Japan's Nuclear Energy Development

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Commissioner, Atomic Energy Commission

Outline

- ✓ **Historical evolution of Nuclear Energy Programme in JAPAN**

Current key challenges

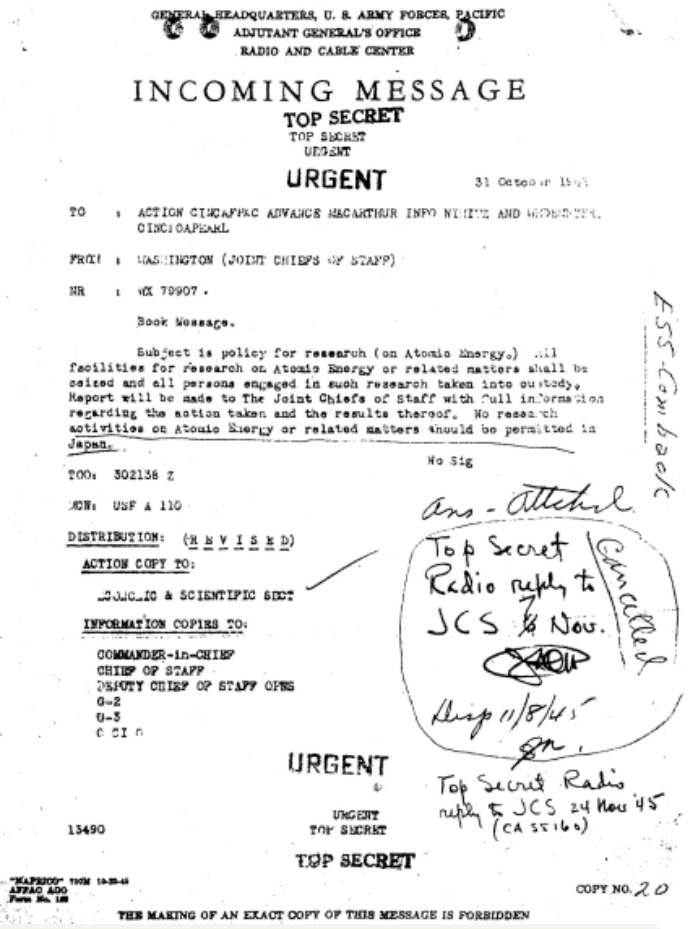
Government and Nuclear Energy

Concluding remarks

Early days programme

1. Post World War II era

- "All facilities for research of Atomic Energy or related matters shall be seized and all persons engaged in such research taken into custody" (Incoming message from Washington DC to GHQ Tokyo, dated 31Oct1945)
- Consequently, cyclotrons in RIKEN (Physics and Chemistry Lab) and universities were destroyed and dumped into lake or Pacific Ocean immediately by GHQ.



GENERAL HEADQUARTERS, U. S. ARMY FORCES, PACIFIC
ADJUTANT GENERAL'S OFFICE
RADIO AND CABLE CENTER

INCOMING MESSAGE

TOP SECRET
TOP SECRET
URGENT

URGENT 31 October 1945

TO : ACTION CINCAFPAC ADVANCE MACARTHUR INFO WHITE AND MIDDLETON, CINCPOAPEARL

FROM : WASHINGTON (JOINT CHIEFS OF STAFF)

NR : WX 79907 .

Book Message.

Subject is policy for research (on Atomic Energy.) All facilities for research on Atomic Energy or related matters shall be seized and all persons engaged in such research taken into custody. Report will be made to The Joint Chiefs of Staff with full information regarding the action taken and the results thereof. No research activities on Atomic Energy or related matters should be permitted in Japan.

No Sig

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ans - Attchd Top Secret Radio reply to JCS 6 Nov. Cancelled Disp 11/8/45

URGENT

Top Secret Radio reply to JCS 24 Nov '45 (CA 55160)

13490

URGENT
TOP SECRET

TOP SECRET

COPY NO. 20

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

PROFESSOR NISHINA PLEADS for his equipment. "This is ten years of my life," he said. "It has nothing to do with bombs." His wife and secretary wept quietly.

Riken cyclotron dumped into ocean *[source] LIFE magazine (24December 1945)*

2. “Atoms for Peace” address at the GA of the UN, 8December1953

“That new language is the language of atomic welfare”

“…..The United States would seek more than the mere reduction or elimination of atomic materials for military purposes. …..”

“…make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic energy agency. “

2. Early days of Nuclear Energy in Japan

1954: Nuclear research budget JPY235 million (appropriation by the Diet)

1955: 1) Atomic Energy Basic Law
- Strictly for peaceful purpose
- "For the *welfare of human kind* and to *raise national living standards*"
- Three principles – democratic decision-making, independent management, and transparency

2) US-J Nuclear Cooperation agreement put into force

1956: Joined the IAEA and established national organs for nuclear energy (NE)

1) Atomic Energy Commission (1956Jan4-)

2) Science and technology agency (Government)

3) Japan Atomic Energy Research Institute (JAERI) and The Atomic Fuel Corporation

1957: JAERI's Japan Research Reactor unit-1 (JRR-1) reached first criticality

1963: First electricity by JPDR (JAERI's Power Demonstration Reactor, 12.5 MWe BWR)

JRR-1

Atomic Energy Commission

- To plan, deliberate and decide on basic NE policy
- Immediate deliverable:
  Long-term Plan for R&D and Utilization of NE

1st Long-term Plan for R&D and Utilization of NE (1956)

- Reliance on domestic uranium resources, while import deficit from outside
- Atomic Fuel Cooperation as a sole reprocessor using indigenous technology
- Research into indigenous enrichment technology
- Domestic fast breeder as a target in light of effective use of resources
- Several NPPs from overseas then domestic production

Nuclear Power

Early commercial nuclear power plants

1966: First NPP in Japan – TOKAI NPP (GCR, 166MW)

1970: TSURUGA unit 1 (1st BWR, 357MW)

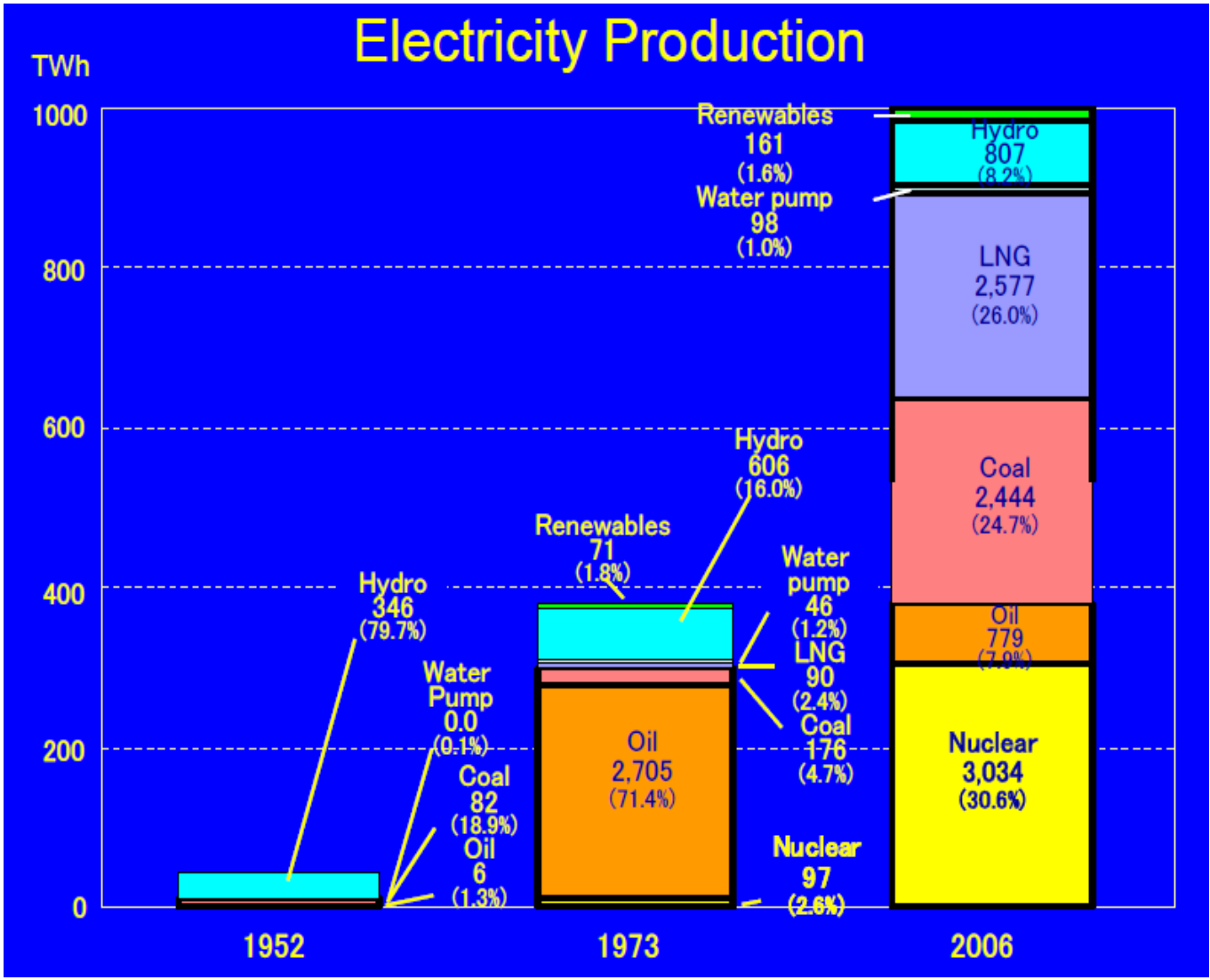
1970: MIHAMA unit 1 (1st PWR, 340MW)

