IFNEC, Keynote speech, November 15, 2018 Tokyo

Utilization of nuclear energy

Yoshiaki Oka

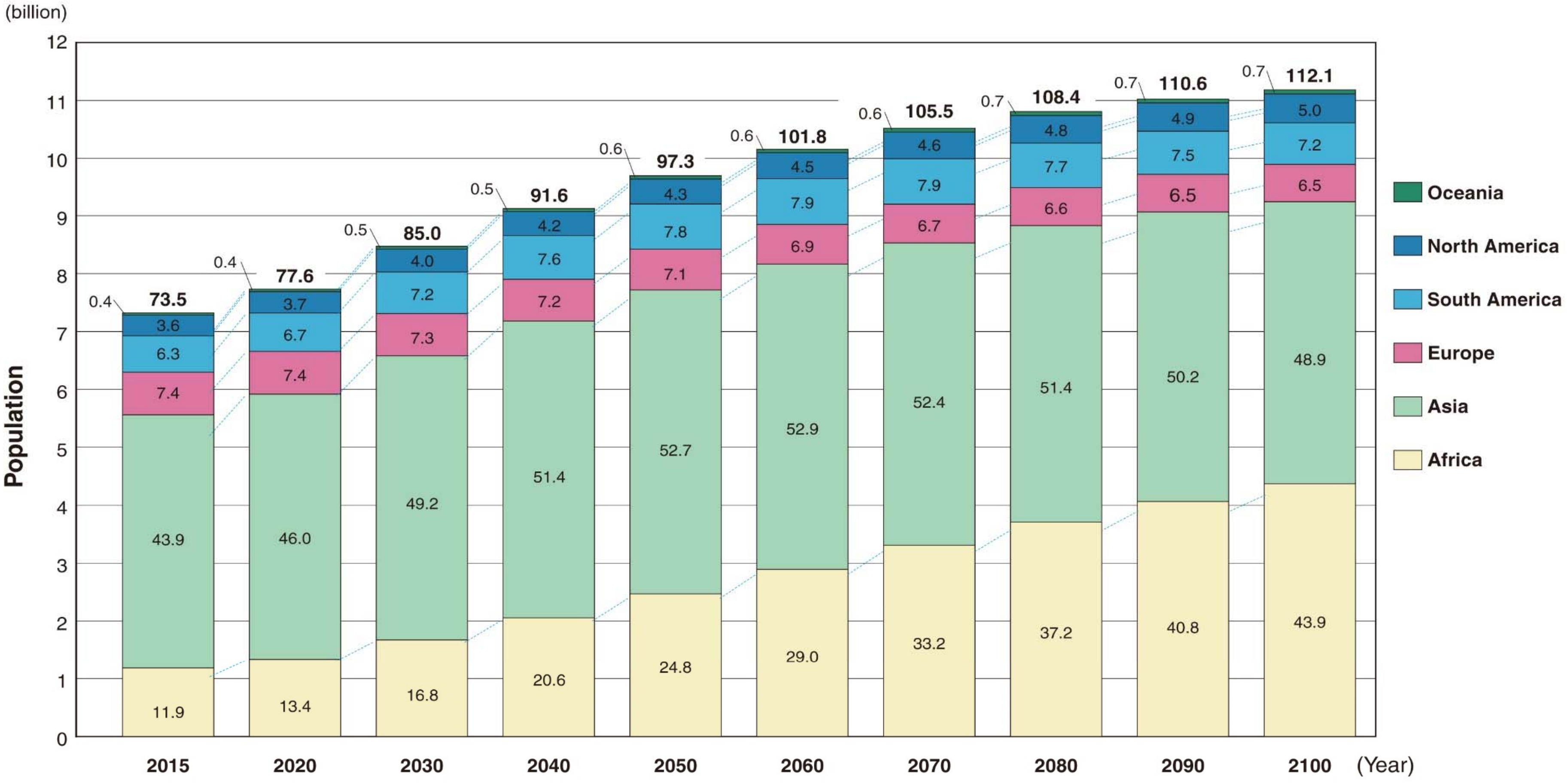
Chairman

Japan Atomic Energy Commission

Contents

- Energy and Environment
- Nuclear power reactors
- Advances in LWR technologies
- Nuclear utilization in Japan

World Population Projections



(Note) Figures may not add up to the totals due to rounding.

