 2020
Generated spent fuel	14,000tU	13,500tU
Transport to Rokkasyo	6,700	8,000
Transport to abroad	70	-
Storage in NPP	2,900	2,800
Need for spent fuel storage (Interim storage etc.)	4,400	2,700

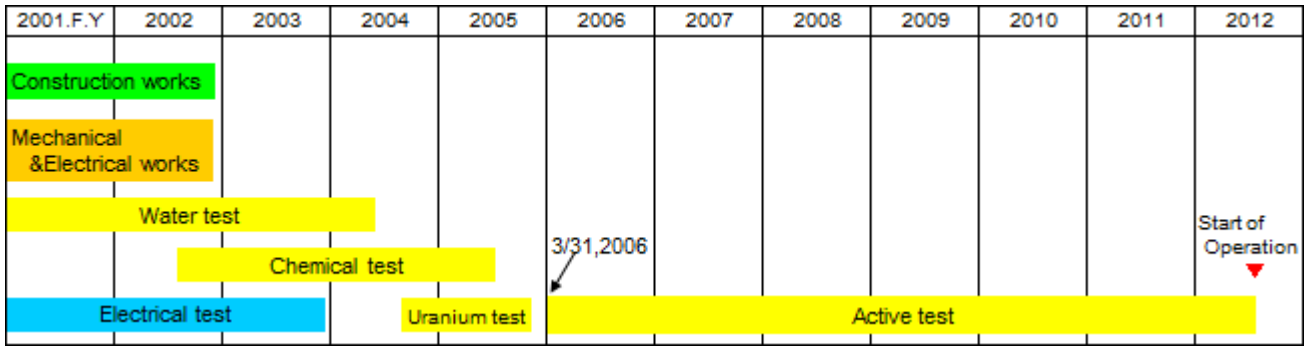
Total 7,100tU

Source : Basis of energy 2010-2011 (The Federation of Electric Power Companies of Japan, 2011)

2(4-1) Operational Status of Rokkasho Reprocessing Plant

- RRP is in the stage of "Active Test" and planned to complete its construction in October 2012.
- Reprocessing capability will be 800tU per year in 2016 and already 425tU reprocessed since 2006 under the active test.
- Before Fukushima disaster, some technical difficulties confronted the vitrification process. Preparation for the updated vitrification process was restarted in January 2012.
- The scheduled start : <u>October 2012</u>

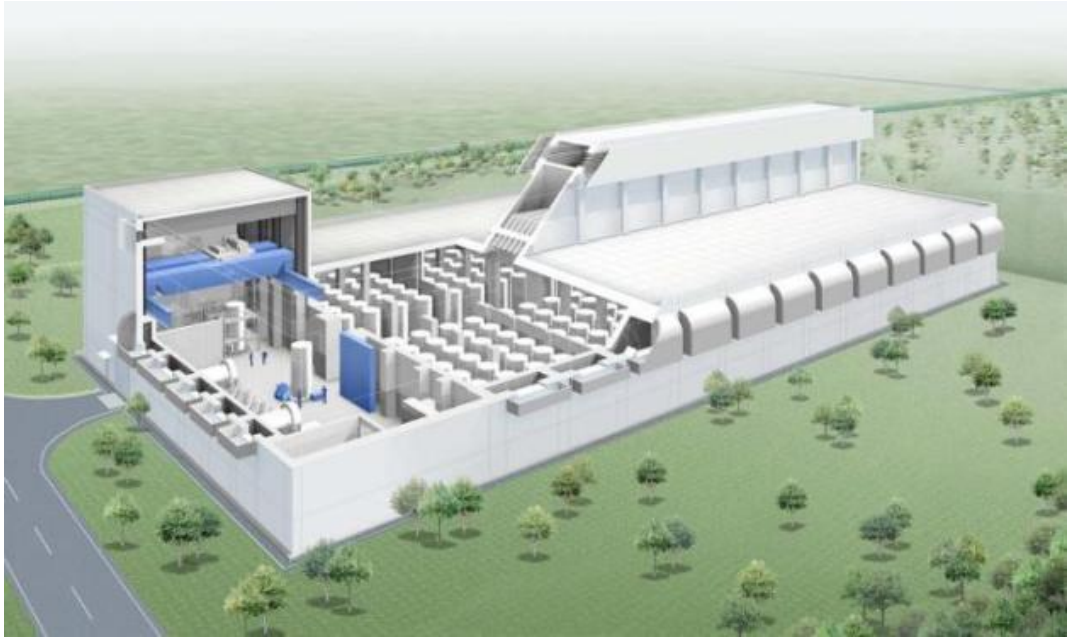
Estimated Construction Cost: 2,193 billion JPY