Subsequent deployment of commercial nuclear power plants

• To meet growing electricity demand associated with the economic growth

•5 decades of continuous Deployment

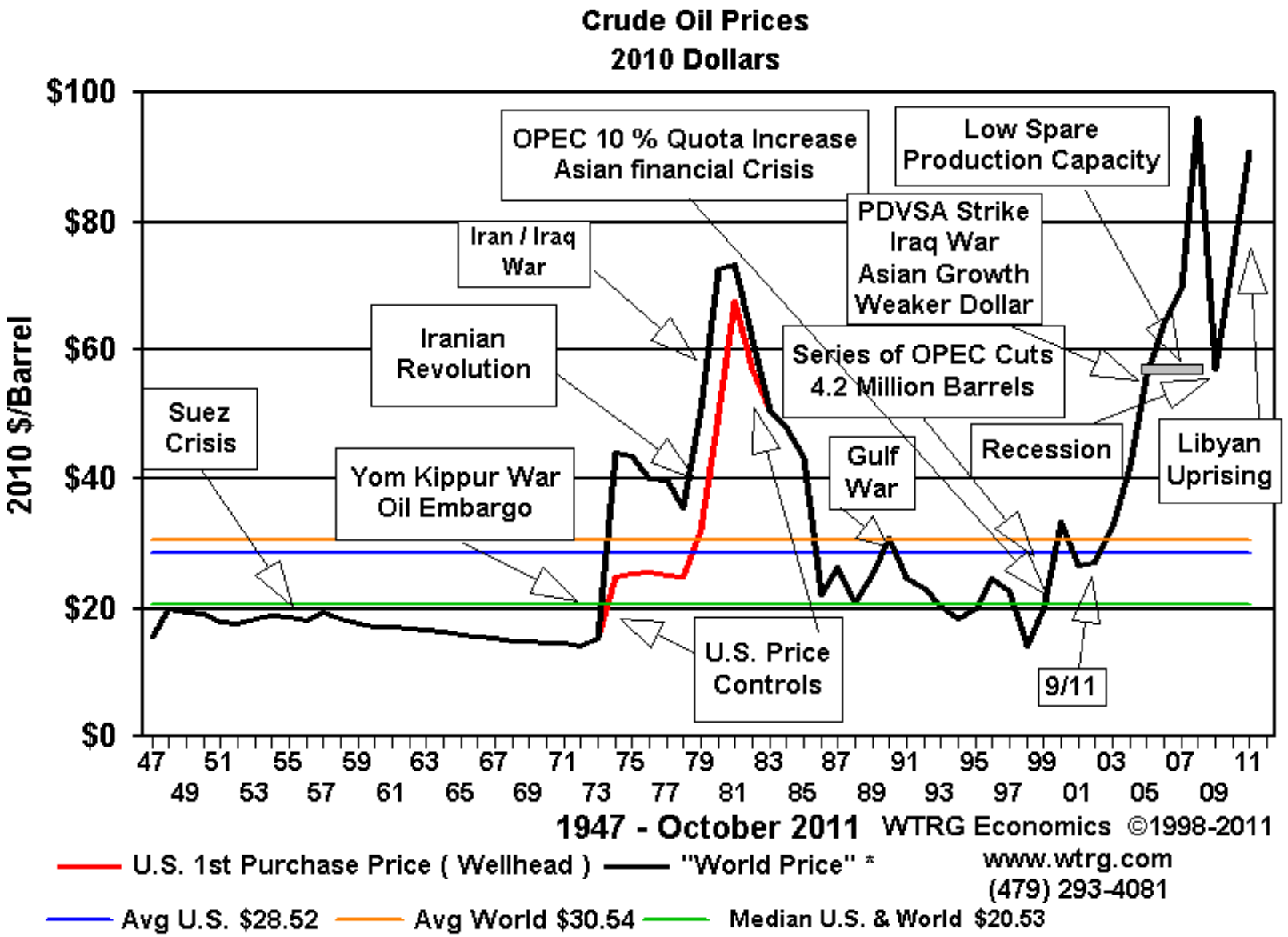
•54 units installed in1970-2010
  28 BWRs
  26 PWRs
(30% share in electricity)



500kwhr/capita-year 3500 7800

Crude oil price fluctuation

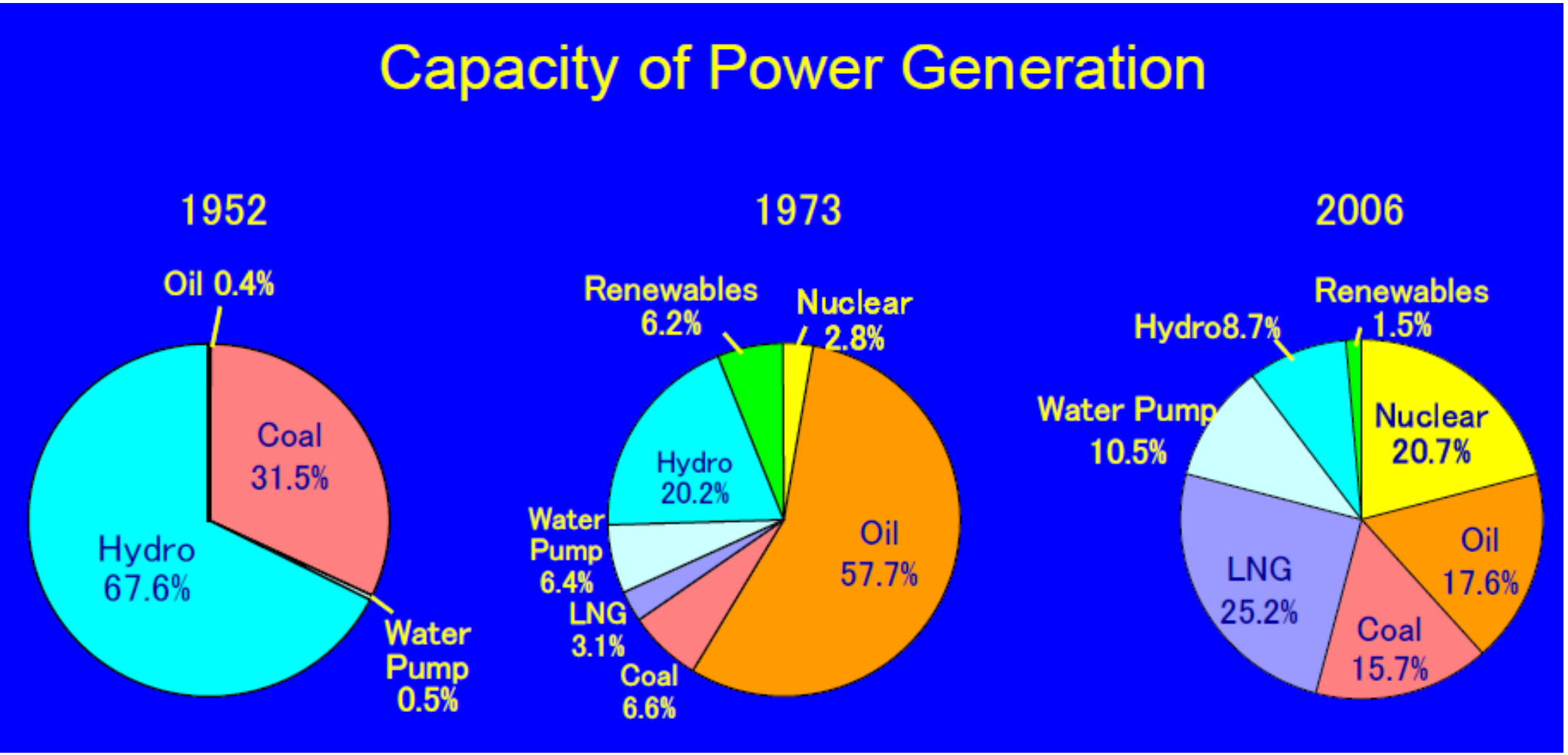
[SOURCE] http://www.wtrg.com/prices.htm



Intended

a) To diversify energy supply (NE: quasi-domestic), and

b) To avoid environmental issues associated with fossil



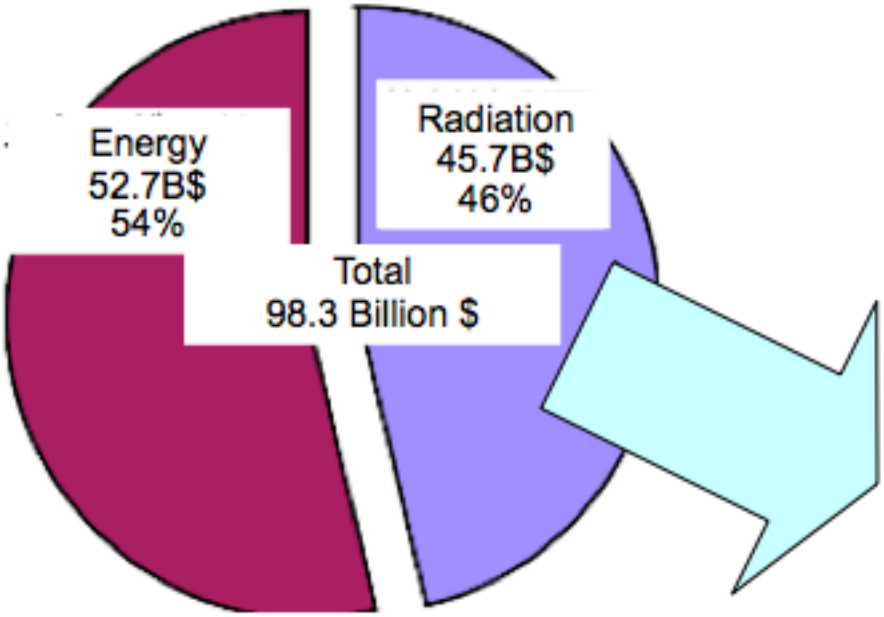
Nuclear Applications

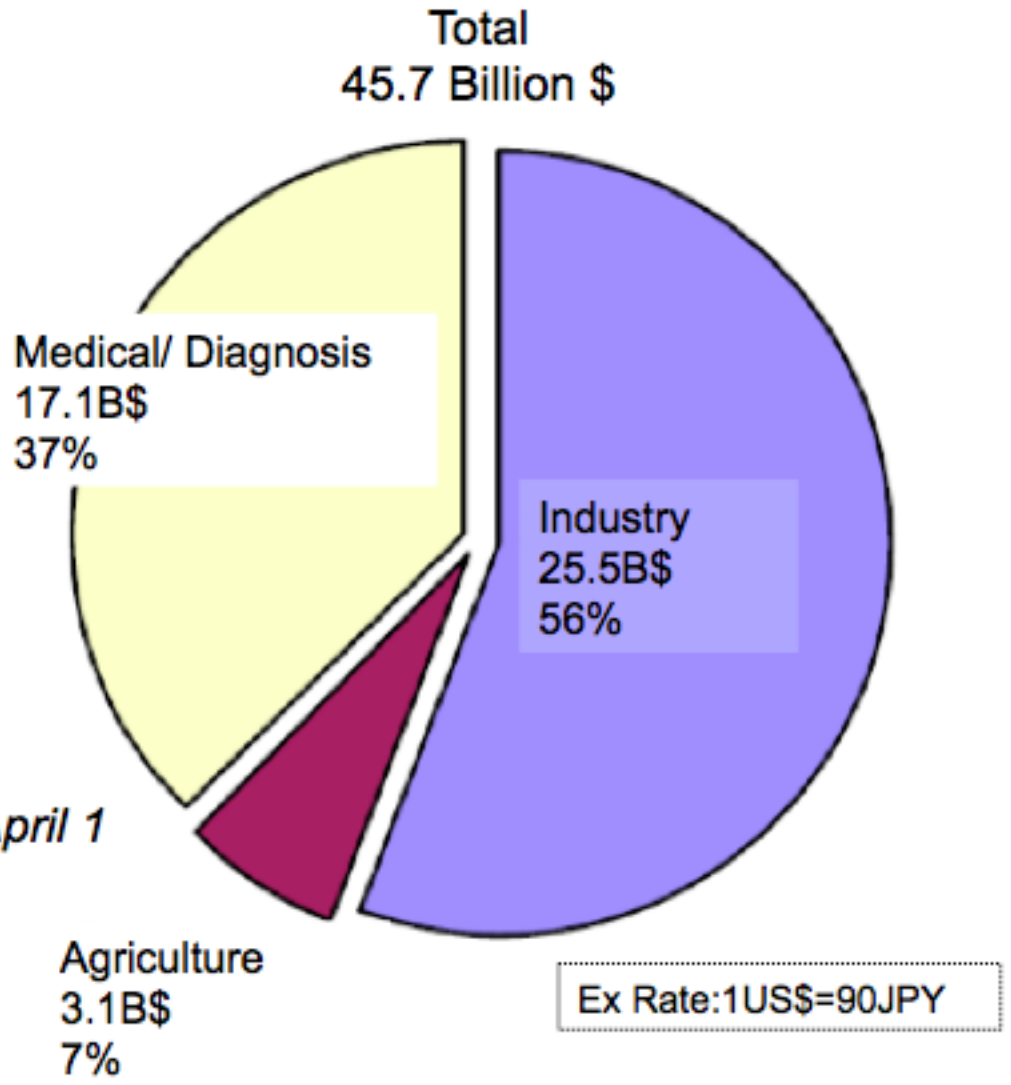
- **AEC regarded nuclear applications equally important "for the welfare of human kind and to raise national living standards" from the beginning**