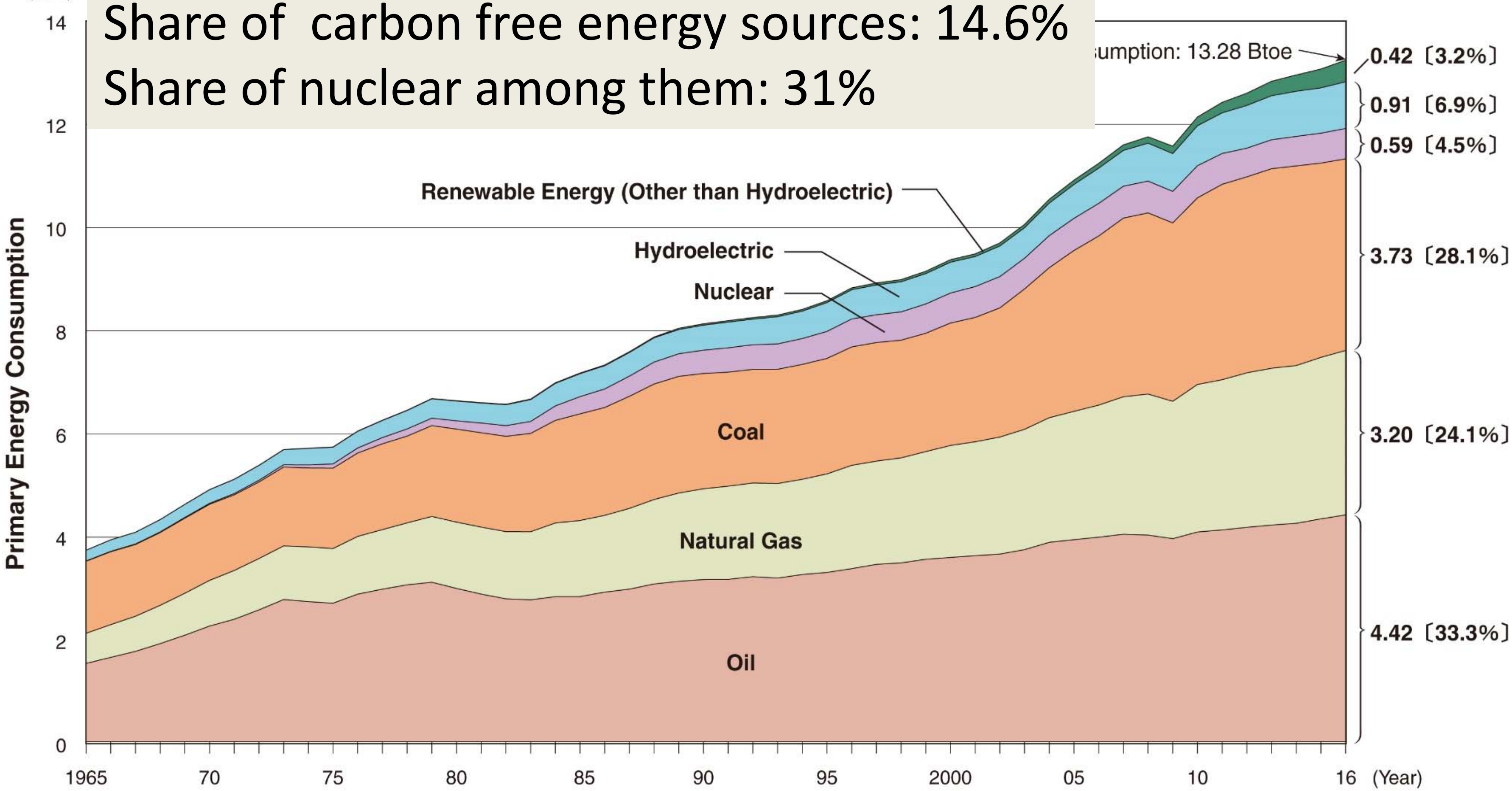
1-1-2

Source: UN, World Population Prospects, the 2015 Revision

Source: http://www.ene100.jp/map_title_en

The World's Primary Energy Consumption

Share of carbon free energy sources: 14.6%
Share of nuclear among them: 31%



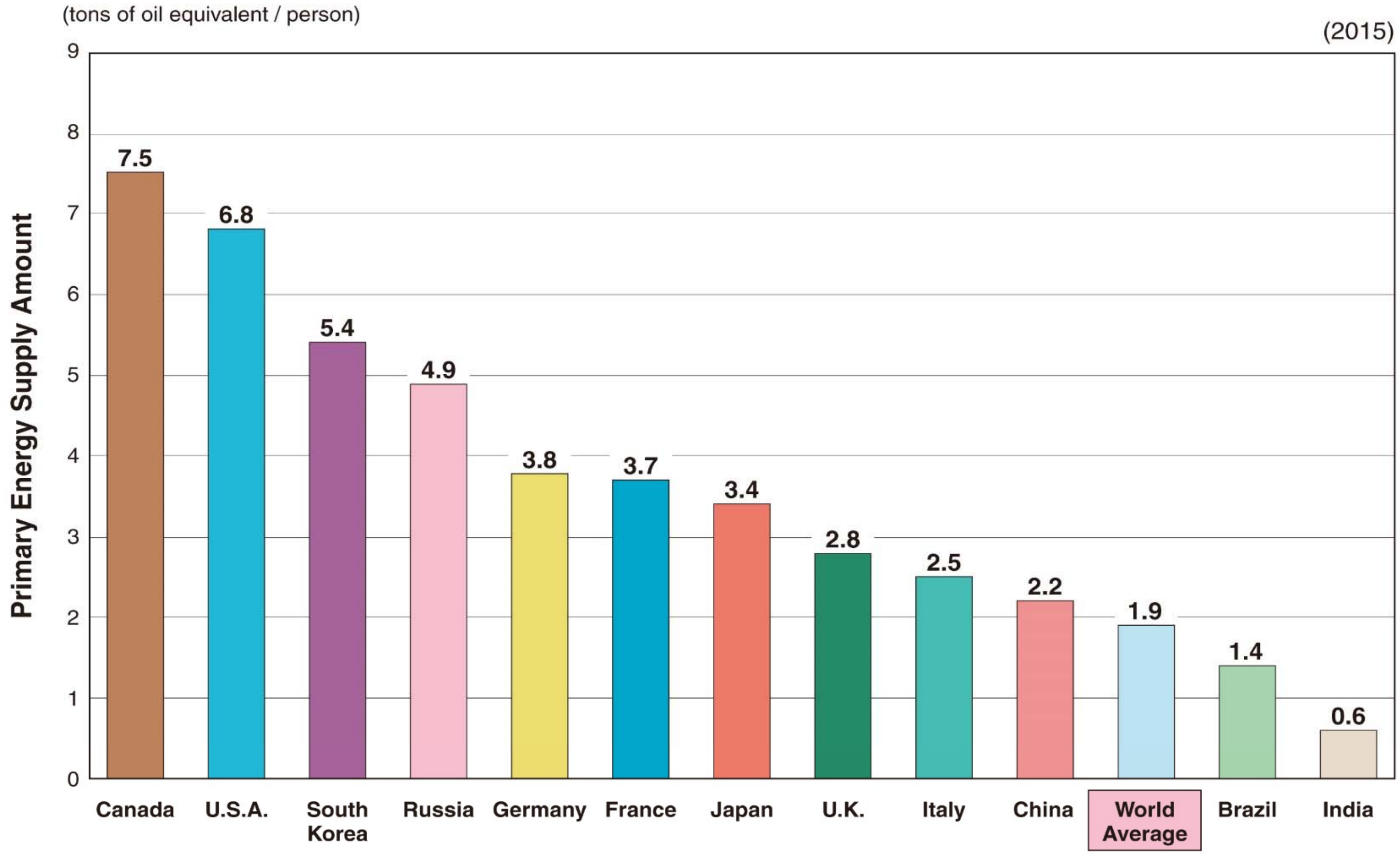
(Note) Figures may not add up to the totals due to rounding. The figures in parentheses are the share of the total.
Btoe: billion tons of oil equivalent

1-1-7

Source: BP Statistical Review of World Energy 2017

Source: http://www.ene100.jp/map_title_en

Primary Energy Supply Amount Per Capita in World

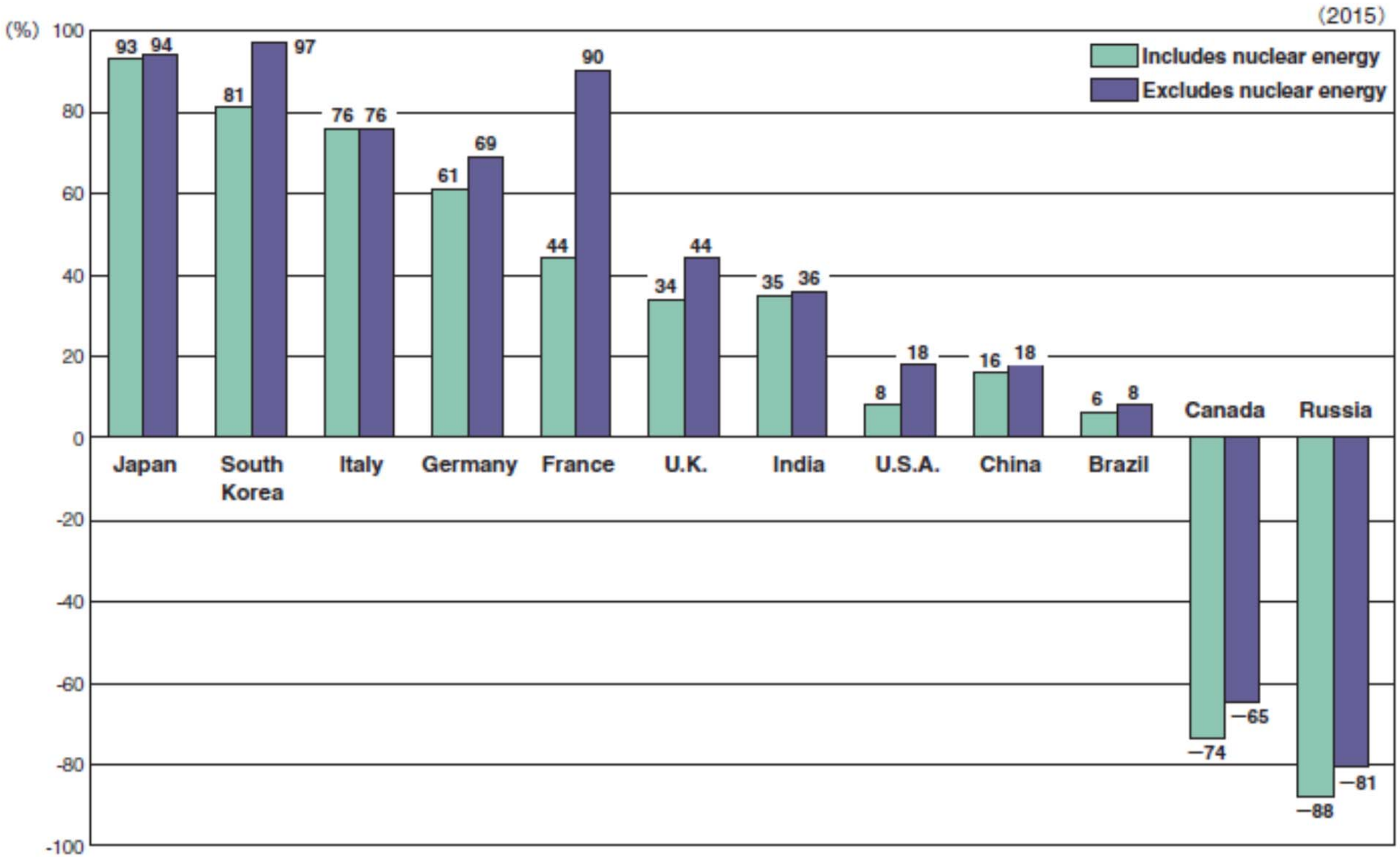


1-1-4

Source: IEA, WORLD ENERGY BALANCES (2017 Edition)

Source: http://www.ene100.jp/map_title_en

Dependence on Imported Energy Sources in Major Countries



(Note) Canada and Russia are net-exporting countries.