Source : JNFL

2(4-2) Construction of Mutsu Interim Storage Plant

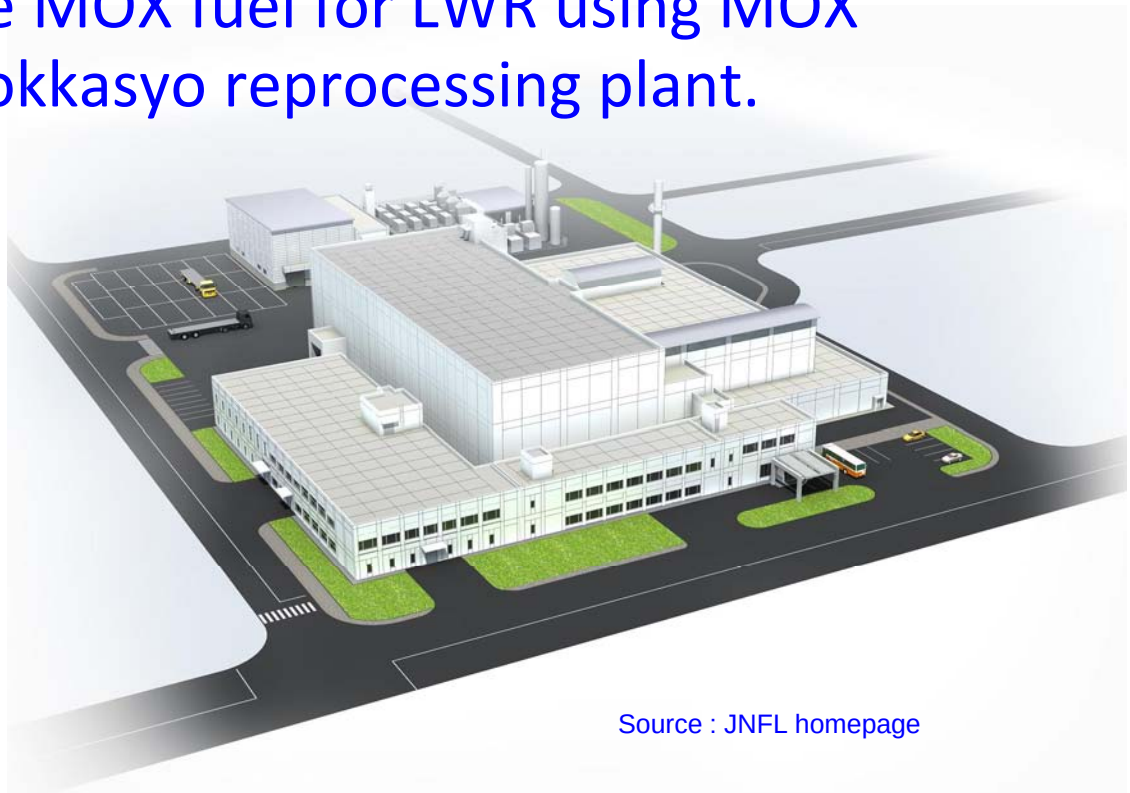
- Mutsu Interim Storage Plant is planned by Recyclable-Fuel Storage Company (RFS), a joint venture of TEPCO and JAPC.
- Construction had been suspended since March 11 2011 - restarted in March 2012.
  - Dry cask storage
  - Operation : Oct 2013
  - Capacity : 5,000tU (initially 3,000tU)
  - Construction cost: 100 billion JPY (including dry casks)



Source : RFS homepage

2(4-3) Construction of Rokkasho MOX Fabrication Plant

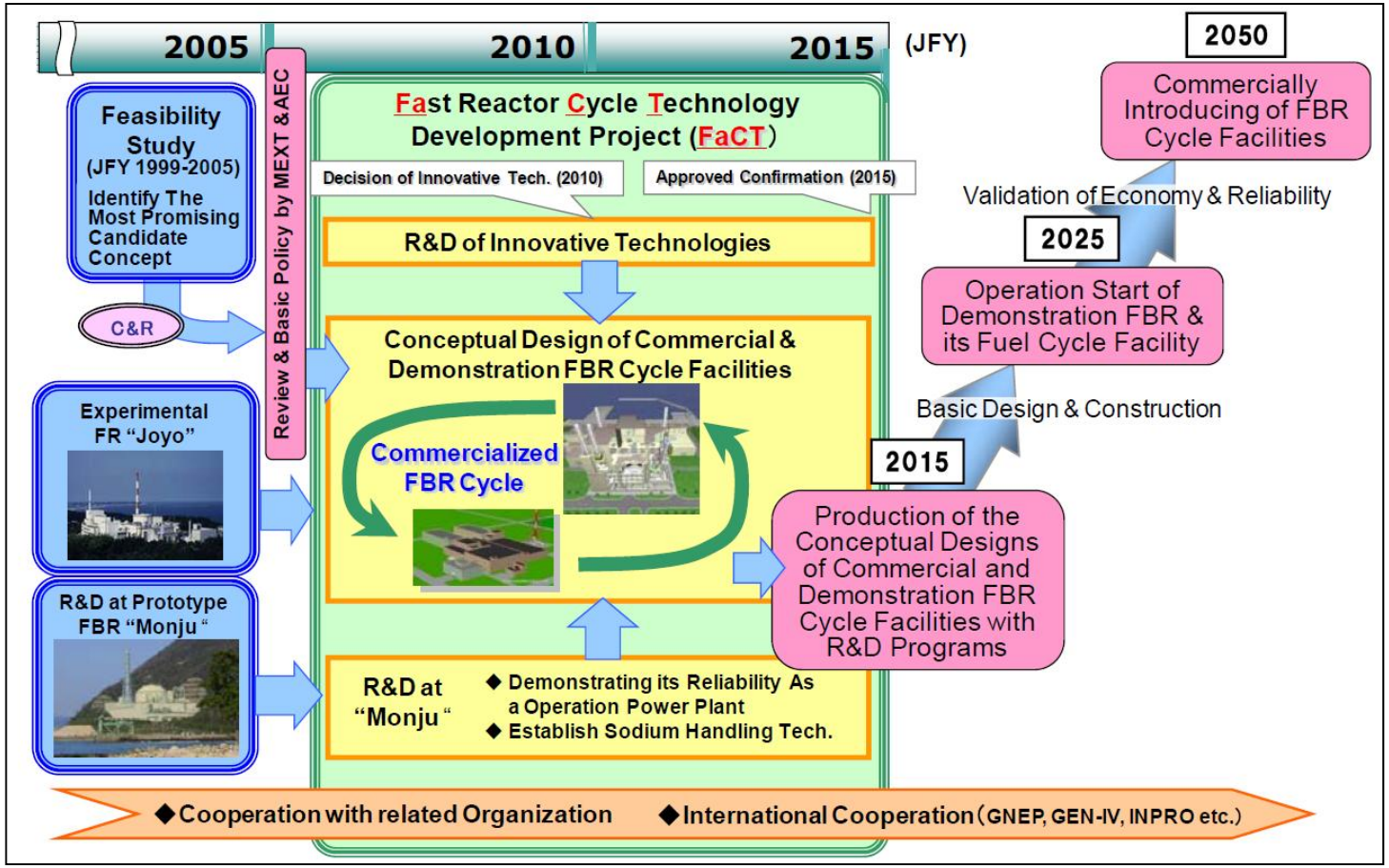
- Rokkasho MOX Fabrication Plant has been under construction since Oct 2010 by JNFL.
- Construction had been suspended since March 11 2011- restarted in Apr 2012.
- This facility will fabricate MOX fuel for LWR using MOX material produced by Rokkasyo reprocessing plant.
  - Operation : Mar 2016
  - Production capacity: 130tHM per year
  - Construction cost: 190 billion JPY