- **Nuclear applications by research Laboratories**

  - ✓ **Radiation-related research institute in JAERI was established later than reactor laboratory established in 1963 (7 years later than reactor laboratory)**

Economic Impact of the use of NE





SOURCE: Report to AEC by JAEA, 2008 April 1

Nuclear applications for developing countries (FNCA Activities)

Cancer diagnosis & therapy
Use of radiation for bio-organic fertilizer and for plant growth promoter in agriculture
etc

Agriculture

Radiation induced mutation

Post- harvest control utilizing radiation

Non-irradiated Irradiated

Medicine

Diagnosis; PET-CT

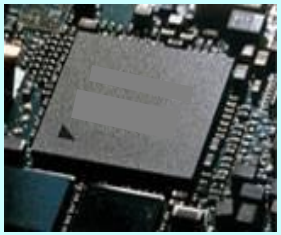
Therapy; Ion beam therapy

Industry

Radiation process;

Radial tires

Semiconductors



Non-destructive inspection

Fuel Cycle Programme

a) Start of commercial operation of Reprocessing Plant

b) Interim storage of SF beyond reprocessing capacity

JNFL Reprocessing plant

5,000 Tons Dry Storage at Mutsu
By TEPCO/JAPC, under construction since 2010 August

c) Use of MOX fuel in LWRs

- MOX in LWRs
  - Plan for use of MOX in 16-18 LWRs by 2015
  - 6 LWRs : licensed
- Domestic MOX fabrication plant (130 MT/YR)
  start construction 2010/Oct28
  start production 2016

MOX fabrication plant

Closed FC using FR for sustainable NP programme

2005 | 2010 | 2015

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

Fast Reactor Cycle Technology Development Project (FaCT)

Decision of Innovative Tech. (2010)

R&D of Innovative Technologies

Experimental FR "Joyo"

Conceptual Design of Commercial & Demonstration FR Cycle Facilities

R&D at Prototype FR "Monju "

R&D at "Monju "

- **Demonstrating its Reliability as a Operation Power Plant**
- **Establish Sodium Handling Technology**

Omoto, IAEA NMS, 2012June

2015

Conceptual Design

2025

Start of operation of Demonstration FR (& Fuel Cycle Facility)

2050

Commercial FR and Fuel Cycle Facilities

Geological disposal of vitrified HLW

1985- 1999: Feasibility study of geological disposal of HLW in Japan

- ✓ JAEA (JNC at that time) report on the technical feasibility of geological disposal of HLW in Japan.

2000: AEC decision on open and transparent policy

- ✓ Open application from municipality
- ✓ Nuclear Waste Management Organization (NUMO) for siting, construction and operation of the geologic repository

2002- : Two underground research laboratories

2004-Now: No mayor had successfully applied: Even the announcement of a mayor to study the merit and demerit of the application met public protest and intense media attention.

General plan: Selection of disposal site around mid 2020's
Start disposal in late 2030's

Historical evolution of Nuclear Energy Programme in JAPAN

✓ **Current key challenges**

Government and Nuclear Energy

Concluding remarks

3.11 has completely changed “nuclear landscape”

Key challenges

- **Environmental remediation, return of /compensation to evacuees**
- **Reform of nuclear regulation**
- **Revisiting basic nuclear energy policy**

AEC's Framework of NE policy is being updated

- *Cabinet's Energy and Environment Committee*
- *METI's Integrated Energy Committee*
- *AEC's committee on the "Framework of NE Policy"*

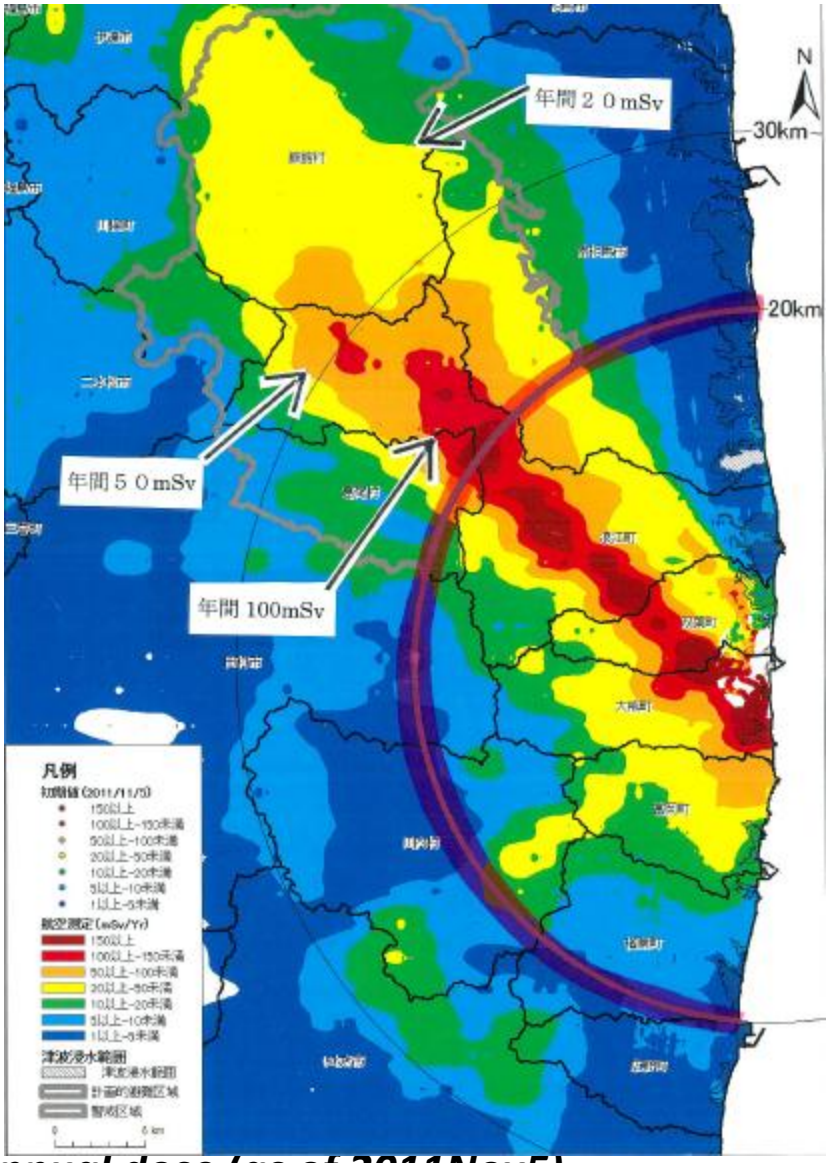
New zoning after April2012

Announcement by the Nuclear Emergency Response Headquarters to change zoning (26December2011) after achieving Step II goal at Fukushima NPP

1. To prepare lifting “evacuation” order for areas <20mSv/a by March 2012: Green and Blue zone within 20km radius
   (decontamination and rebuilding infrastructure)

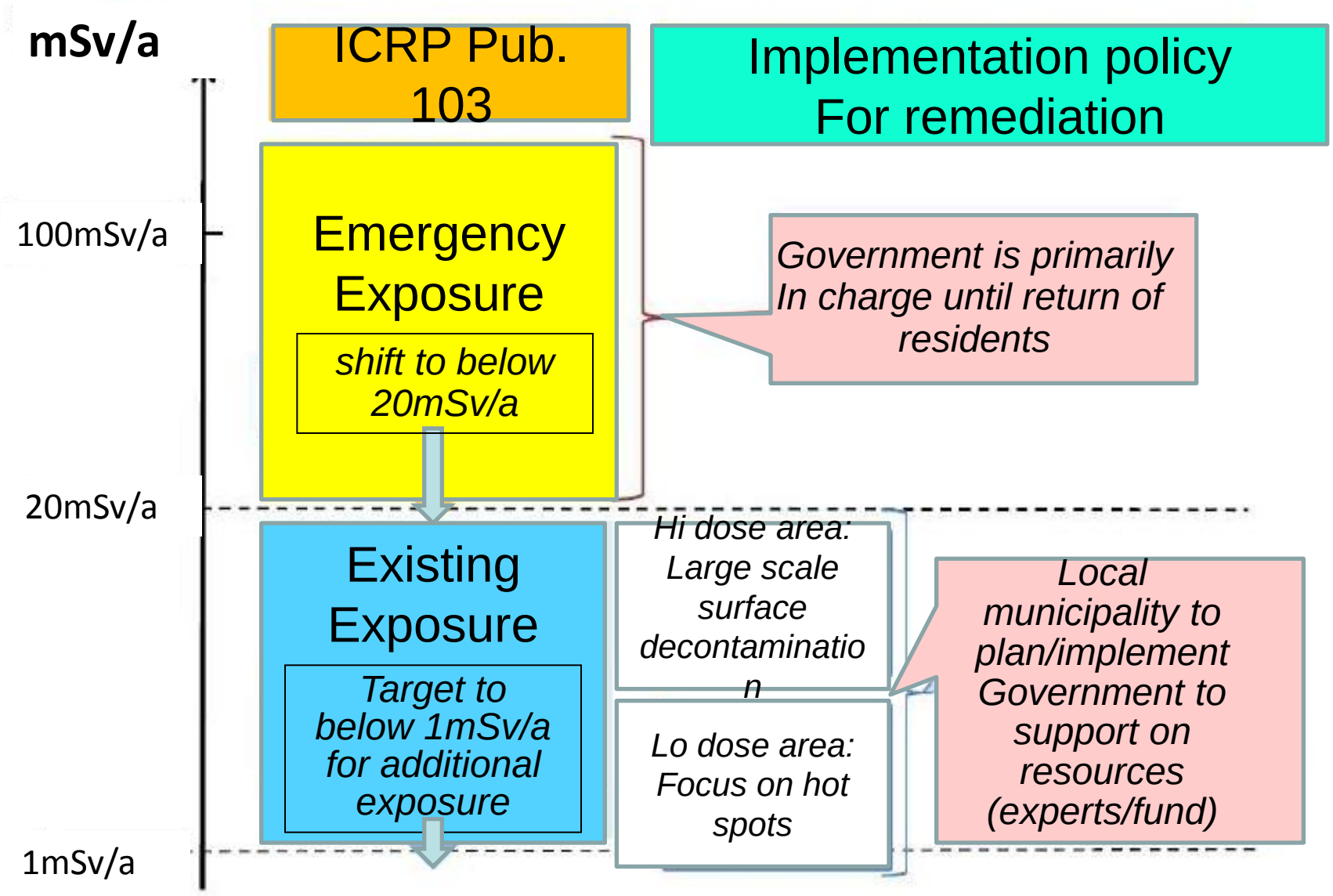
2. Continued off-limit for areas between above 20 but below 50 mSv/a: Yellow area, but shift to the above 1 after decontamination
   (decontamination)

2. Designate “areas difficult to return”: above 50mSv/a, applicable for 5 years: Brown and Red
   (consultation for relocation etc)



Predicted annual dose (as of 2011Nov5)

[SOURCE] http://www.meti.go.jp/earthquake/nuclear/pdf/111226_01a.pdf



[SOURE] http://www.meti.go.jp/press/2011/08/20110826001/20110826001-4.pdf

Emerged policy issues in the use of NE in Japan

- **Is nuclear energy a dependable source of energy?**

Issues includes: risk management, vulnerability of multiple unit installation, economics, liability

- **Is current fuel cycle policy appropriate?**

Issues includes: reprocessing plant, Spent Fuel management, development of fast reactor

- **Is current utility business regulation appropriate?**

- Cabinet's Energy and Environment Committee
- METI's Integrated Energy Committee
- AEC's committee on the "Framework of NE Policy": AEC's Framework of NE policy is being updated

Further, concern could include….