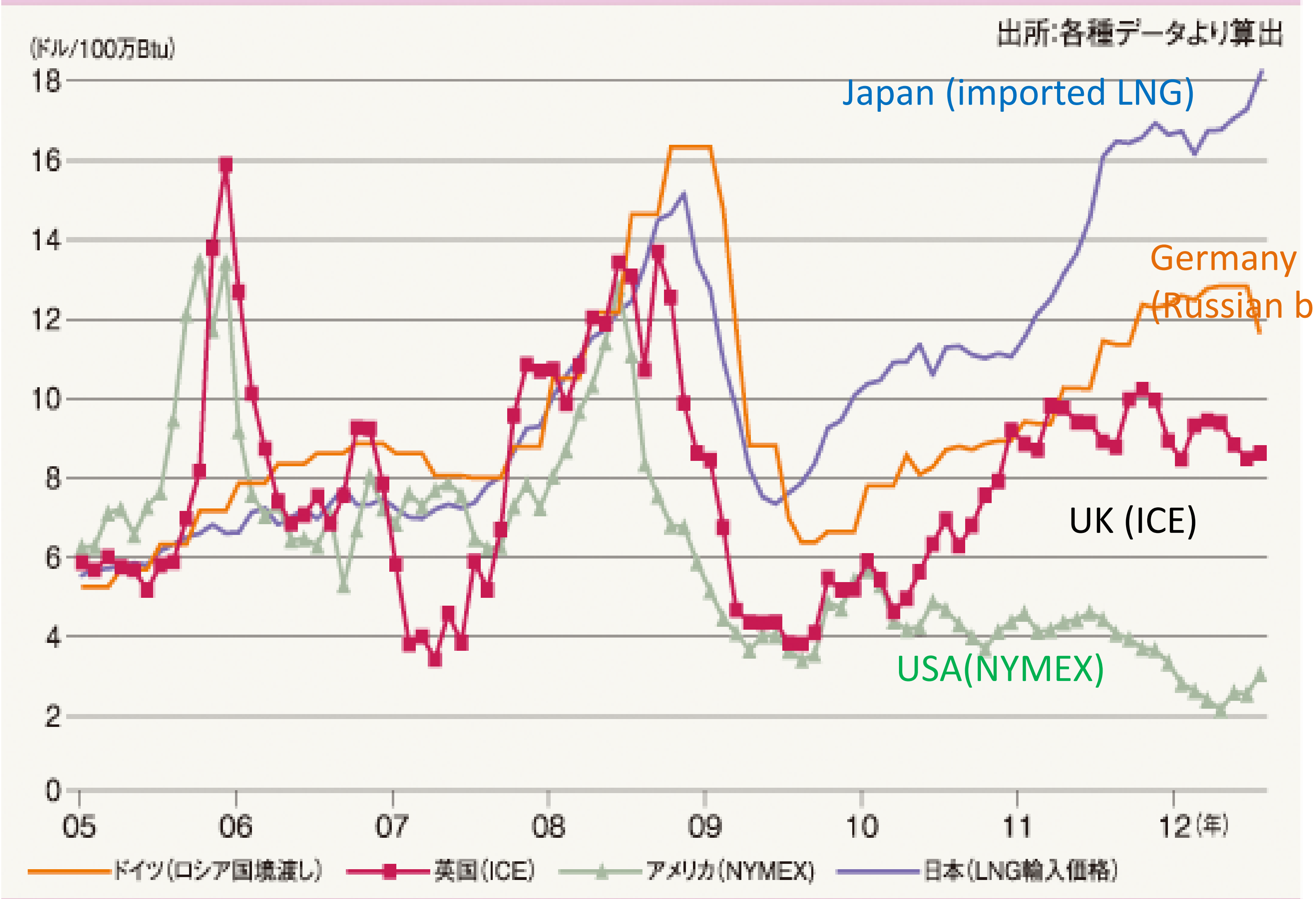
1-1-11

Source: IEA, WORLD ENERGY BALANCES (2017 Edition)

Source: http://www.ene100.jp/map_title_en

Natural gas prices (2005-2012)

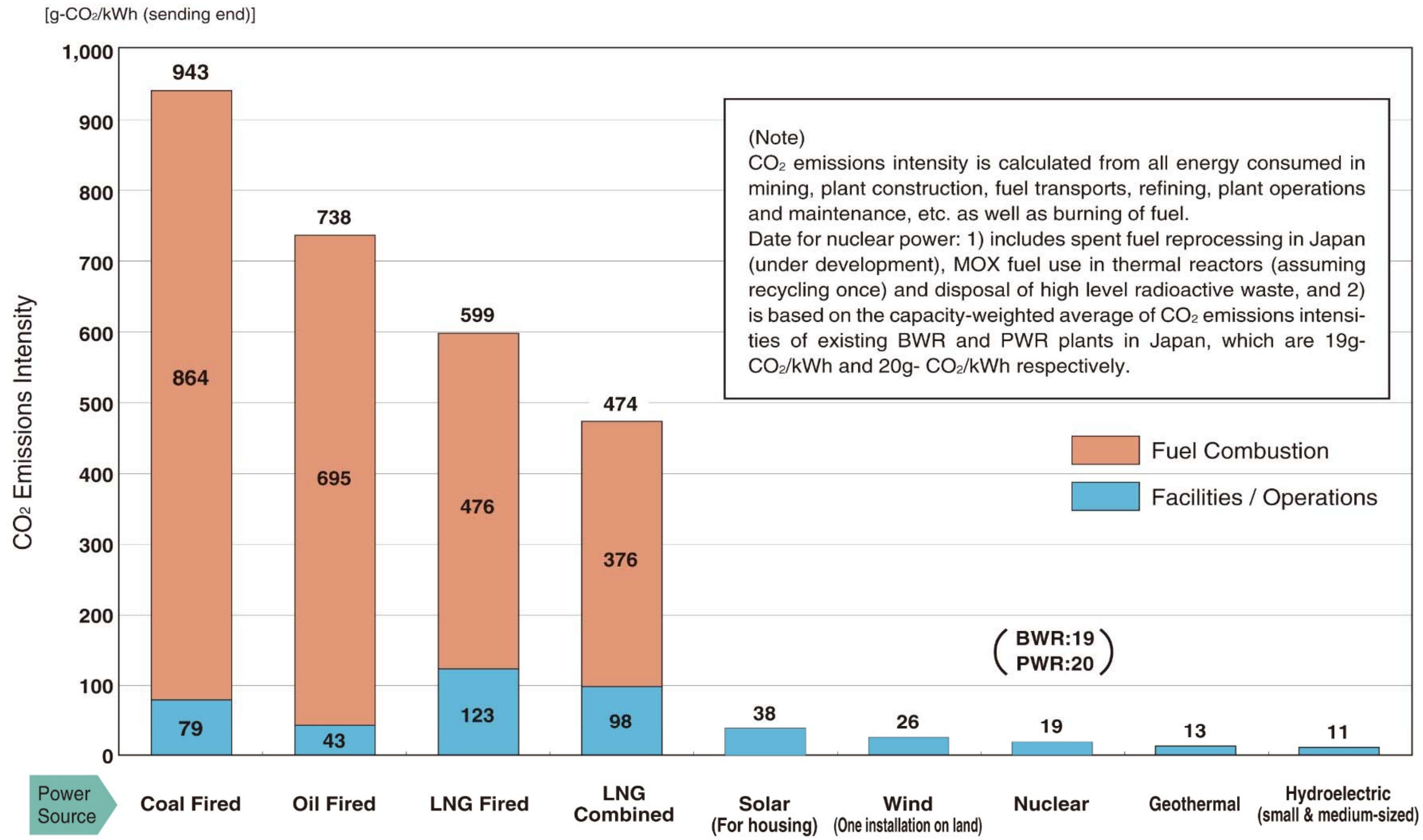
not stable



Source：JOGMEC, http://www.jogmec.go.jp/library/contents8_05.html

Global warming and energy scenario

Lifecycle-Assessed CO_2 Emissions Intensity of Japan's Energy Sources



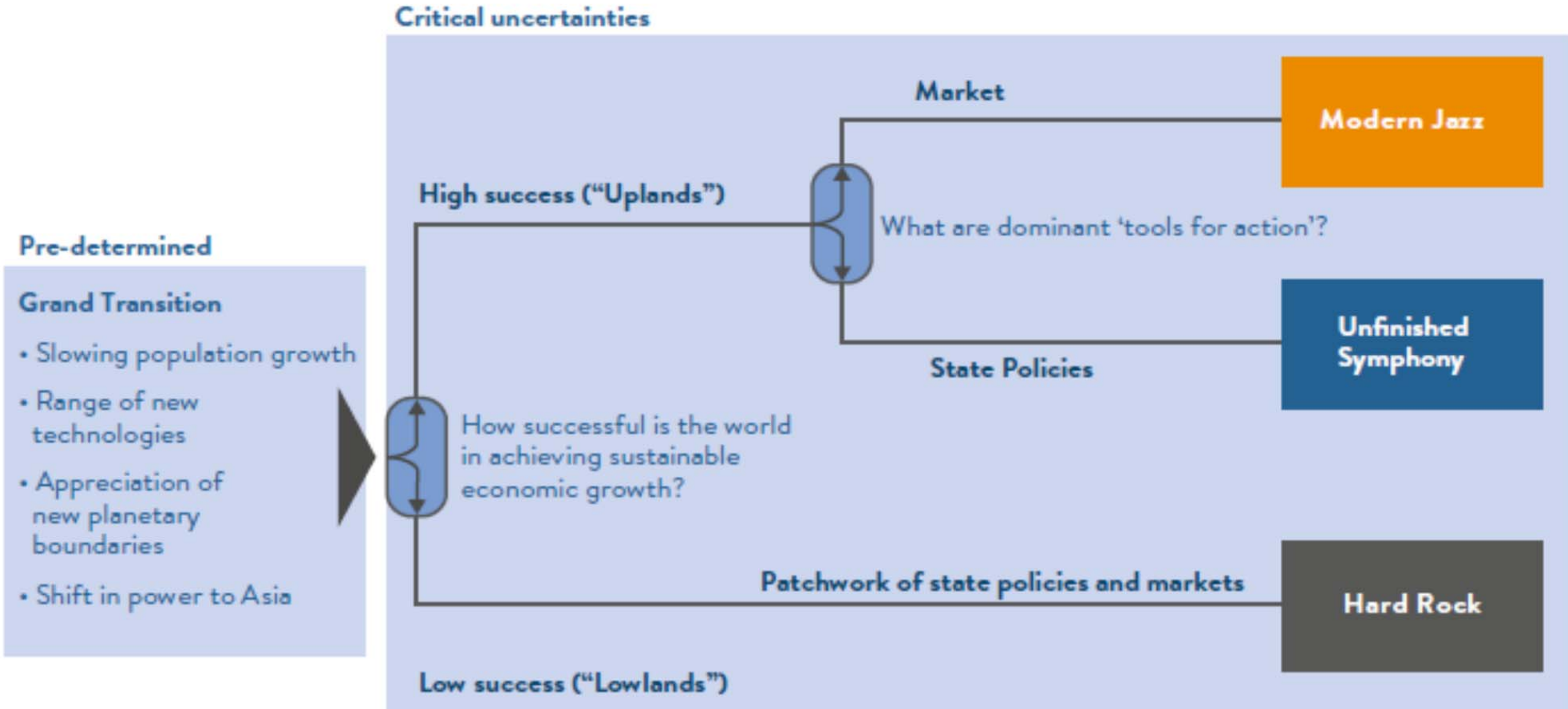
2-1-9

Source: Central Research Institute of Electric Power Industry, Comprehensive Assessment of Life Cycle CO_2 Emissions from Power Generation Technologies in Japan (July 2016)