Source : JNFL homepage

2(5) FBR – Monju toward Commercialization

- JAEA and JAPC launched Fast Reactor Cycle Technology Development Project (FaCT) in 2006. In 2010, They judged the innovative technologies to be adopted.
- "The Japan sodium-cooled fast reactor (JSFR) with MOX fuel, the advanced aqueous reprocessing, and the simplified pelletizing fuel fabrication systems" have been studied as a main concept in the FaCT project.



Source : JAEA homepage

3. Quantitative Assumptions by Scenarios

(1)Restructuring of the power portfolio

(2)Possible scenarios for mid-long term power portfolio

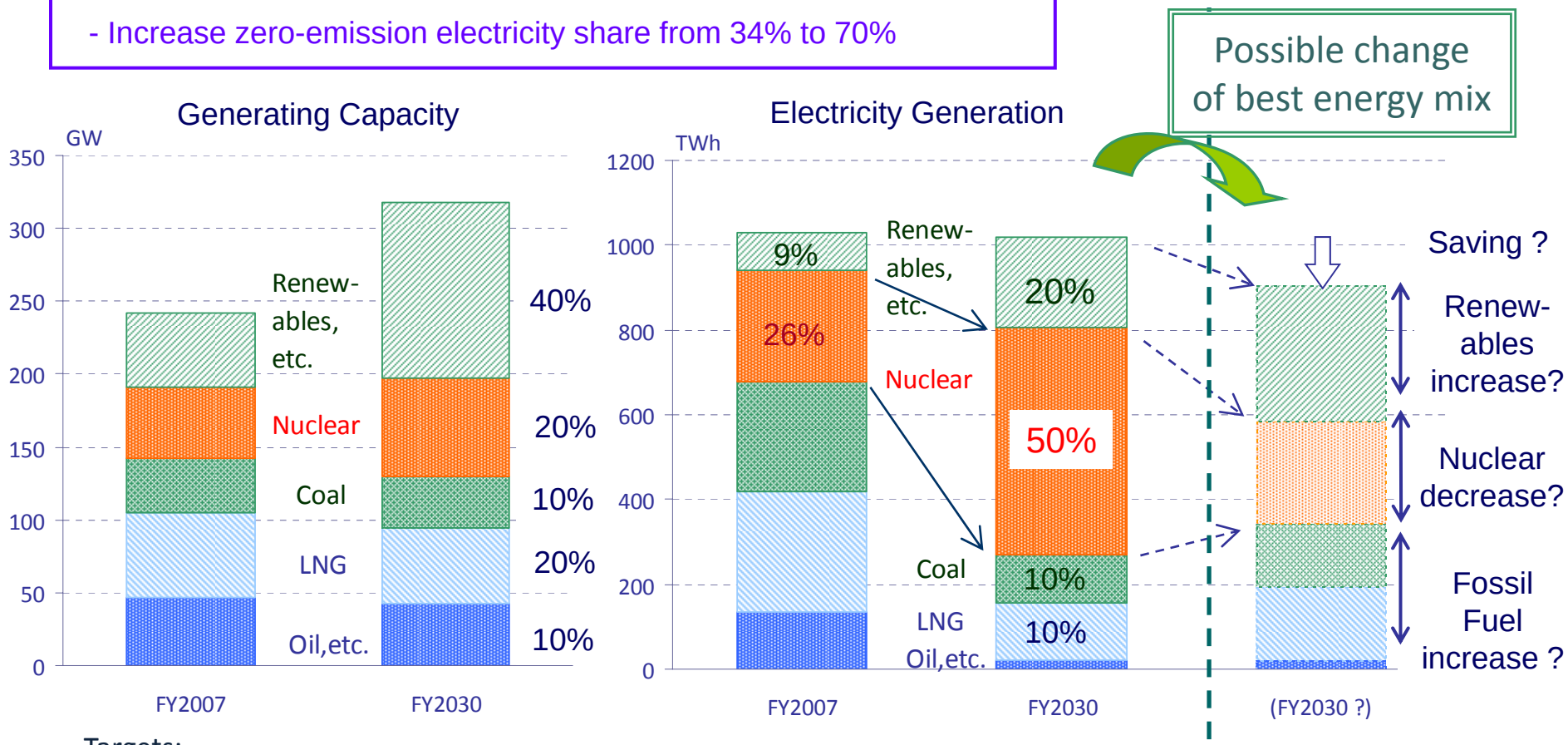
(3) Outlook for the spent fuels by each scenario