- Is nuclear energy ethical?
- Is nuclear energy acceptable in the light of "precautional principle(s)"?
- Given the sea of epistemic uncertainties, how can we make decisions on technological risks?
- What is the role of the Government (and AEC) in Nuclear Energy Programme?

for deliberation

- **Knowledgeable decision-making**
- **Safety as a pre-requisite: societal safety goal, for NE to be dependable**
  - ✓ *beyond acute/latent cancer risk, include liability, lost opportunities, energy replacement cost etc.*
- **What is the strategic target of energy policy and what is the role of NE in power generation portfolio?**
  - ✓ *Long-term goal of sustainable development: equity in time and space*
  - ✓ *Consideration of Japan's specific condition (geopolitics, resources availability, source of economic power…)*
  - ✓ *Energy supply security*
  - ✓ *Part of technological competence for growth*
  - ✓ *Low carbon economy*
- **Public consultation**

Brundtland report "Our Common Future" 1987

- Creation of a bridge to address possible strain
  - Economic development
  - Environmental protection
- Defined sustainable development

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

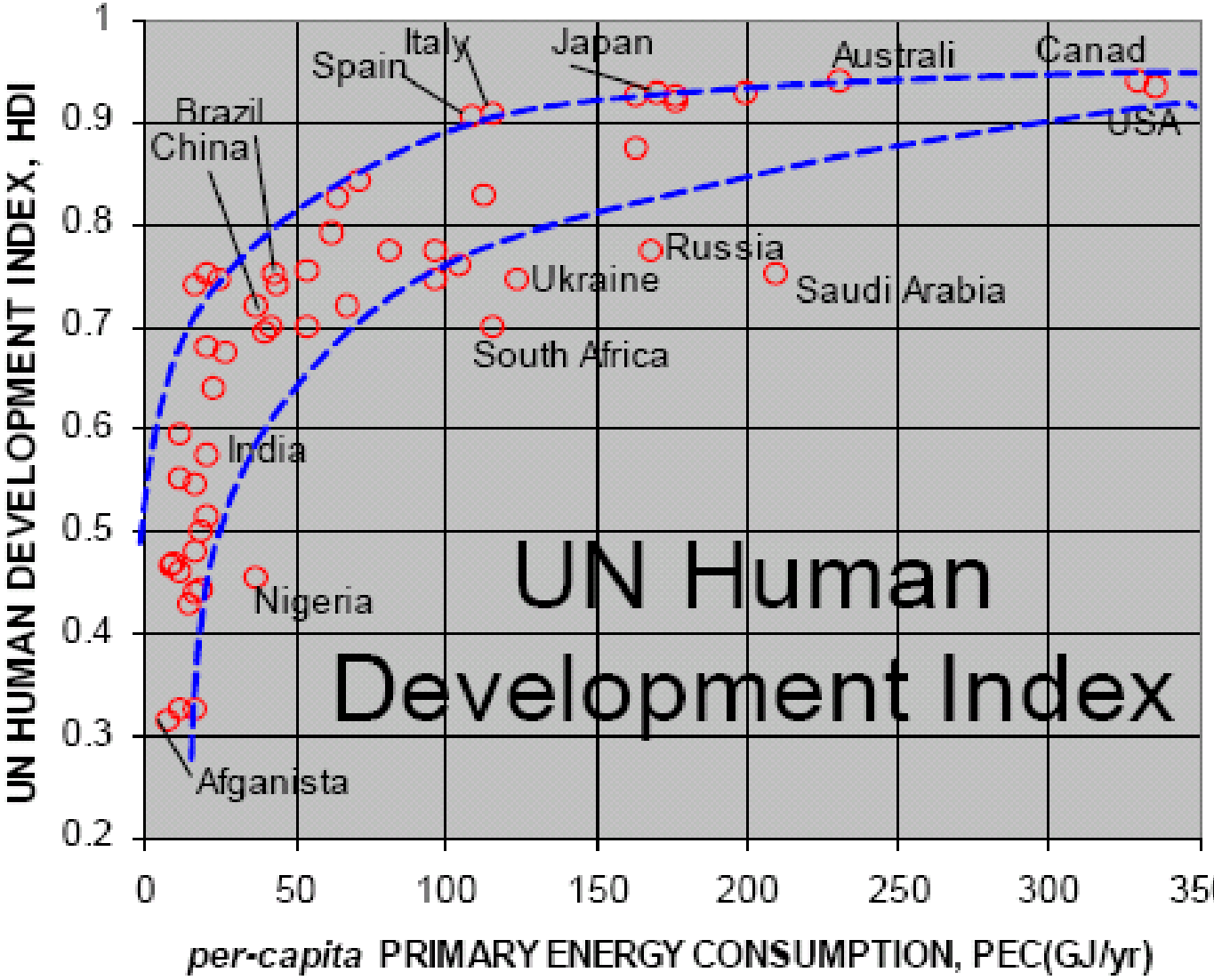
- Three dimensions

  Social / Economic / Environmental

- Recognized that achieving global *equity* (Within and across countries (space) as well as across generations (time)) and *sustainable growth* would require *technological and social changes*
- Energy area: goal to distance measured by using EISD

Inequity across countries

HDI and primary energy consumption

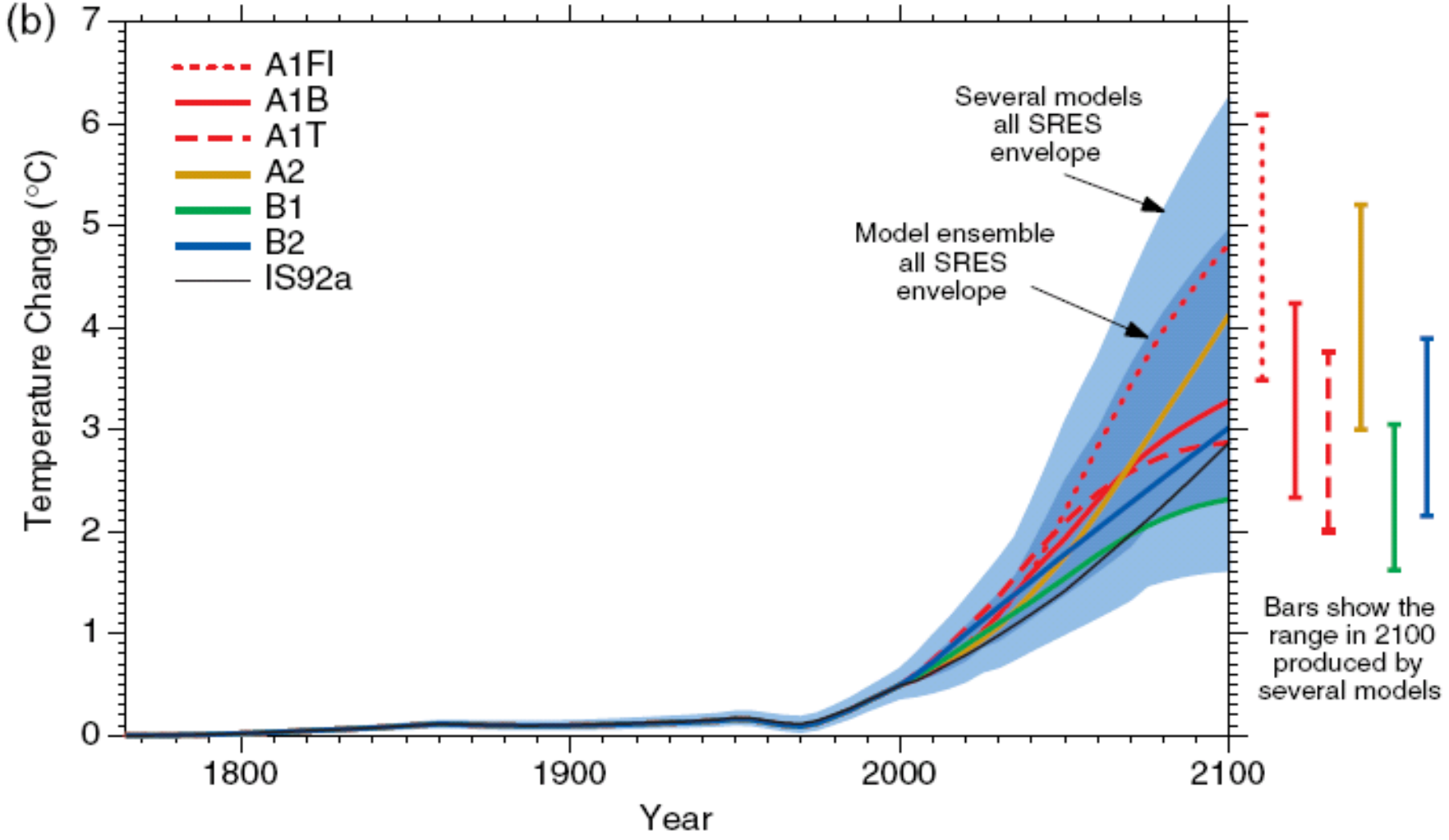


HDI
comparative measure of poverty, literary, education, life expectancy & others

[Source] UN Human Development Index report, UNDP, 2000

Inequity across generations

Projected range of temperature change
(SRES scenario, IPCC 2001)



Options of policy change and implications

- Current administration's policy: Decrease dependency on NE and increase renewable's share
- Share of nuclear electricity

	Nuclear	Renewables	Thermal	Co-generation	Energy saving	CO2 discharge (compared to 1990 level)	
Current	26%	11%	60%	3%	-	+6%	
Existing plan	45%	20%	27%	8%	-	-31%	
Option I	0%	35%	50%	15%	20%	-16%	*Phase-out*
Option II	15%	30%	40%	15%	20%	-20%	*Reduced*
Option III	20-25%	25-30%	35%	15%	20%	-23%	*Reduced & diversified*
Option IV	35%	25%	25%	15%	20%	-28%	*Maintain the same level*
Option V	Leave it to market decision						