Source: http://www.fepc.or.jp/library/pamphlet/zumenshu/pdf/all_english.pdf

World Energy Scenarios 2016
THE GRAND TRANSITION, 3 scenarios

1. Market driven（Modern Jazz）
2. State policies（Unfinished Symphony）
3. Patchwork　　(Hard rock)



Source: The World Energy Council

Reduction of CO2 emission

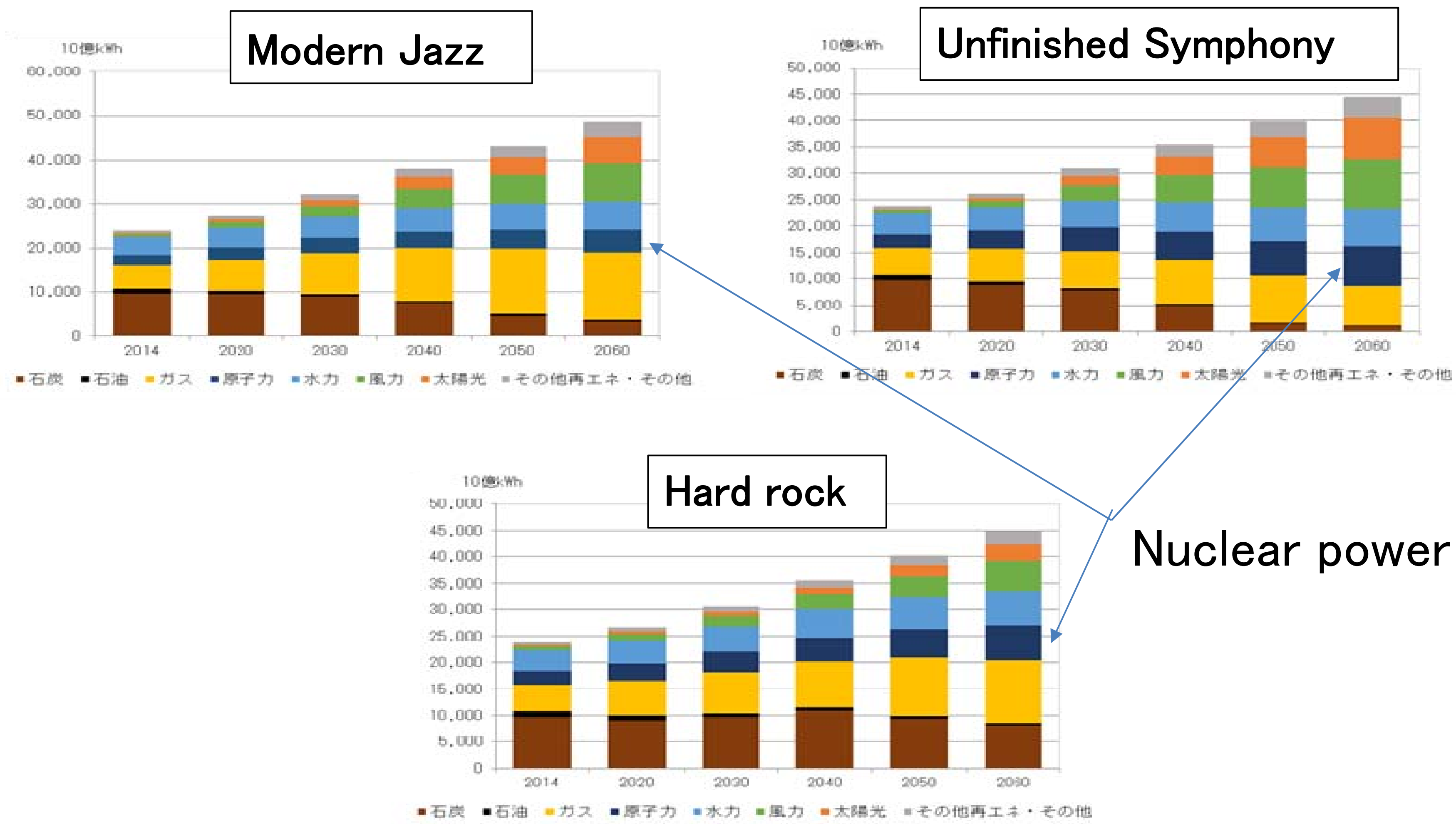
Patchwork (Hard rock) fails the reduction

Modern Jazz　　Unfinished Symphony　　Hard rock

Nuclear power increases for all scenarios

,but smallest by market driven scenario (modern Jazz)

Nuclear power needs policy for recovering large investment



Nuclear power reactors

PWR development

PWR was developed based on nuclear submarine reactor technology of US Navy by Westinghouse

Nautilus（1954, north pole voyage 1958）

Shippingport PWR（1957, Westinghouse, demonstration reactor, 60MWe）

Yankee Rowe（1961, 1st commercial plant,185MWe）

Saxton(1960, testing reactor,20MWt)

Mihama I (1970, 340MWe, Kansai EPCO, Japan)

Standardization ; 2 loop (600MWe), 3 loop (900MWe), 4 loop (1200MWe): same design of steam generators and coolant pumps

Research of LOCA (loss of coolant accident) by national Labs.

USS Nautilus (Nuclear submarine)

Source: http://www.hnsa.org/ships/nautilus.htm

Shippingport Atomic Power Station

Source: http://www.mbe.doe.gov/me70/history/photos.htm

BWR development

BORAX-I; Inherent safety, power excursion test

BORAX-II; Pressurization, instability study

BORAX-III; Power generation test

BORAX-IV; UO2 fuel, stability, radiolysis, radioactivity in turbine island

BORAX-V; High power density core, nuclear superheat

EBWR (Argonne national lab. 5MWe）; Power demonstration, Accumulation of trouble experience

VBWR（GE）； Economic improvement, natural/forced circulation, direct/indirect cycle, materials testing

Dresden-I (Demonstration reactor, 180MWe,1959, Zircaloy fuel, control rod failure)

JPDR（Japan, JAERI, demonstration reactor, 12.5MWe, 1963）

Dresden-II、Oyster Creek（1st generation of commercial plants, 1965）

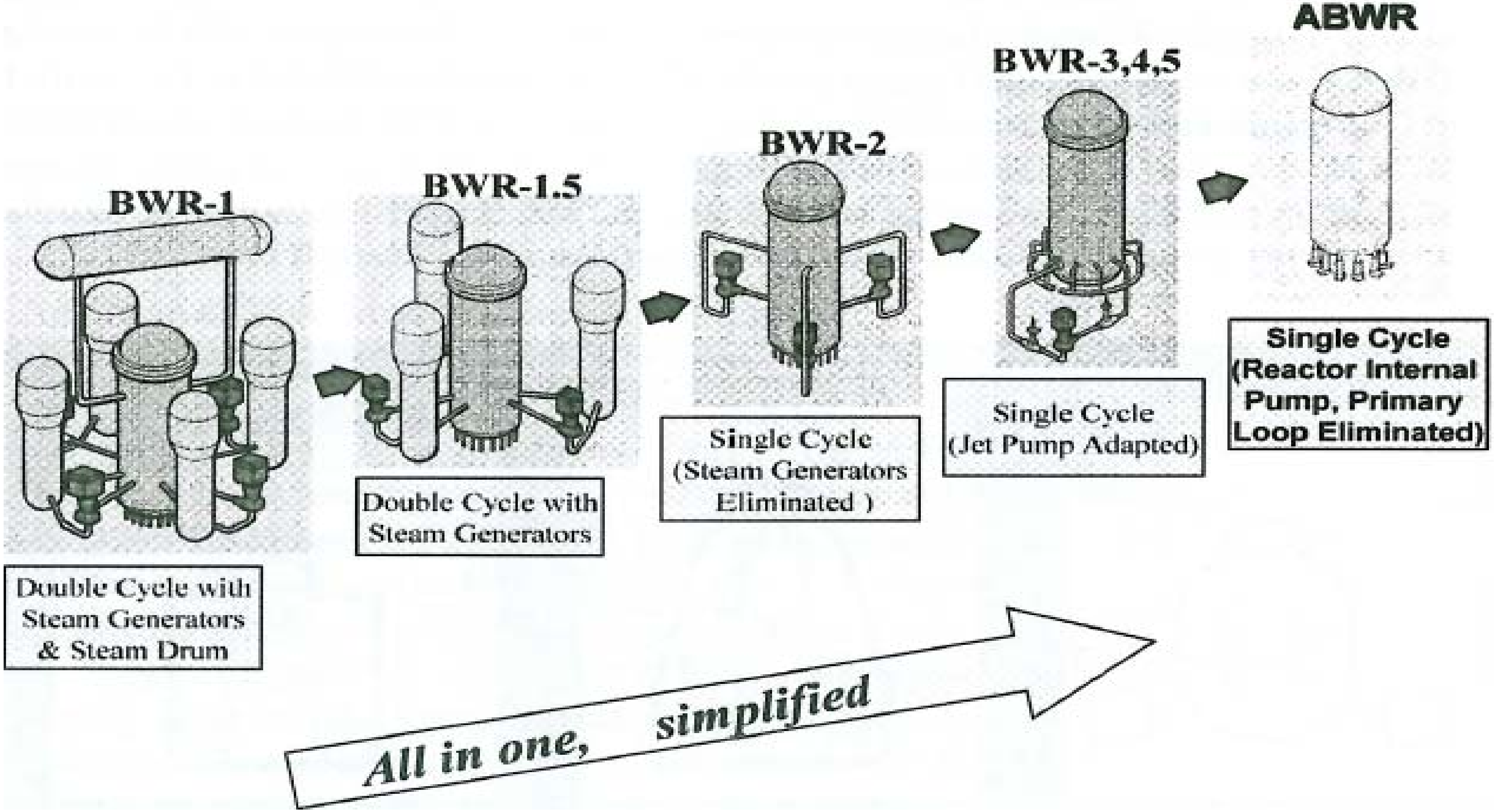
Tsuruga 1（357MWe, 1969, JAPC), Fukushima I （460MWe, 1970, TEPCO）

Argonne National Laboratory-West 201-709

BORAX-I, the "runaway" reactor.