(4)Assumptions for the spent fuel management by scenarios

3(1)Restructuring of the power portfolio

Current Strategic Energy Plan of 2010

- Build 14 new reactors and raise the load factor from 60% to 90%
- Increase zero-emission electricity share from 34% to 70%



Targets:

- raise self-sufficiency of energy supply : 38% -> 70%
- reduce emissions by 30% in 2030 compared to 1990 level

3(2)Possible scenarios for mid-long term power portfolio-

IEEJ suggested at the Governmental Advisory Committee

Breakdown of Power Portfolio in 2030

	Nuclear	Renewables	Thermal	Energy Saving (+ Cogeneration[1)])	Zero emission electricity ratio
Strategic Energy Plan of 2010	50%	20%	30%	0%[3)]	70%
Scenario 1	30%	25%	30%	15%	70%
Scenario 2	25%	30%	30%	15%	70%
Scenario 2-2	25%	25%	35%	15%	70%
Scenario 3	15%	30%	40%	15%	60%
Scenario 4	0%	40%	45%	15%	55%

1) For the purpose of simpler comparison with Strategic Energy Plan of 2010, here the influence of energy saving and cogeneration, which should be deducted from denominator, is added to numerator.

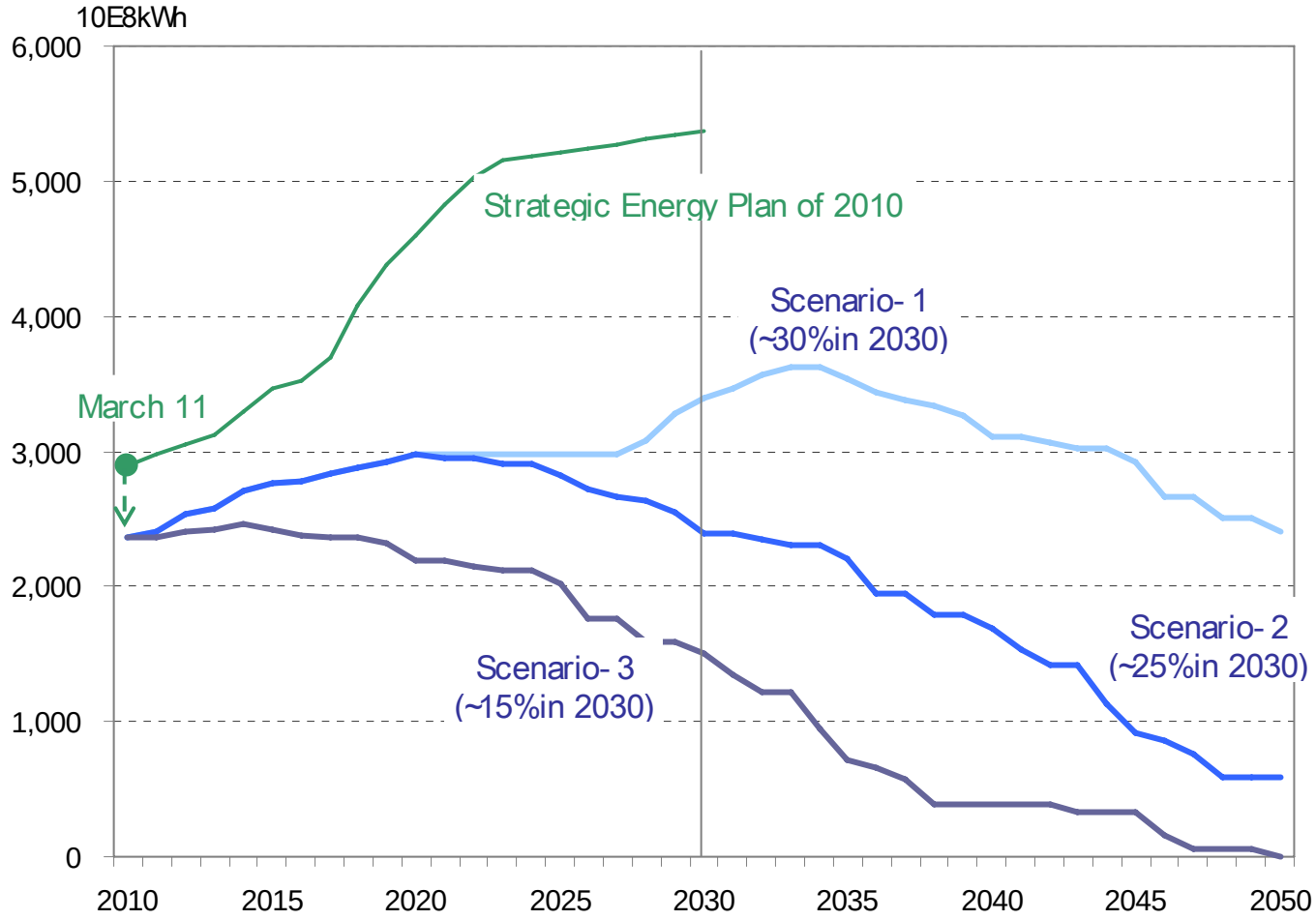
2) Energy saving contributes 12.5% and cogeneration contributes 2.5%.

3) 30% of increment of electricity demand is cut by improvement of efficiency.