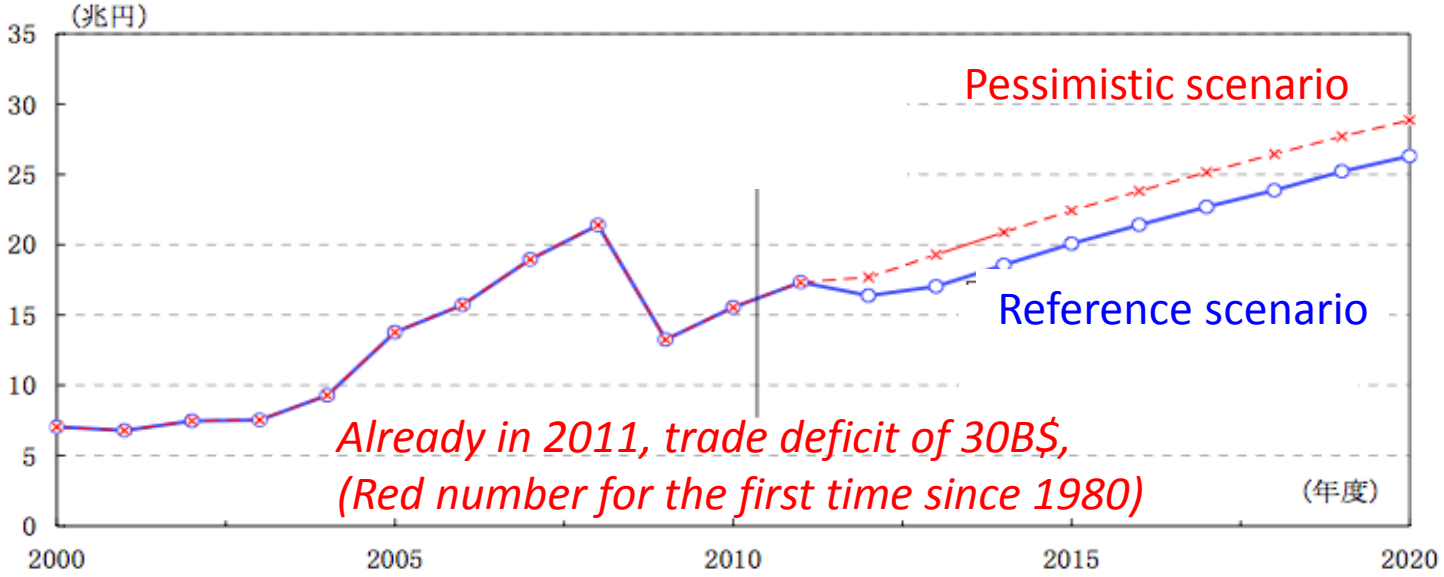
[SOURCE] http://www.enecho.meti.go.jp/info/committee/kihonmondai/25th/25-3-2.pdf

- **Implications**

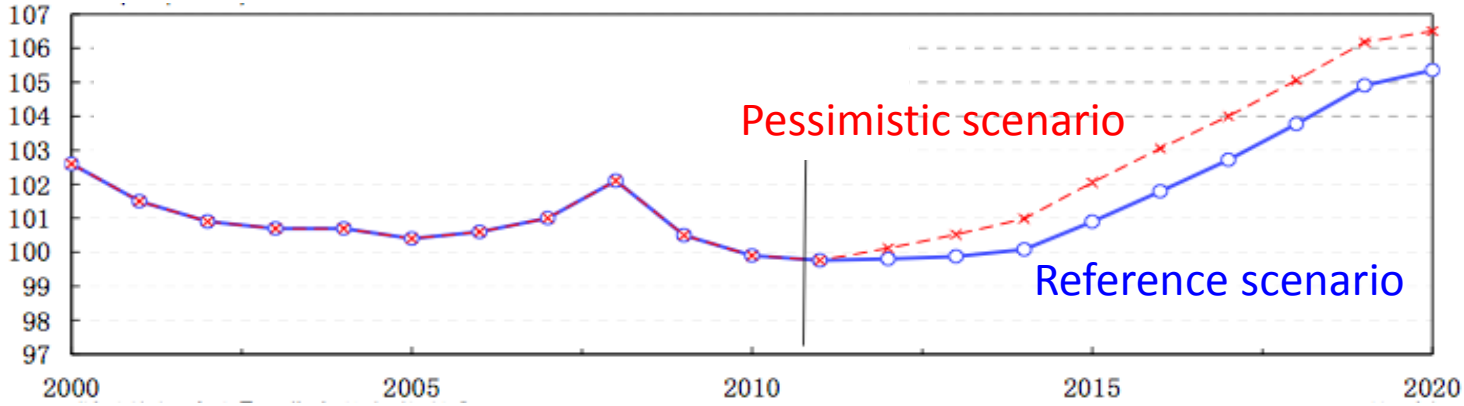
✓ *Low carbon economy*
✓ *Electricity demand and supply*
✓ *Electricity price and competitiveness of industrial products in global market*
✓ *Long-term sustainability w/o nuclear*

Impact of reduced dependence on NE [by JCER]

Yearly fossil import in 10B$ ($=100JPY)



Consumer's price index

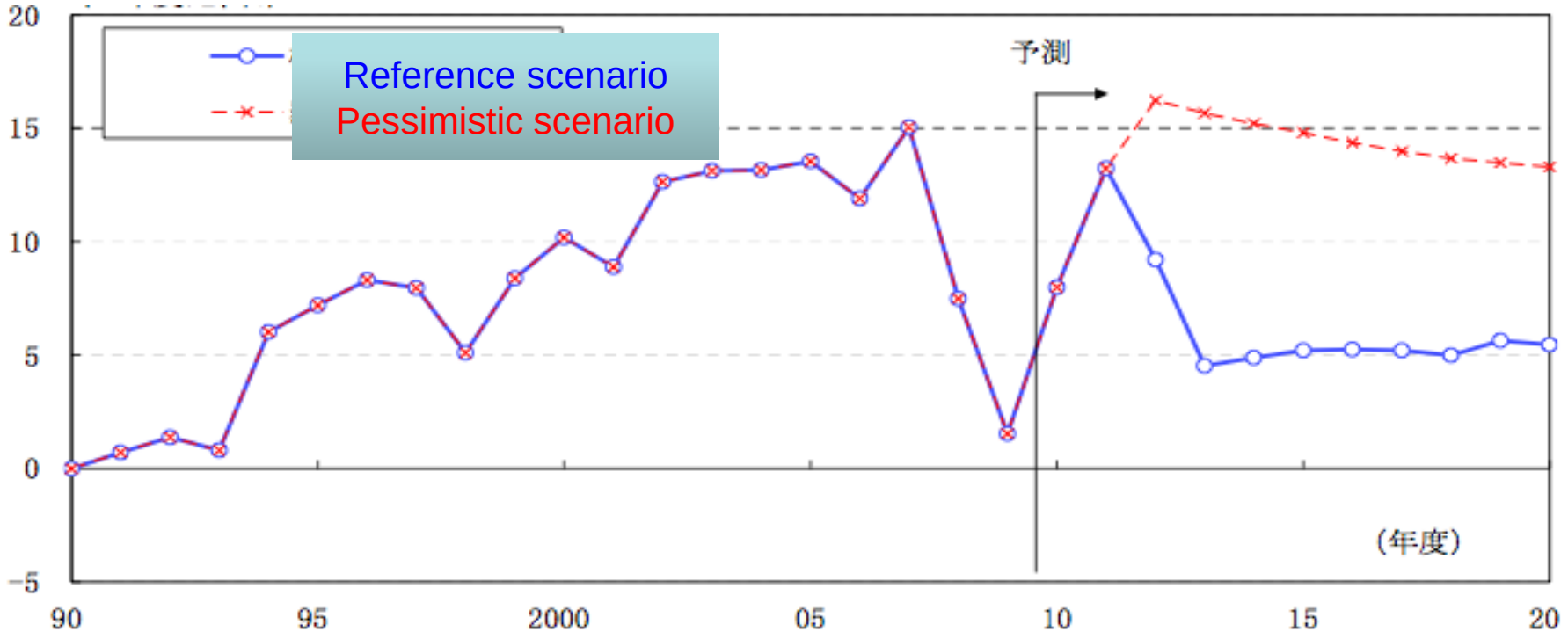


Reference scenario: No NPPs in TEPCO nor Chubu resume operation, while others operate until nuclear phase our by 2050

Pessimistic scenario: No NPP resume operation after 2012

[SOURCE] JCER (Japan Center for economic Research, 2011Dec)
http://www.jcer.or.jp/research/middle/detail4300.html

CO2 discharge [% increase from 1990]

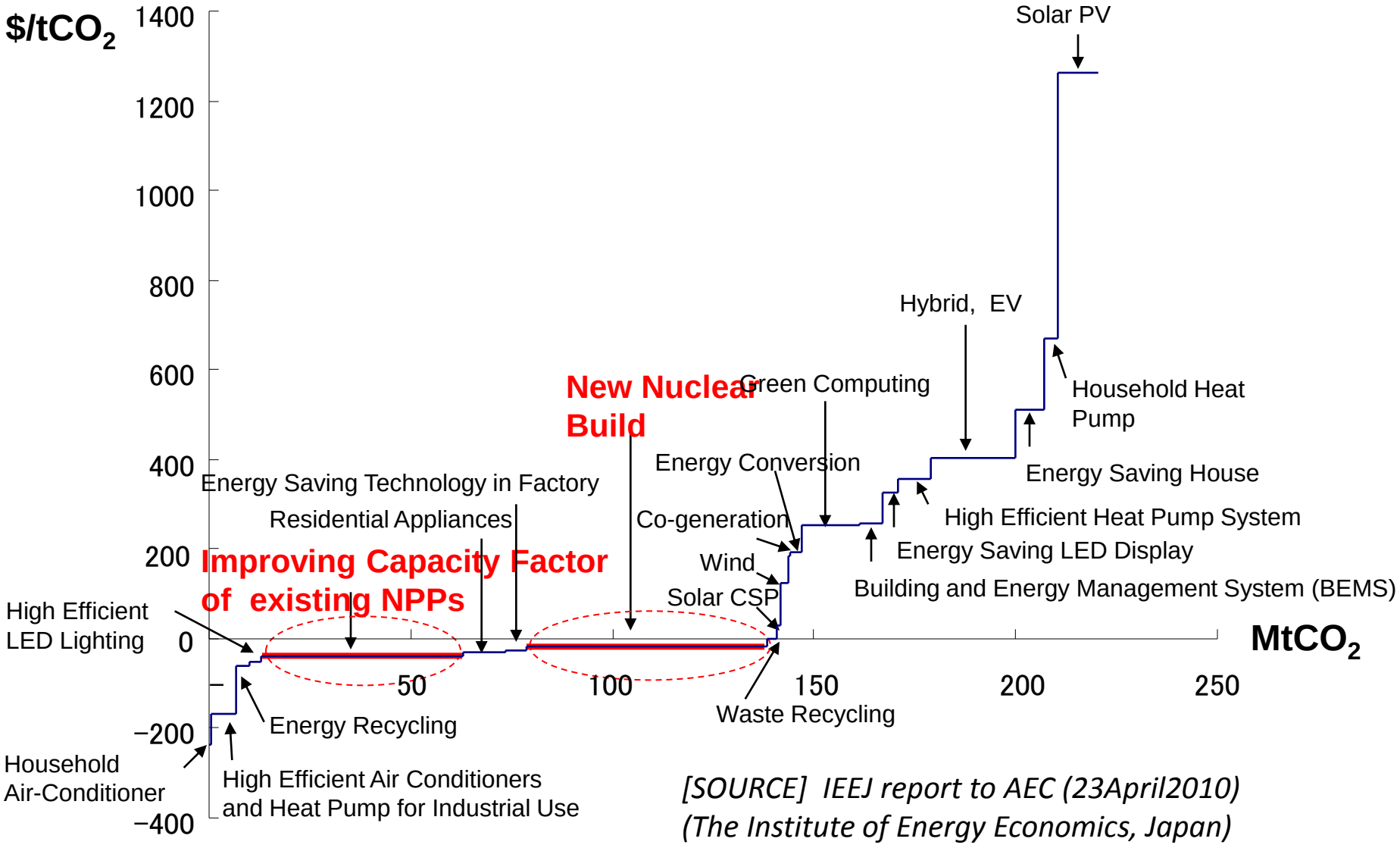


[SOURCE] JCER (Japan Center for economic Research, 2011Dec)
http://www.jcer.or.jp/research/middle/detail4300.html

NIES (National Institute of Environmental Studies) report (2012.4.12): 25% reduction of GHG release(from 1990 level) will be possible w/o NE, if renewables share increase from 9% (2010) to 34% and primary energy saving of 24% from 2010 level