Source: S.M. Stacy "Proving the principle" DOE/ID-10799

Evolution of BWR



Source: Y.Oka (editor) " Advances in light water reactor technologies", Springer 2011

Lessons of Innovation dynamics
J.M.Utterback

- Innovation occurs by conventional technologies + new element, for example
- Manual typewriter was made of conventional mechanical components + key board
- Electric typewriter was combination of mechanical typewriter components + motor
- PC (word processor) consisted of electronic devices such as a TV monitor, printed boards, memory chips, semiconductors +QWERTY key board.
- Variety of designs are developed at the beginning, but “dominant design” takes the largest market share.
- After “dominant design” is established, innovation of production process occurs.

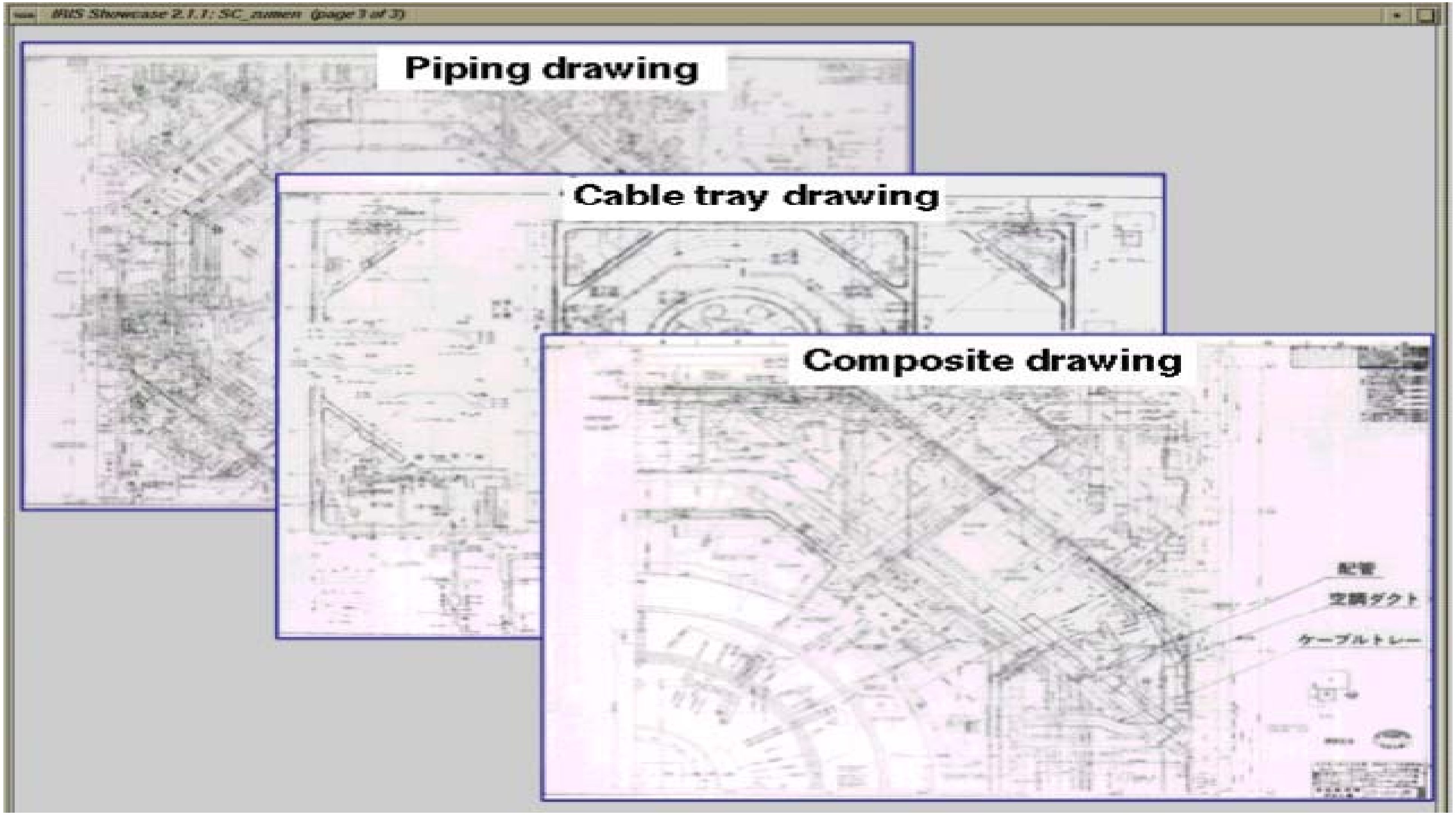
LWR is the dominant design of nuclear power plants. It is based on coal fired power plant technologies such as pumps. steam turbines, an electric generator, piping + reactor core.

Production process innovation occurred, after LWR design was established.

Ref. J.M.Utterback,”Mastering the dynamics of Innovation”, Harvard Business School Press, 1994

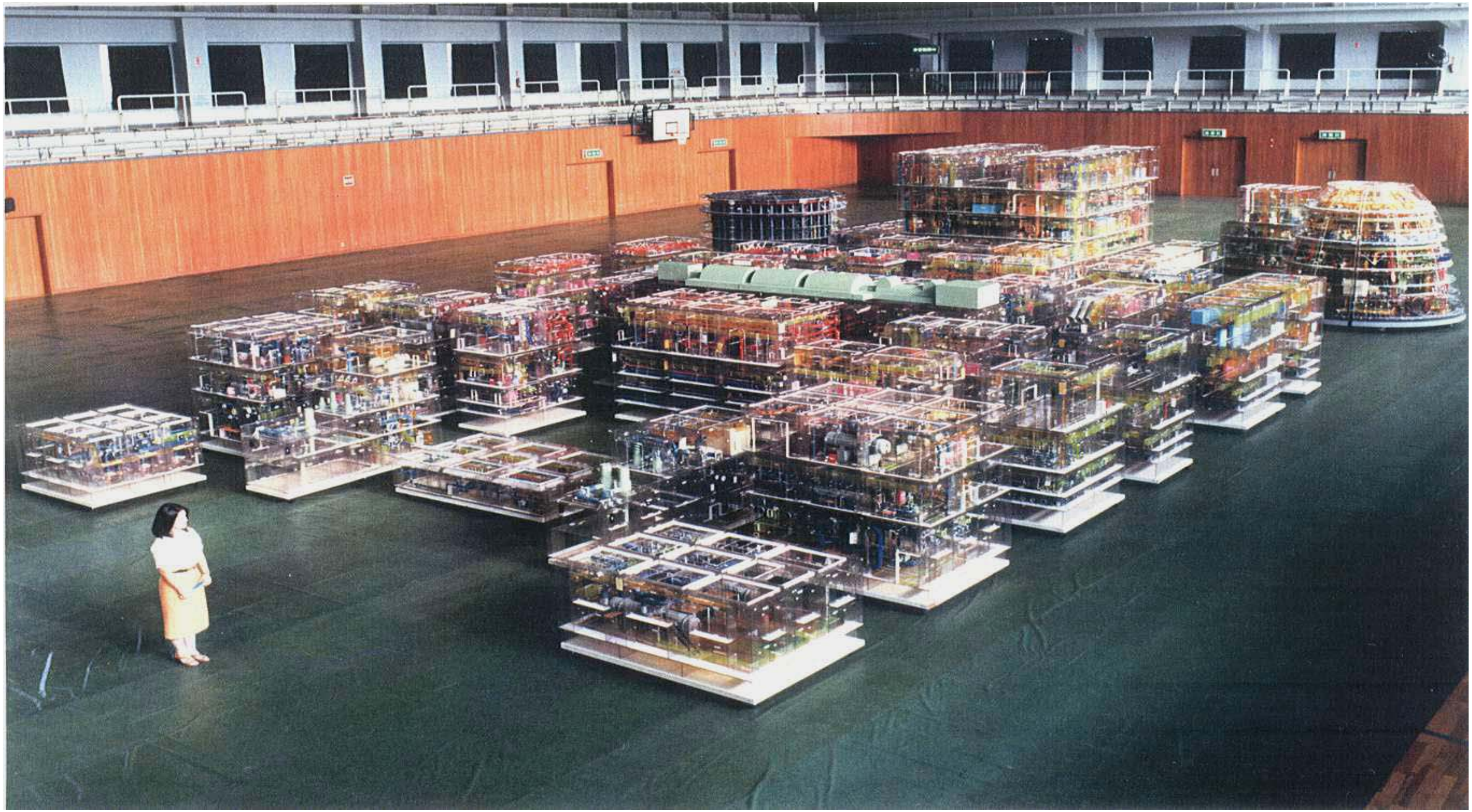
Advances in LWR technologies

Design by Hand drawing (1975)