Please also see http://eneken.ieej.or.jp/data/4129.pdf (Japanese only)

3(2)Possible scenarios for mid-long term power portfolio – Outlook of nuclear generation

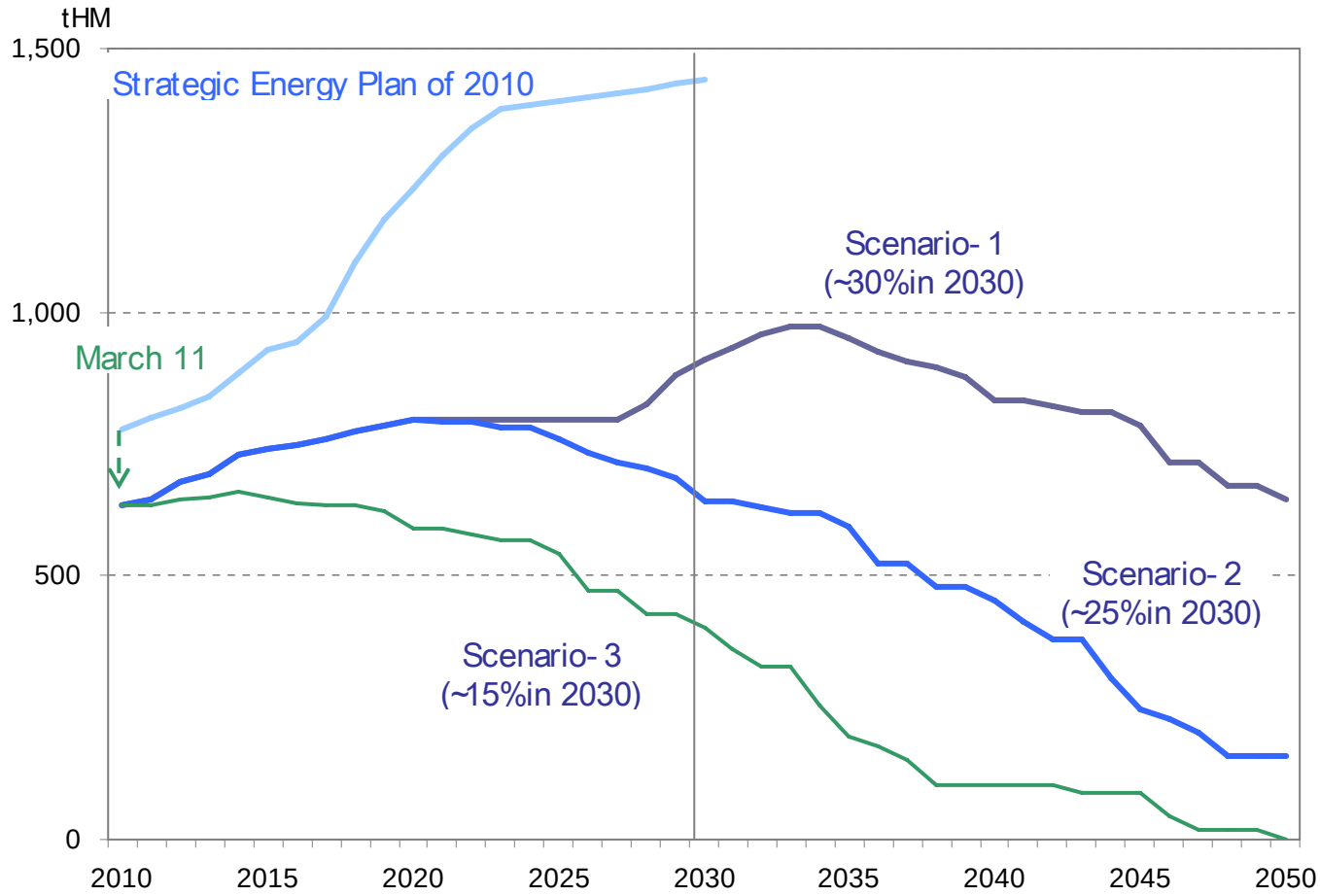
- Conditions and assumptions
  - Scenario-1: existing + new, life extension to 60 years
  - Scenario-2: existing + new, shut down after 40 years of operation
  - Scenario-3: existing, shut down after 40 years