Further, estimation by the IEEJ (Institute of Energy Economics Japan of the economic impact of nuclear phase-out → GDP loss : -3.6%, job loss : 200,000, accelerate manufacturing industry's shift to overseas

Marginal Abatement Cost curve in Japan

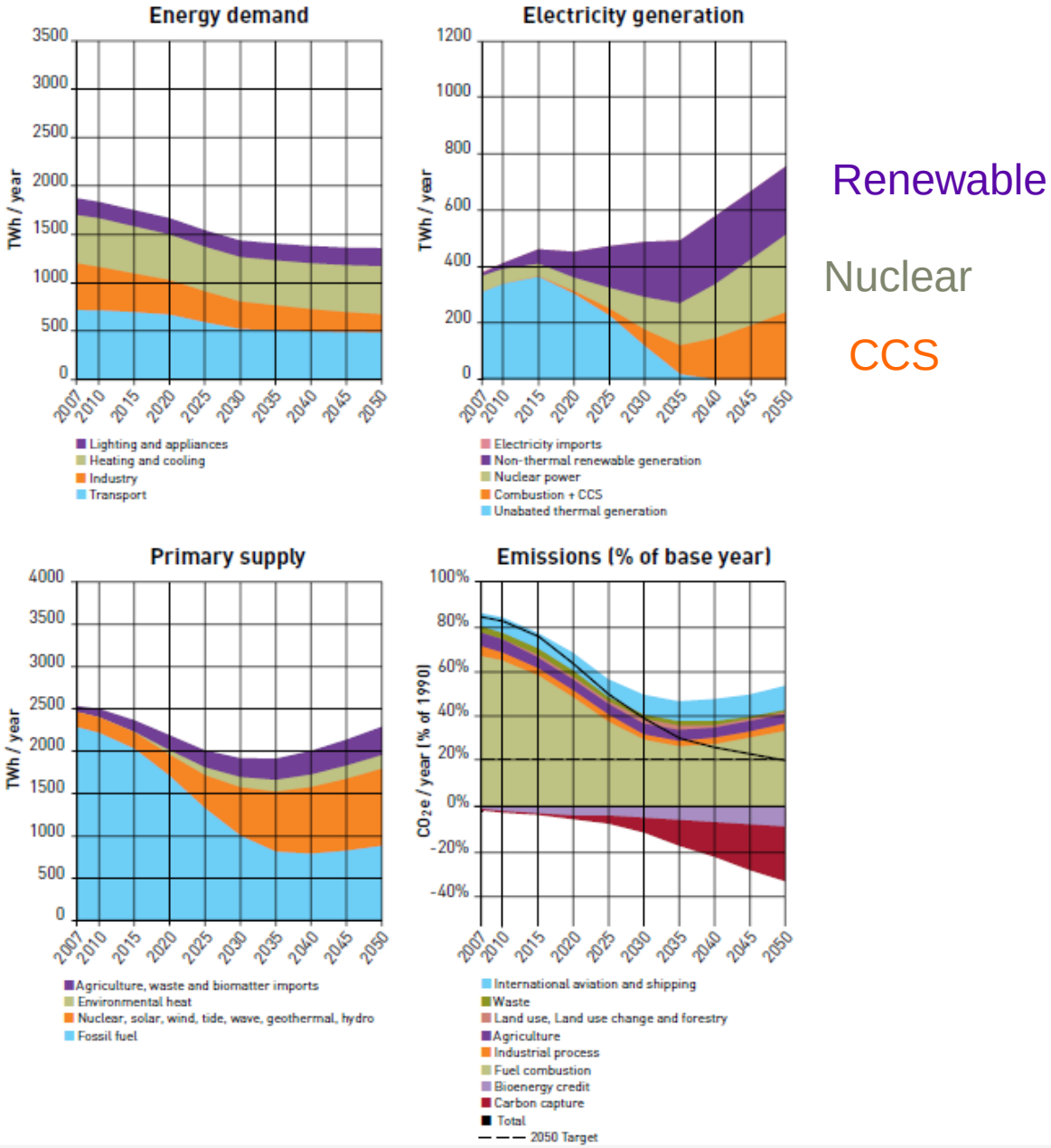


[SOURCE] IEEJ report to AEC (23April2010)
(The Institute of Energy Economics, Japan)

Examples of scenario analysis in other countries

(Case of UK)

One of the 6 cases of “2050 Pathways Analysis”
(July 2010)



Renewable

Nuclear

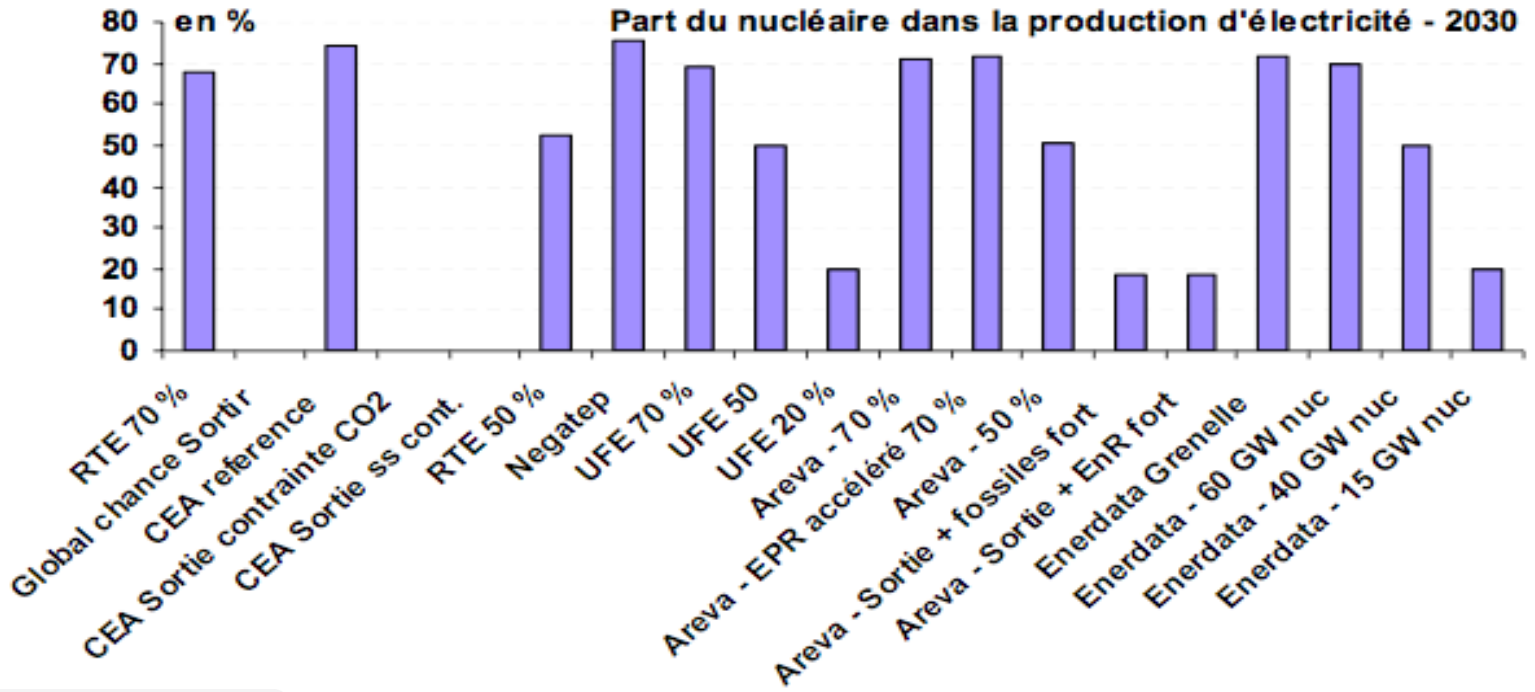
CCS

(Case of France)

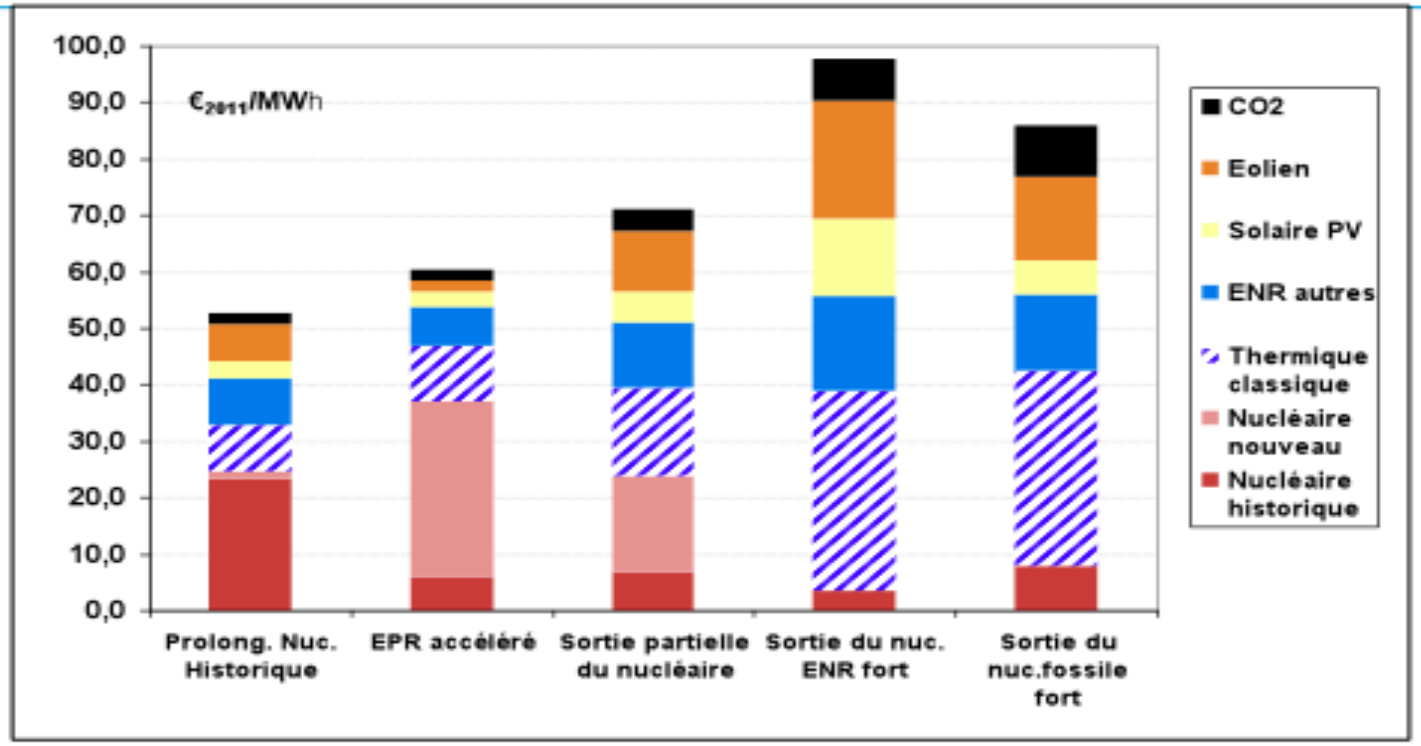
"Energie Rapport 2050" (Feb 2012) evaluated 4 options over electricity price, energy security, GHG reduction, job in 2030

① Replace to EPR or Gen-IV after 40 years operation of current fleet
② Plant life extention to 60 years
③ Reduced share of NE
④ Phase-out NE after 60 years of operation

Graphique 1 : Place du nucléaire dans la production d'électricité en 2030



Coûts complets de production en €/MWh de l'électricité HT en 2030 selon l'option (3/5)