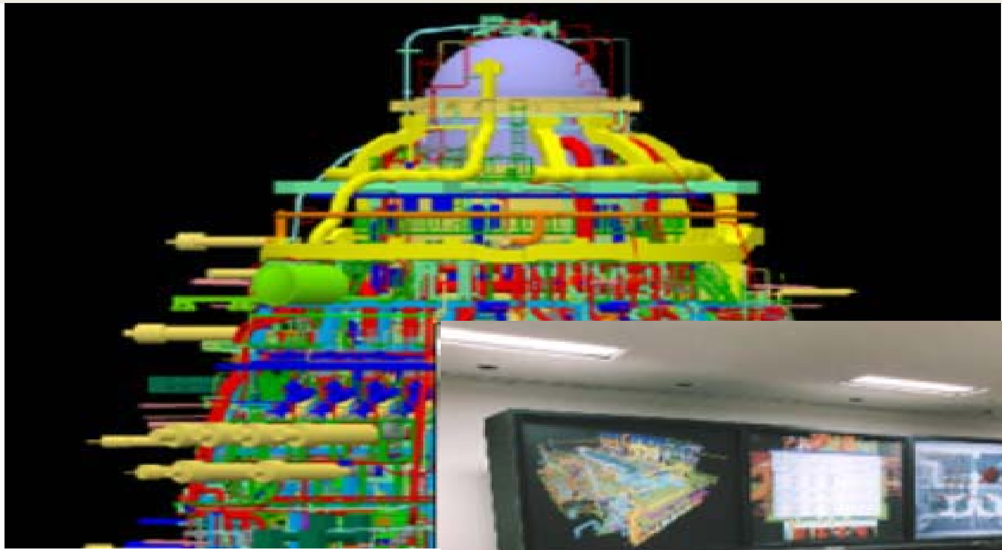
“Source: Kawahata, Hitachi-GE Nuclear Energy, Ltd., Intn’l Summer School of Nuclear Power Plants, Tokai-mura, Univ. Tokyo 2009"

Design by plastic model (1985)



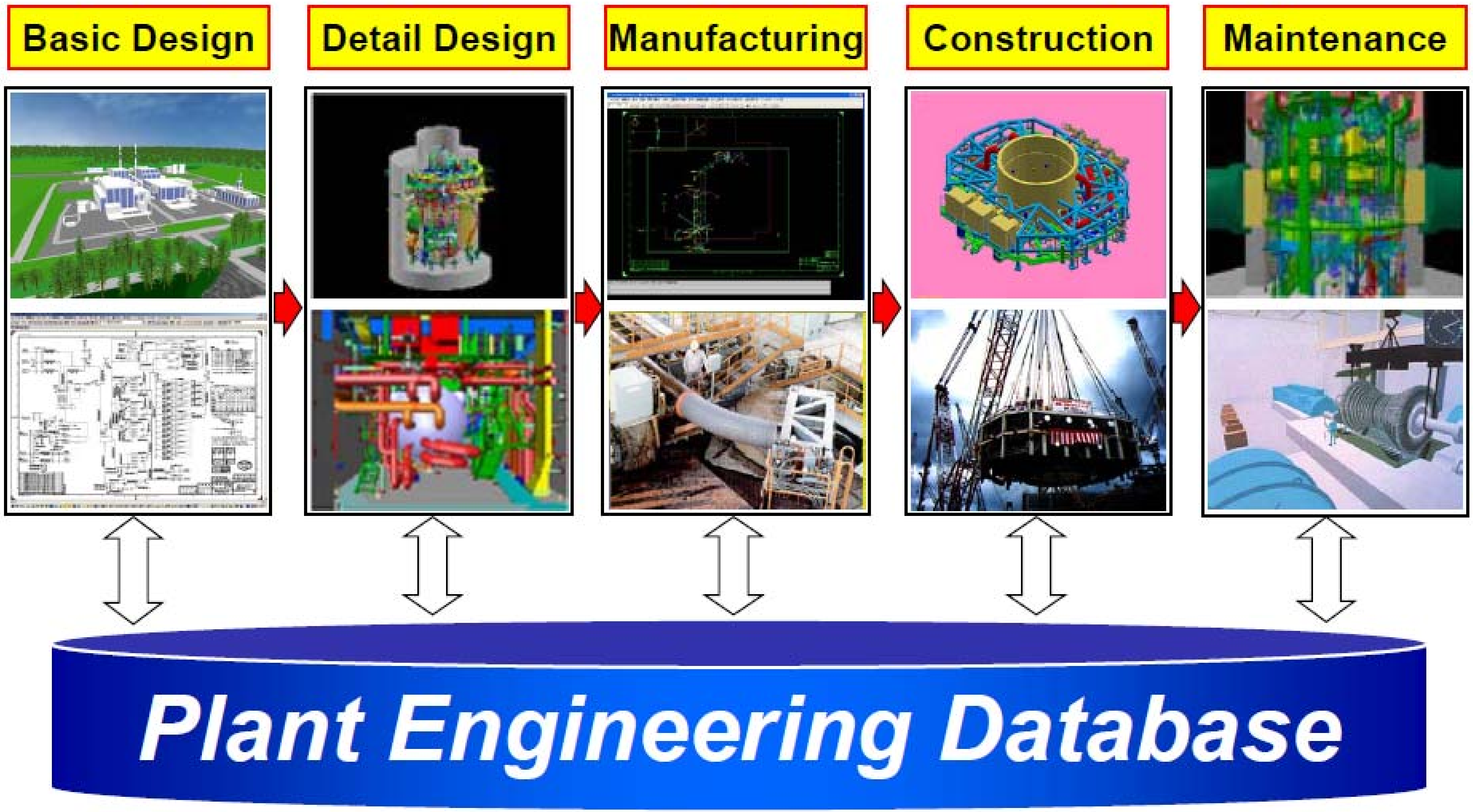
“Source: Kawahata, Hitachi-GE Nuclear Energy, Ltd., Intn’l Summer School of Nuclear Power Plants, Tokai-mura, Univ. Tokyo 2009"

Design by 3D CAD (1990's)



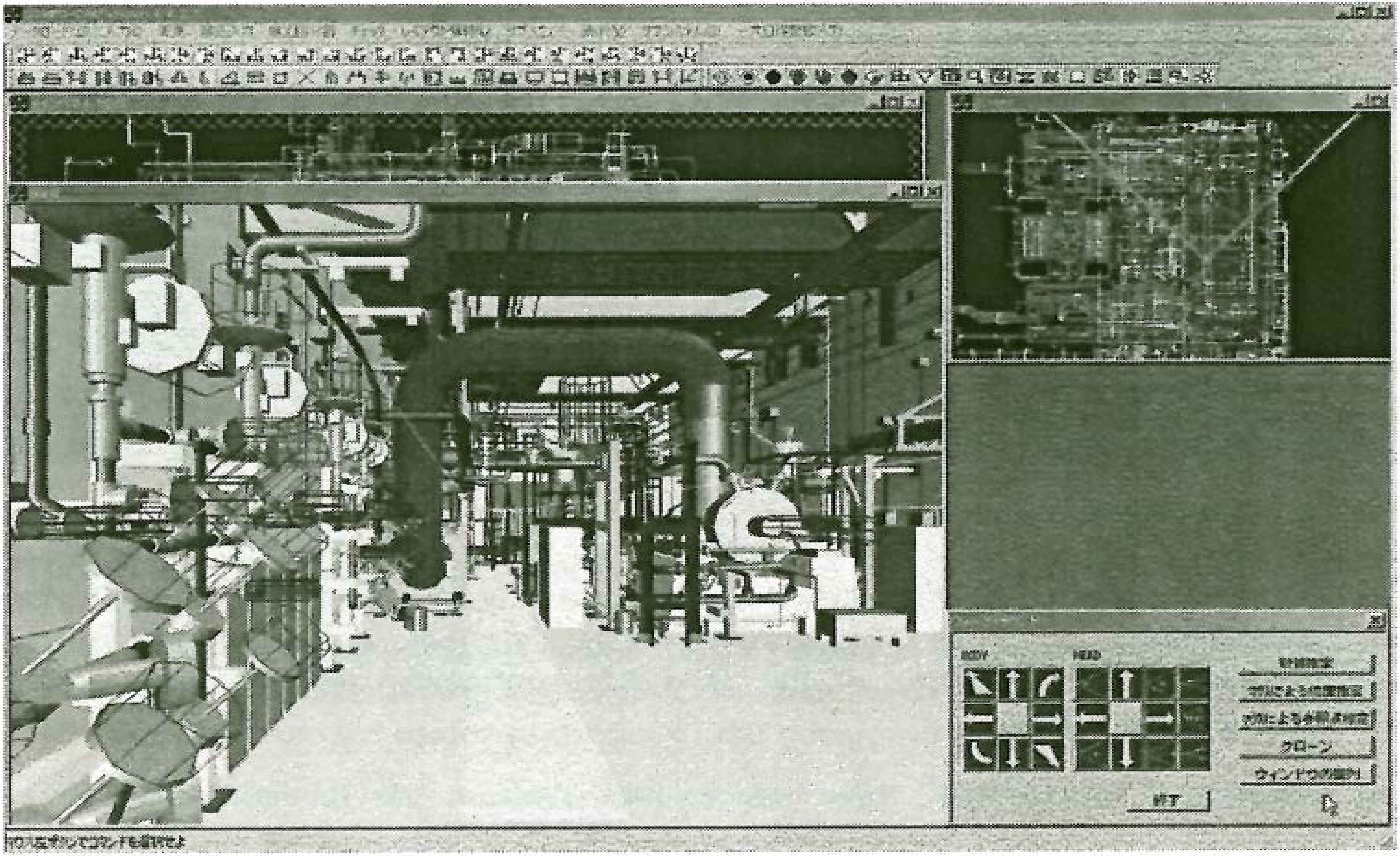
"Source: Kawahata, Hitachi-GE Nuclear Energy, Ltd., Intn'l Summer School of Nuclear Power Plants, Tokai-mura. Univ. Tokyo 2009"