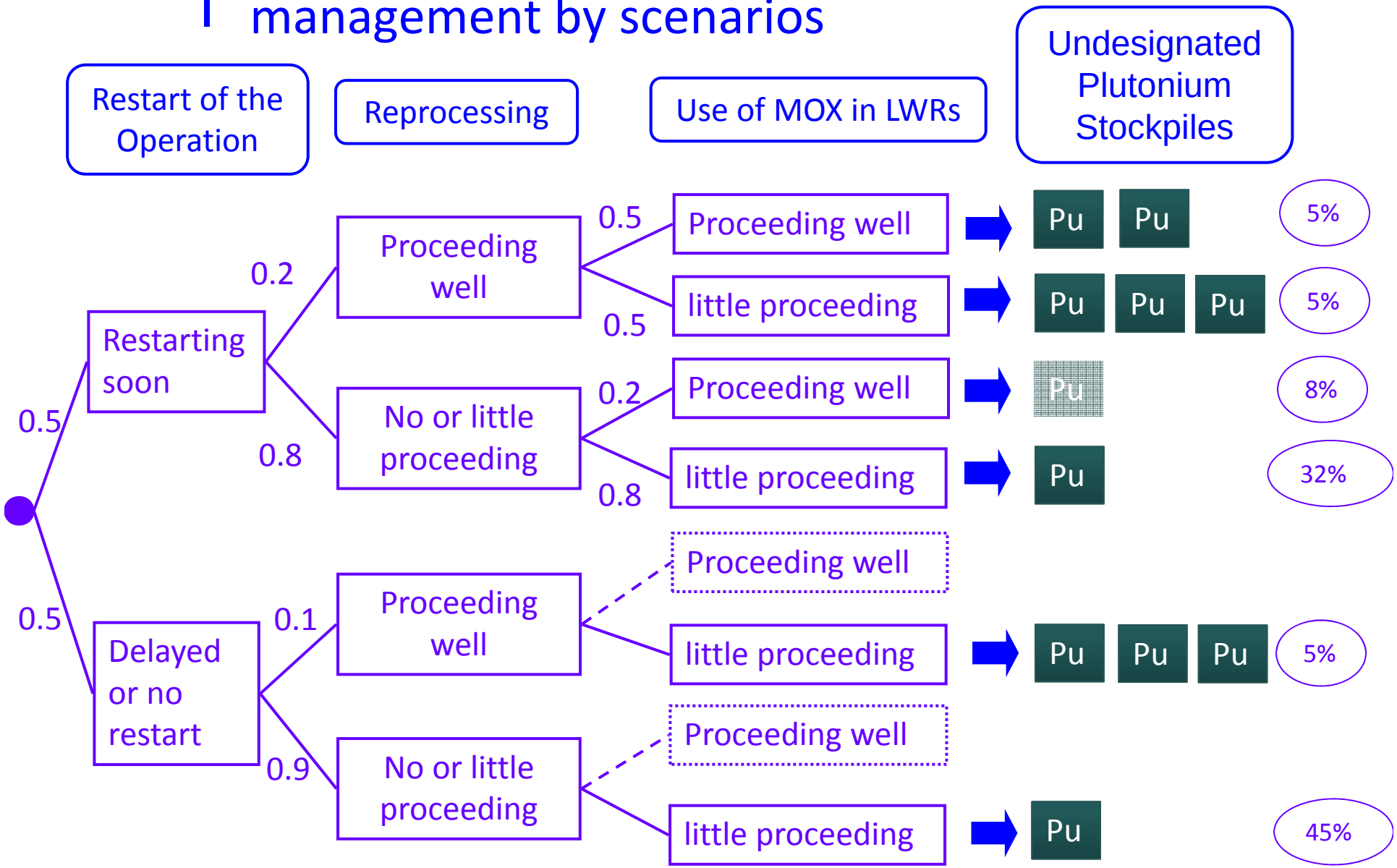
3(3)Outlook for the spent fuels by each scenario

- Conditions and assumptions
  - Enrichment:4%, burnup= 45GWd/t, tail assay:0.3%

  -> Spent fuels : 0.27 tHM/kWh



3(4)Assumptions for the spent fuel management by scenarios



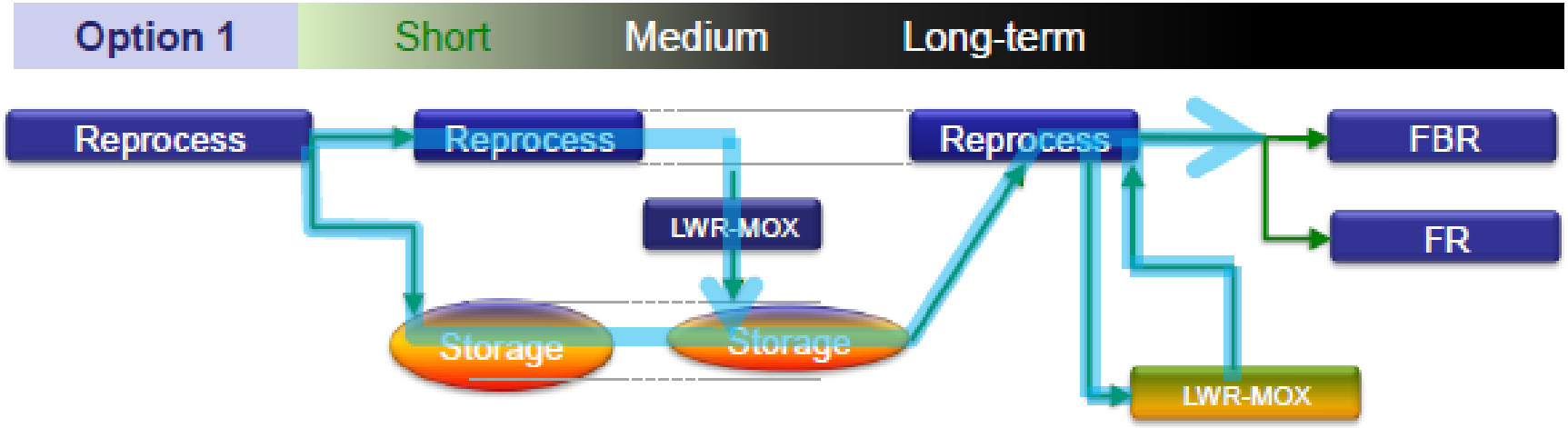
3(4)Options under discussion for the spend fuel management