Source : Energies 2050

Hors dépenses de réduction de la demande et hors coûts de réseau (raccordement et renforcement)
Incertitudes inhérentes à l'exercice : coût des EnR, du nucléaire, du gaz,…

RAPPORT énergies 2050

Lundi 13 février 2012

Historical evolution of Nuclear Energy Programme in JAPAN

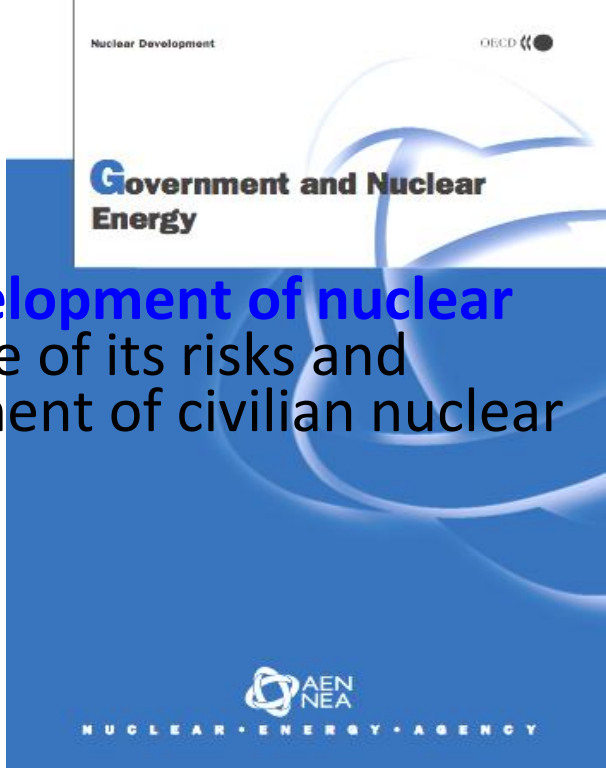
Current key challenges

✓ Government and Nuclear Energy

Concluding remarks

Role of the Government

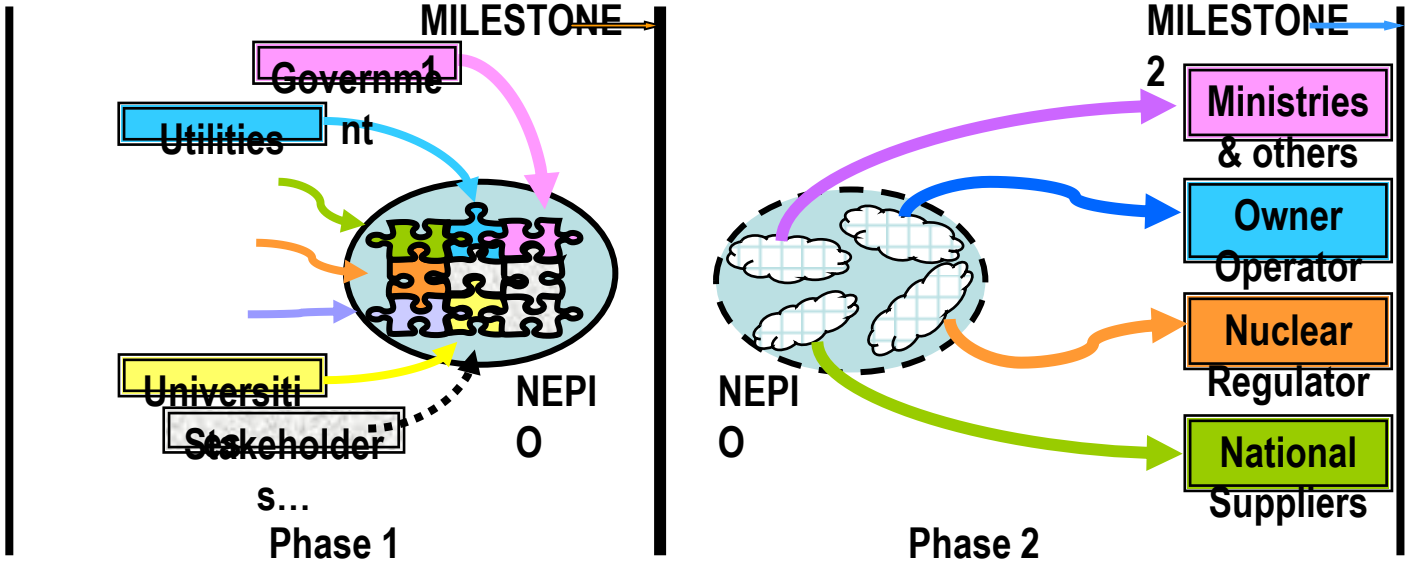
(1,2&3 below from "Government and Nuclear Energy", OECD, 2004)



1. Governments have been deeply involved in the development of nuclear energy….because of its strategic nature and the scope of its risks and benefits. Governments later supported the development of civilian nuclear energy.

- ✓ Localization programme
- ✓ Funding R&D

[EXAMPLE] NEPIO in the very early stage for coordination



IAEA "Responsibilities and Competencies of a Nuclear Energy Programme Implementing Organization (NEPIO) for a National Nuclear Power Programme"

Role of the Government

(1,2&3 below from "Government and Nuclear Energy", OECD, 2004)

2. In the 1980s and 90s:

- Governments came under pressure to cut expenditures and diminish their direct involvement in the economy.
- Expanding international trade forced all industries to be more competitive. Markets were championed as an alternative to government direction and regulation.
- Environmental protection and the concept of sustainable development increased in importance in policy making, whilst the need to ensure security of energy supplies persisted or even increased.

3. In the current era of privatization and competitive markets:

- Government still has an essential role in energy, electricity and NE
- While, in some countries, it may not exercise as much direct control through ownership and economic regulation as in the past, it still has the basic responsibility for creating policy frameworks within which market forces can function and public policy goals can be achieved.

An option could be leaving for the decision by the market, while assuring level playing field among different sources

(1)Assurance of recovery of investment

- Recovery in early stage
- Long-term power off-take

(2) Considering "external cost"

- External cost is internalized in nuclear, whereas not necessarily in other options
- Environmental cost of GHG emission
- Security credit

The case of Japan

a) AEC's long-term plan for NE
   - ✓ "Peaceful use" and "in accordance with the established programme"

b) Nuclear Power
   - ✓ Private business
   - ✓ Government support considering non-market value of NE

c) Fuel Cycle
   - ✓ Private business
   - ✓ Government endorsement statement to local government
   - ✓ Government support to development of FR cycle considering long-term sustainability

d) R&D:
   - ✓ Private sector investment >public sector (Japan in general)
   - ✓ Government support to nuclear R&D

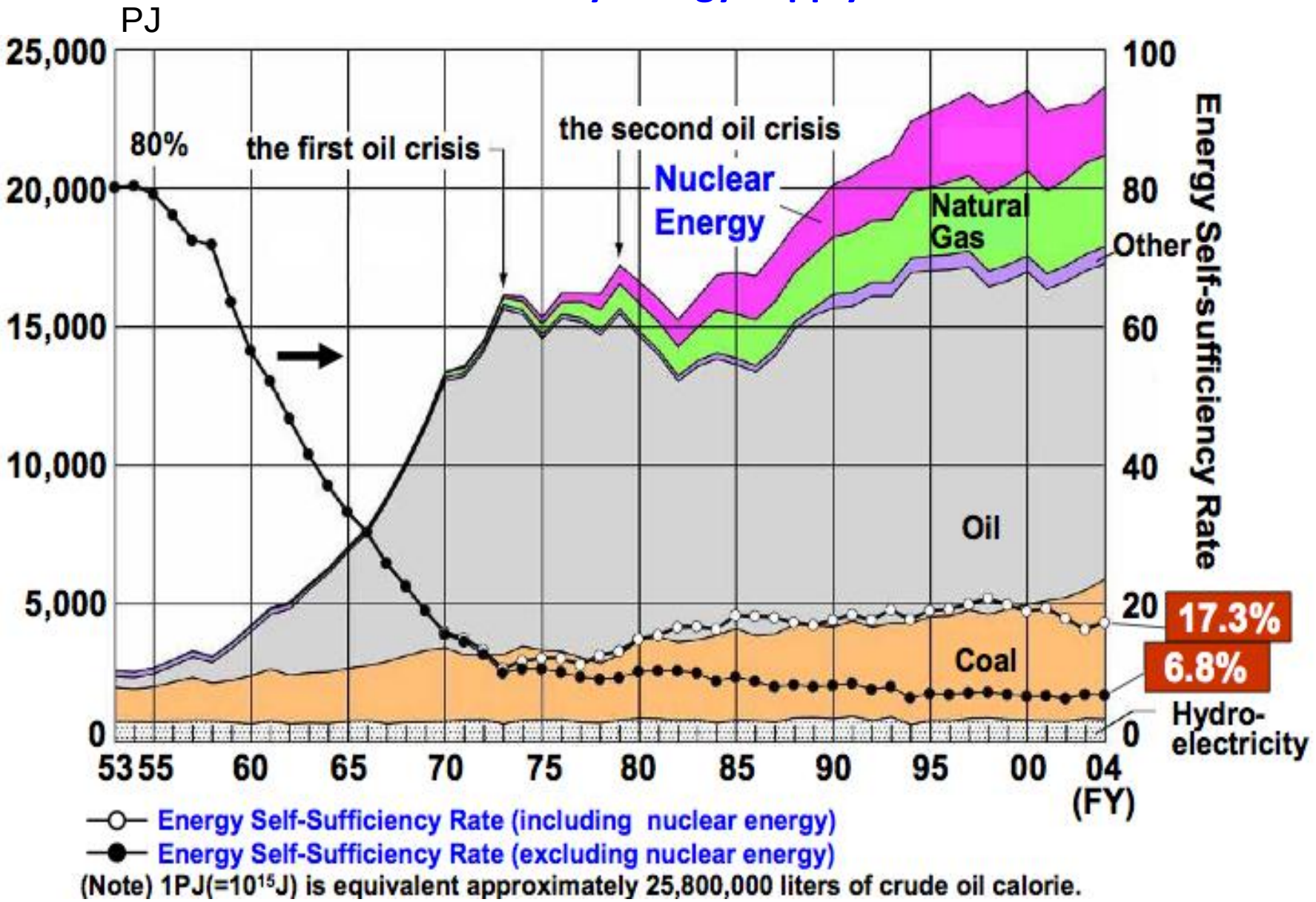
Japanese government assisted diversification of energy portfolio - Energy security and environment -

- As a resources-poor nation, considered Nuclear Energy as domestic (in the very beginning) or quasi-domestic energy source
- Accelerated deployment of NP after Arab Oil Embargo (1973)
  - ➢More than 70% of electricity generation : dependent on oil
  - ➢Immediately enacted laws to;
    - ✓Collect tax (0.375 JPY/KWhr) from electricity customers
    - ✓Used through special account

  a) to promote siting of nuclear facilities (preparation of local infrastructure including road, bridge etc)

  b) To accelerate development of power generation sources replacing oil

Primary Energy Supply



(Note) 1PJ(=10^{15}J) is equivalent approximately 25,800,000 liters of crude oil calorie.