Plant integrated CAE system (present)



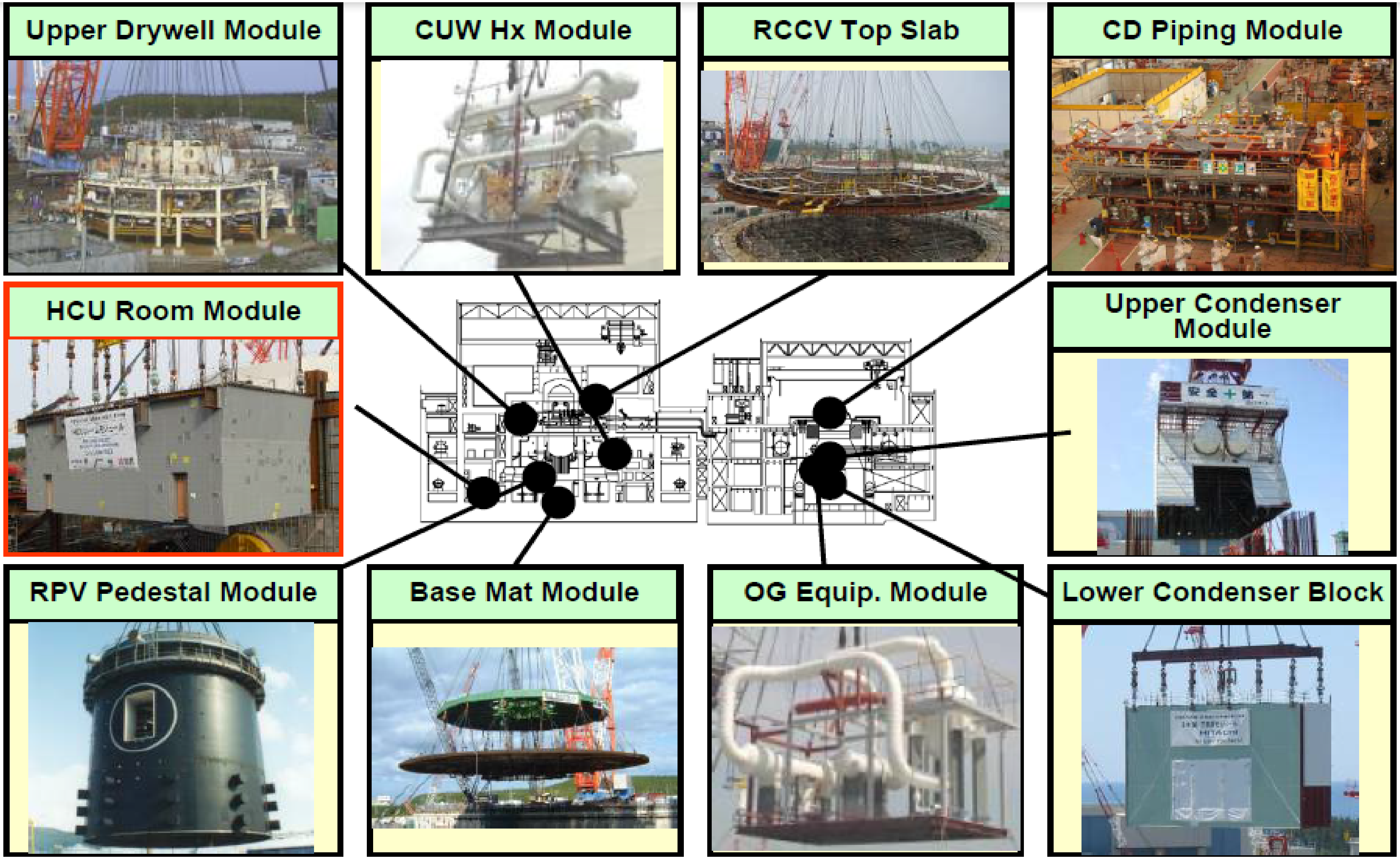
"Source: Kawahata, Hitachi-GE Nuclear Energy, Ltd., Intn'l Summer School of Nuclear Power Plants, Tokai-mura, Univ. Tokyo 2009"

Walk – through simulation with CAE



Source: Y.Oka (editor) “ Advances in light water reactor technologies”, Springer 2011

Modular construction



“Source: Kawahata, Hitachi-GE Nuclear Energy, Ltd., Intn’l Summer School of Nuclear Power Plants, Tokai-mura, Univ. Tokyo 2009"

Summary of Nuclear Power Plant Development in 1950's and1960's

NUCLEAR POWER PLANTS

Design, Operating Experience and Economics

ROBERT L. LOFTNESS

Atomics International
Washington, D.C.

D. VAN NOSTRAND COMPANY INC.
PRINCETON, NEW JERSEY
TORONTO LONDON
NEW YORK

Published in 1964

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1.Engineeting principles
2. Reactor fuels and materials
3.Pressurized water reactors
4.Boiling water reactors
5.Heavy water reactors
6.Organic cooled reactors
7. Liquid metal cooled reactors
8.Gas cooled graphite moderated natural uranium reactors
9. High temperature gas cooled reactors
10.Fluid fuel reactors
11. Aerospace reactors
12.Economics

Design improvements of LWR in 1970's and 80's

PRINCIPLES OF DESIGN IMPROVEMENT FOR LIGHT WATER REACTORS

L. S. Tong
Gaithersburg, Maryland

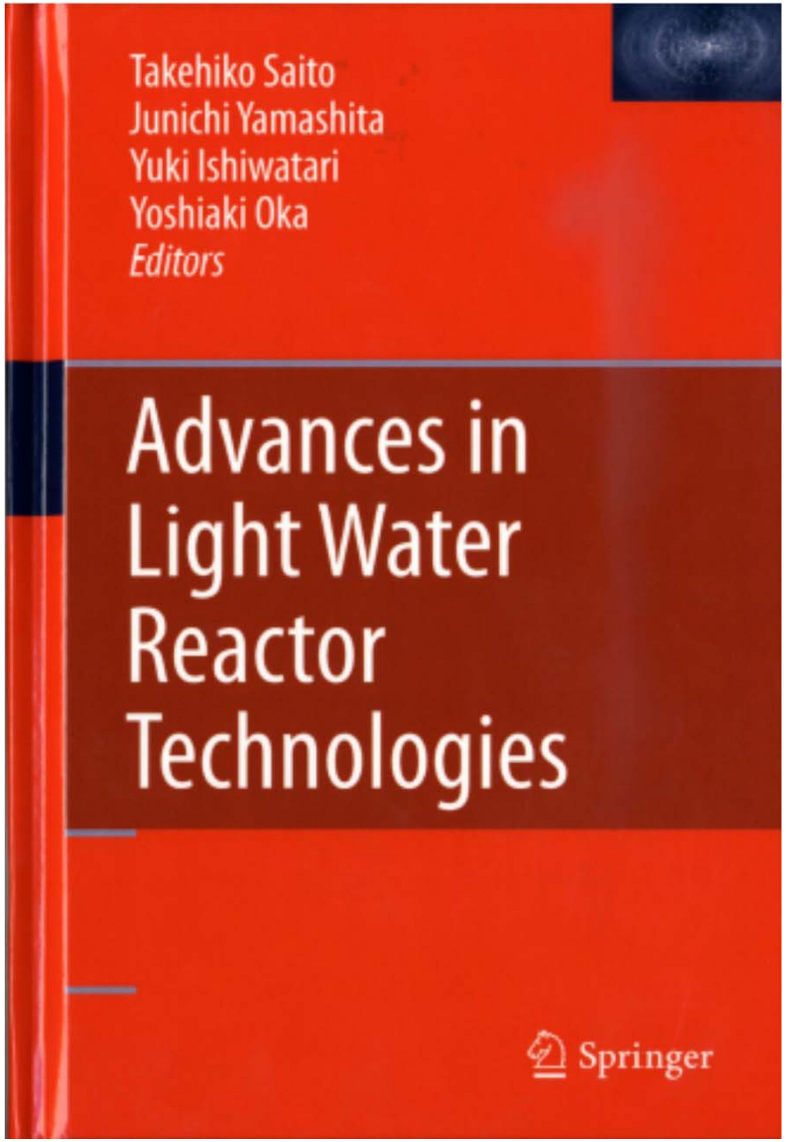
HEMISPHERE PUBLISHING CORPORATION
New York Washington Philadelphia London

DISTRIBUTION OUTSIDE NORTH AMERICA
SPRINGER–VERLAG
Berlin Heidelberg New York London Paris Tokyo