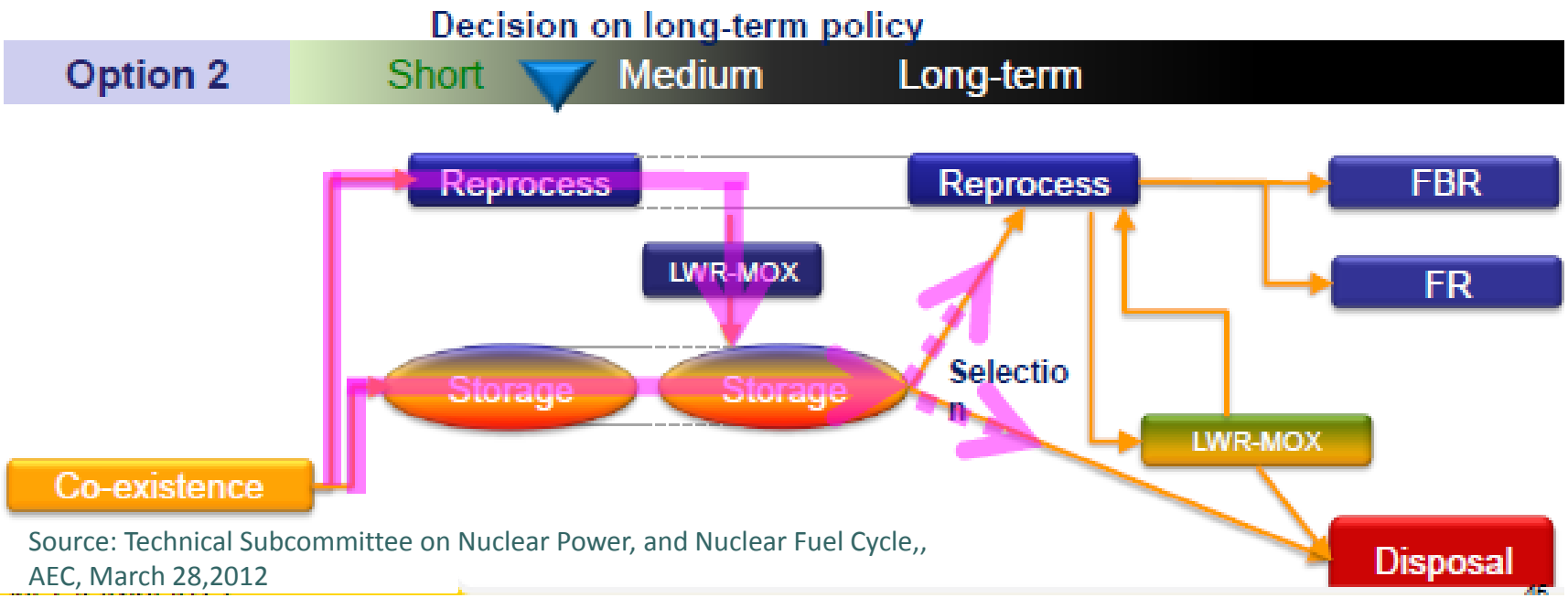
- Option 1: All reprocessing
  - Reprocess all spent fuels, burn Pu as MOX in LWRs while keeping some amount in Interim Storage Plant until commercialization of FBR
- Option 2: Proceed R&Ds on direct disposal while partially reprocessing
  - Reprocess spent fuels, burn Pu as MOX in LWRs while keeping some amount in Interim Storage Plant
  - Proceed R&Ds on direct disposal
- Option 3: All direct disposal
  - Burn existing Pu as MOX in LWRs without further reprocessing
  - Proceed R&Ds on direct disposal while keeping all amount of spent fuels being produced now and after

All these options should be assessed by the indexes below:

- Energy security
- International relations in safeguard and non-proliferation
- Economical competitiveness
- Flexibility on adapting technologies
- Social responsibility and public acceptance
- Negative effect of changing policies
- ……

3(4) Options under discussion for the spend fuel management -Concept of the options –

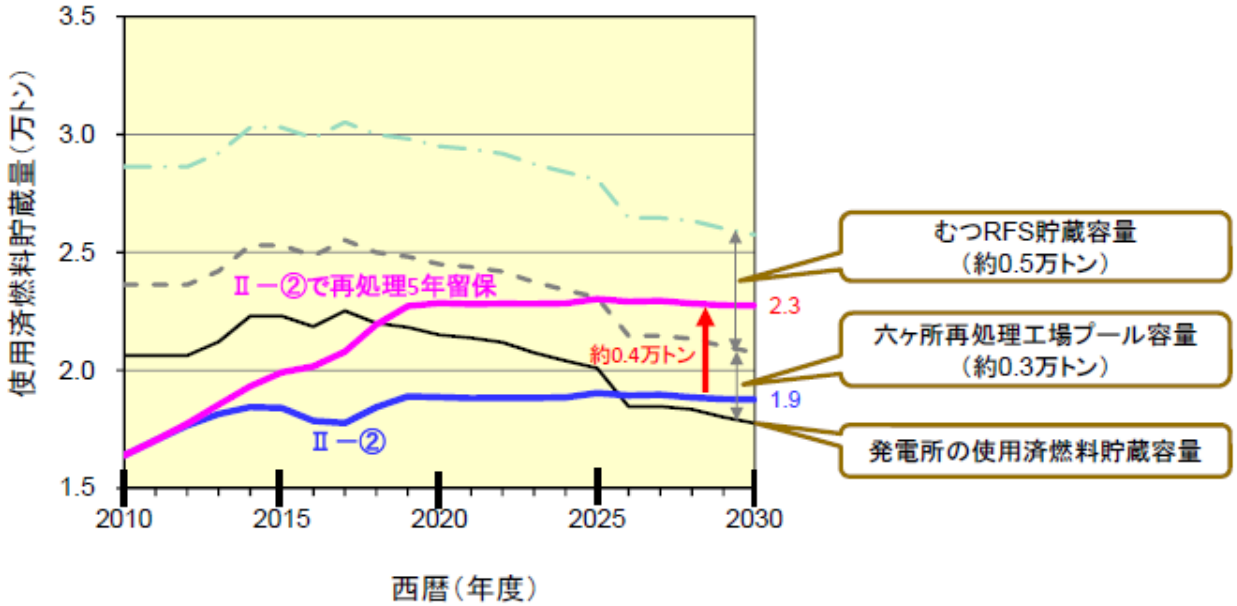




Source: Technical Subcommittee on Nuclear Power, and Nuclear Fuel Cycle,, AEC, March 28,2012