[SOURCE] METI and S. Saito

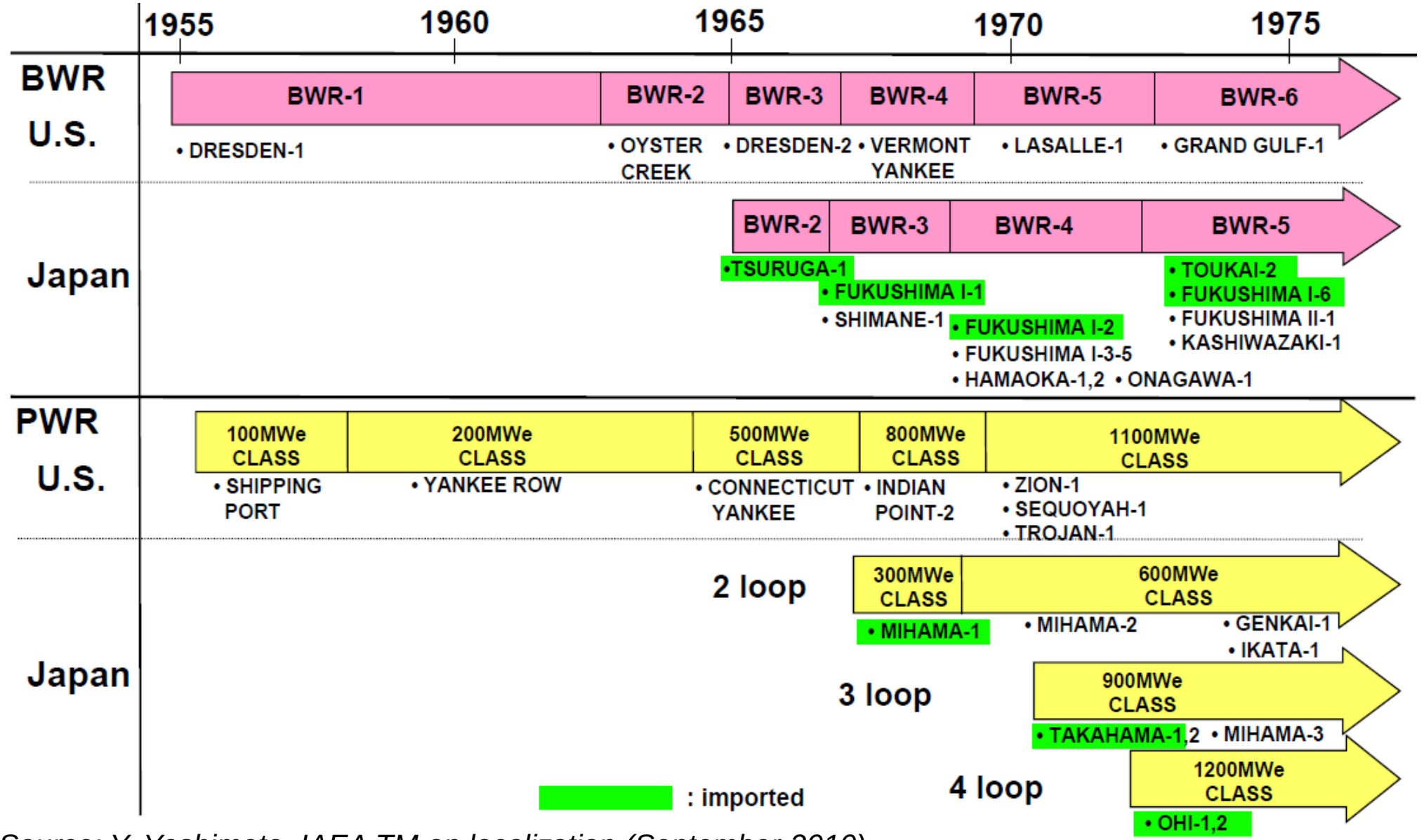
Government assisted localization

- First units of GCR, PWR, BWR (mid 1960s to early 1970s)
  - ✓ Design by UK/US reactor suppliers
  - ✓ Some components manufacturing and erection by Japanese companies

- 2nd units and subsequent units (until middle of 1970s)
  - ✓ T/H/M as primary contractor to Japanese Utilities
  - ✓ Rapid increase of local supply share

- Standardization & improvement Program (late 1970's to mid 1980's)
  - ✓ Modification of original design by NSSS suppliers /Utility (partly from Government funding)
  - ✓ Coping with technical problems arising from operation & maintenance
    - Material to reduce the probability of BWR IGSCC
    - Material & Design to avoid PWR SG tube degradation
    - Reduction of occupational radiation exposure and waste

- Next generation LWR and FR



Source: Y. Yoshimoto, IAEA TM on localization (September 2010)

BWR

Plant Name	Tsuruga-1 331 MWe	Fukushima-1 460 MWe	Fukushima-2 784 MWe	Shimane-1 460 MWe	Fukushima-3 784 MWe	
Owner	JAPC	TEPCO	TEPCO	Chugoku EPCO	TEPCO	
COD	1970.3	1971.3	1974.7	1974.3	1976.3	
Main Contractor	GE	GE	GE/Toshiba	Hitachi	Toshiba	
Fuel	I (Initial core)	I (Initial core)	D	D	D	I:Imported D:Domestic Product
RPV	D	D	D	D	D	
RIN	D	D	D	D	D	
Primary Piping	D	I(Partial)	D	D	I(Partial)	
PLR, Pump	I	I	I	I	I	
CR&CRD	I	I	I	I	I	
Nuetron Monitor	I	I	I	I	I(partial)	
PCV	D	D	D	D	D	
D Ratio	55%	56%	53%	93%	91%	

Source: Y. Yoshimoto, IAEA TM on localization (September 2010)

Plant Name	Mihama-1 340 MWe	Mihama-2 500 MWe	Takahama-1 826 MWe	Genkai-1 826 MWe	
Owner	KEPCO	KEPCO	KEPCO	Kyushu EPCO	
COD	1970.11	1972.7	1974.11	1975.10	
Main Contractor	WH/MAPI	MAPI	WH/Mitsubishi corp	MHI	
Fuel	I (Initial Core)	I (Initial Core)	I (Initial Core)	D	I:Imported D:Domestic Product
RPV	I	D	D	D	
RIN	I	I	I	D	
SG	I	D	I	D	
Primary Piping	I(Partial)	D	I	D	
Primary Pump	I	I	I	I	
Pressurizar	D	D	D	D	
CR&CRD	I	I	I	D	
PCV	D	D	D	D	
D Ratio	62%	76%	73%	95%	

Source: Y. Yoshimoto, IAEA TM on localization (September 2010)

Technology transfer agreement

TT Agreement (system license)

- MHI and WH on PWR system
- 1967 Hitachi and GE, Toshiba and GE on BWR system

Fuel fabrication

- 1967 Established JNF by GE/Hitachi/Toshiba
- 1971 Established MNF by WH/MHI

Industry trade group

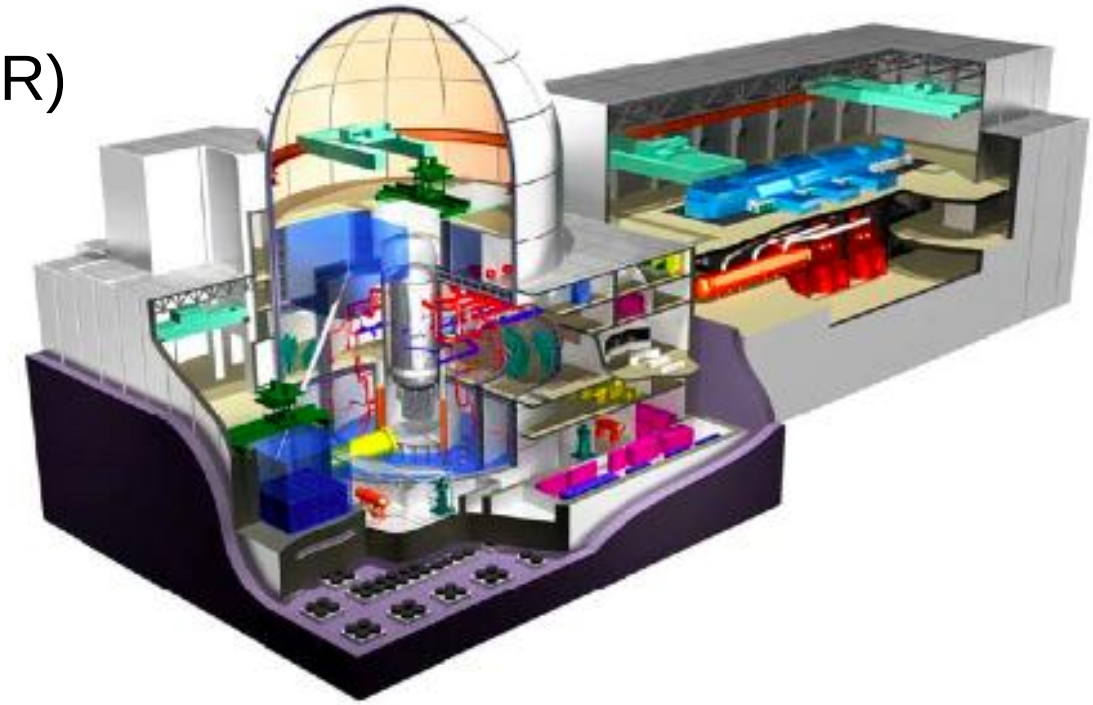
- 1956 Established JAIF (Japan Atomic Industry Forum)

Manufacturing standards

- 1963 ASME Boiler and Pressure Vessel code Section III (nuclear)
- 1970 Japanese manufacturing code/standard corresponding to ASME code

Development of next generation LWRs

- Meeting replacement demand in 2030's but make attractive technologies deployable in preceding LWRs as well in 2020's
- Meeting desired characteristics in terms of Safety & Security/ Economics/Waste/Environment etc. at a higher level
- Example of some technical features (BWR)
  - 180MWe and 90MWe class
  - K-lattice and large fuel (BWR)
  - Seismic isolation
  - Steel-framed concrete



Examples of spin-off technologies and methodologies from nuclear power to other applications in the industry

- Seismic response analysis and anti-seismic devices (anti-vibration dampers, seismic isolation technique etc)
- Disaster prevention and control
- Membrane in Off-gas system for medical use (artificial lung)
- Non-destructive inspection techniques (X-ray and neutron radiography, Ultrasonic, Acoustic, Gamma-ray spectrometry etc) and associated imaging techniques
- Remotely manipulated robotics and devices usable in harsh environment
- Decontamination and cleanup techniques
- Waste treatment techniques (such as solidification of sludge and ashes from incinerators, high efficiency filters)
  → High efficiency filter used in RO systems for desalination systems, spin-off from development of high efficiency condensate filtration system
- Laser techniques for separation, cutting, improvement of residual stress etc.
- Modeling and simulation techniques (fluid dynamics, thermal hydraulics, material and component behavior)
- Probabilistic safety analysis technique

Reference: Oka et al, Journal of Atomic Energy Society of Japan, VOL 39, No 2, 1997

Historical evolution of Nuclear Energy Programme in JAPAN

Current key challenges

Government and Nuclear Energy

✓ Concluding remarks

CONCLUDING REMARKS

1. Historically, Japan's NE programme had strong and stable commitment by the Government, Utility and Manufacturing industry
2. "Going to Nuclear" was justified
   - ✓ Diversified energy supply portfolio
   - ✓ Decreased dependency on fossil (environment, security, volatility of price)
   - ✓ Contribution to growth and power by science and technology
3. AEC's Long-term plan ("framework document", recently) served as a basis for the programmatic use of NE including R&D
4. 3.11 has completely changed this landscape
   - ✓ Is nuclear energy a dependable source of energy?
   - ✓ Is current fuel cycle policy appropriate?
   - ✓ What is the role of the Government in the planning and the use of NE?

Thank you for your attention