3(4) Options under discussion for the spend fuel management – Wait and See –

- Lower risk of selecting an unfavorable option due to large uncertainty
  - Prolonging discussions while collecting latest informations
  - Watching and pursuing as many technologies as possible
  - And after 5 years, decision making would be done.
- Concerns - Additional suspension of RRP

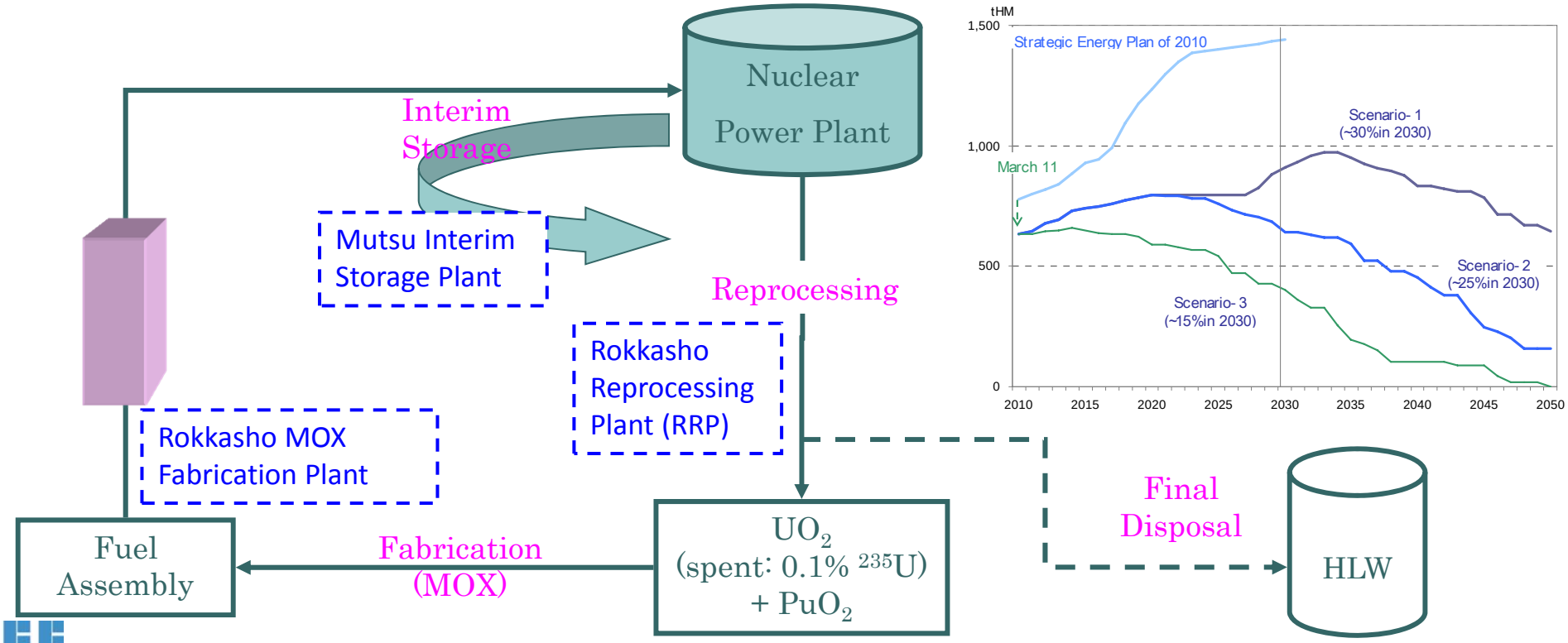


Source : Technical Subcommittee on nuclear power and fuel cycle, AEC, 12 April 2012

"Nothing is fixed for now" is a good political decision?

4. Summary and implications: How should we manage the spent fuels?

- Short term issues
  - Restarting the nuclear units
  - Proceeding the fuel cycle projects- RRP, Mutsu and MOX
  - Restructuring the fuel cycle options – reprocessing / direct disposal?
  - How should we cope with the “wait and see “ option?
- Mid-and long term issues
  - Restructuring of the energy policy and the power portfolio



Just for your information: Discussions on the energy portfolio in Japan

- Governmental committee, "Advisory Committee for Natural Resources and Energy" started in October 2011 and 18 meetings have been held so far.
- Some quantitative assumptions and scenarios have been proposed but nothing has been determined yet.
- In summer 2012, the revised version of the "Strategic Energy Plan of 2010" is to be released.

<Quote from our CEO, Mr.Toyoda's presentation>

There is no perfect energy which can replace nuclear energy. It is necessary to diversify energy sources and to promote technological development based on safety.

It is important to mix safer nuclear energy, cheaper renewable energy and cleaner fossil fuels (especially, natural gas and clean coal) and to promote energy conservation.

It is essential to internationally standardize the safety criteria and to share best practices through international cooperation for assuring the safety of nuclear energy and risk management.

"Only rich countries can afford discussions of phasing nuclear out".
By Mikola Azalov, Ukrainian Prime Minister, 15 March 2011
-> Can Japan afford expensive alternatives or not?

Thank you
Vielen Dank
terima kasih banyak
非常感谢
정말 감사합니다
Tack så mycket