Published in 1988

Contents

Advances in LWR technologies in 1990's and 2000's



Contents

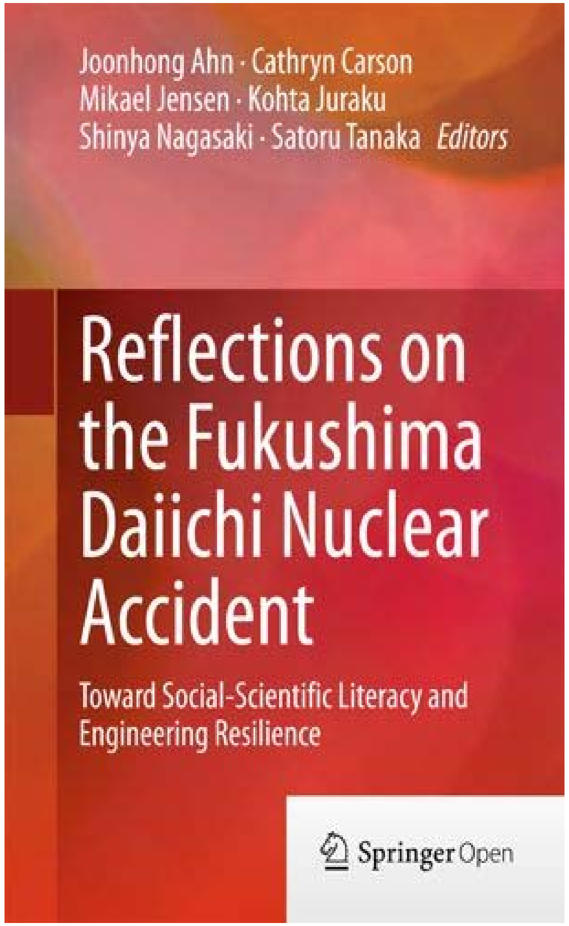
PSA in design and maintenance of ABWR, Passive ECCS of APWR, Severe accident mitigation features of APR1400, EPR core catcher, Severe accident research in China, Full MOX core design of ABWR, CFD applications, Digital I&C system, 3D-CAD application to construction, Progress in seisimic design

Available from Springer, 295 pages

Based on the lectures of International summer school of NPP and young generation work shop"; Bridging fundamental research and practical applications" in 2009 in Tokai-mura Japan

http://www.springer.com/engineering/energy+technology/book/978-1-4419-7100-5

Implications and Lessons for Advanced Reactor Design and Operation from FDNP accident



- External Events: Earthquake, Tsunami
- Design of Buildings, Systems and Components: Off-Site and On-Site Electricity Supply
- Bunkering of Buildings with Safety Related Systems, Emergency Feed Building
- Passive Components and Systems Using Natural Forces: Isolation Condenser, Gravity Driven Cooling System, Passive Containment Cooling System, Emergency Condenser, Containment Cooling Condenser, Passive Pressure Pulse Transmitter, Passive Residual Heat Removal System, Passive Containment Cooling System, Advanced Accumulator,
- Mitigation Measures Against Severe Accidents: Hydrogen Mitigation, Containment Venting Systems, Melt Stabilization Measures, Severe Accident Instrumentation

Source : Y.Oka and. D.Bittermann, "Chapter 12, Implications and Lessons for Advanced Reactor Design and Operation", Reflections on the Fukushima Daiichi Nuclear Accident, Jan 2015 Springer

Health implications of radiation exposure of the public resulting from FDNP accident

(UNSCEAR 2013 Report, Appendix E)

- “No discernible risk”: An increased incidence of effects is unlikely. Consequences are small relative to the baseline risk and uncertainties.
- The most important health effects would appear to be on mental and social well-being as a consequence of the evacuation and their displacement to unfamiliar surroundings, and the fear and stigma related to radiation exposure. For example more than 50 hospitalized patients died either during or soon after the evacuation, probably because of hyperthermia, dehydration or deterioration of underlying medical problems. Upward of 100 elderly people may have died in subsequent months.
- Understanding full heath impact of accident forms an important context for the Committee’s commentary.

UNSCEAR: United nations scientific committee on the effects of atomic radiation

“Maintaining health” should be the goal

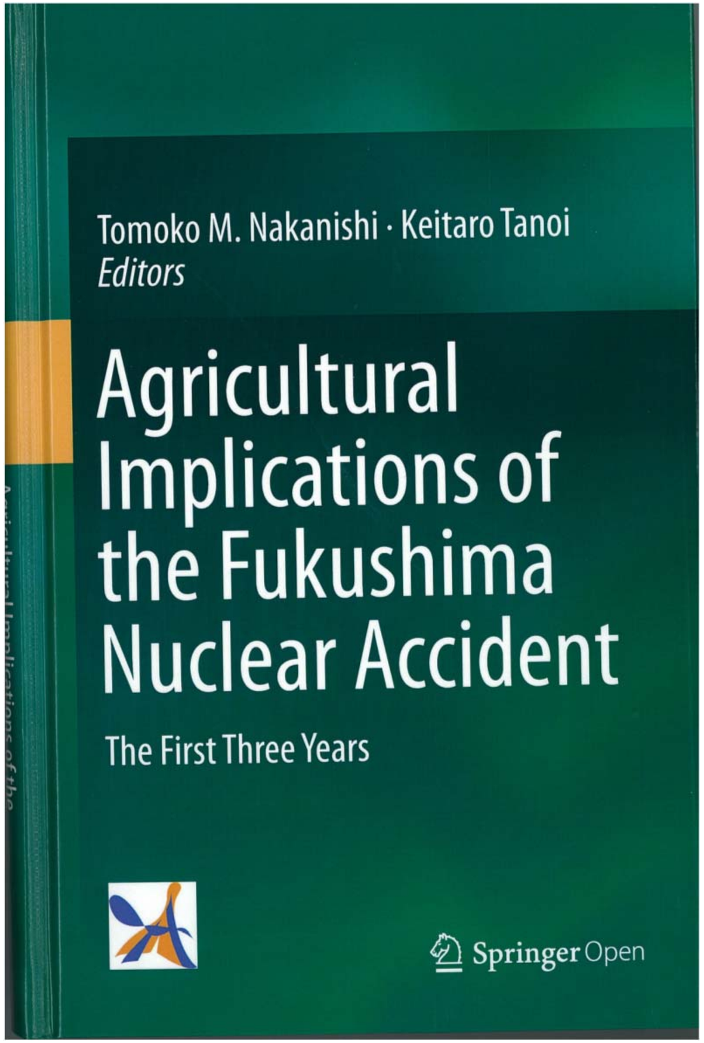
- Order of “sheltering” made most people escape from their homes, but those weak in disaster (single elderly people, patents etc.) were left and separated from outside area.
- Displacement worsen health of the evacuees. No working (farming) increases instability of legs, sugar disease, fatness, osteoporosis
- Displacement for avoiding low level of radiation exposure increased other health risks. It is effective, only when other risks do not increase.
- Lack of exercise and fatness increase cancer risk 1.2 times, equivalent to 100-200mSv of exposure.
- Telling only “radiation” risk increased fear of “radiation”. Radiation risk is a part of cancer risk. It is a part of health risk.
- “Maintaining health” should be the goal for avoiding mental and social health effects of nuclear accidents.

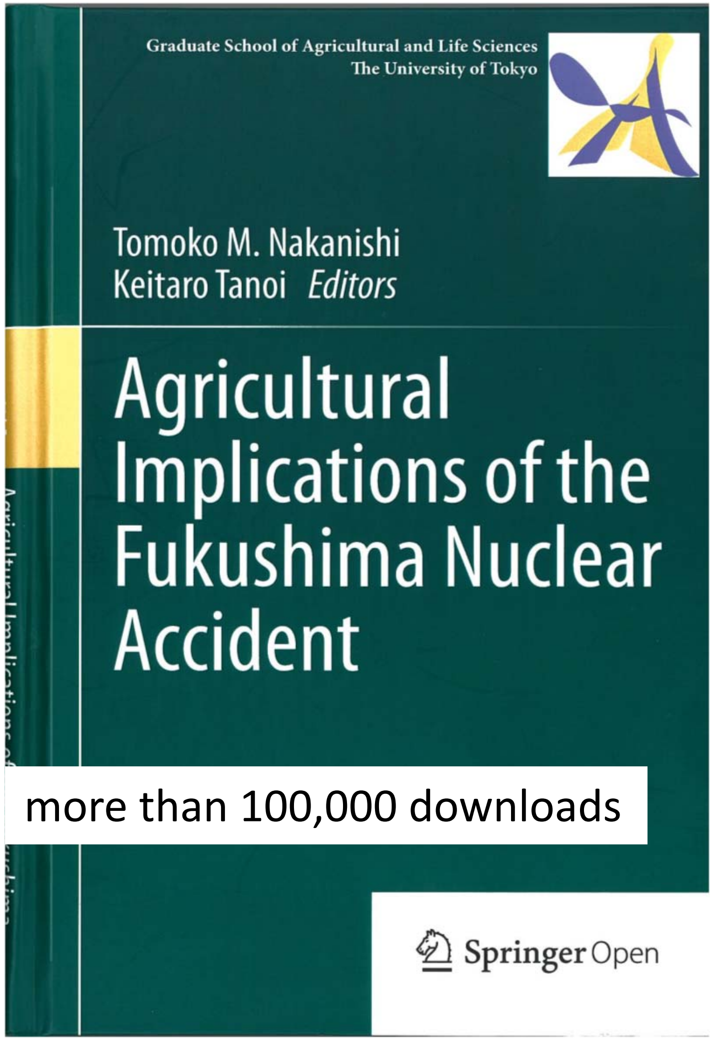
Source: Sae Ochi, Energy review pp7-10, April 2015,(in Japanese)

Sae Ochi, “ Health Impacts Caused by the Fukushima Nuclear Disaster: A Case in Soma District”

JSM Intern Med 1(1): 1002, 2016

Agricultural Implications of the Fukushima Nuclear Accident



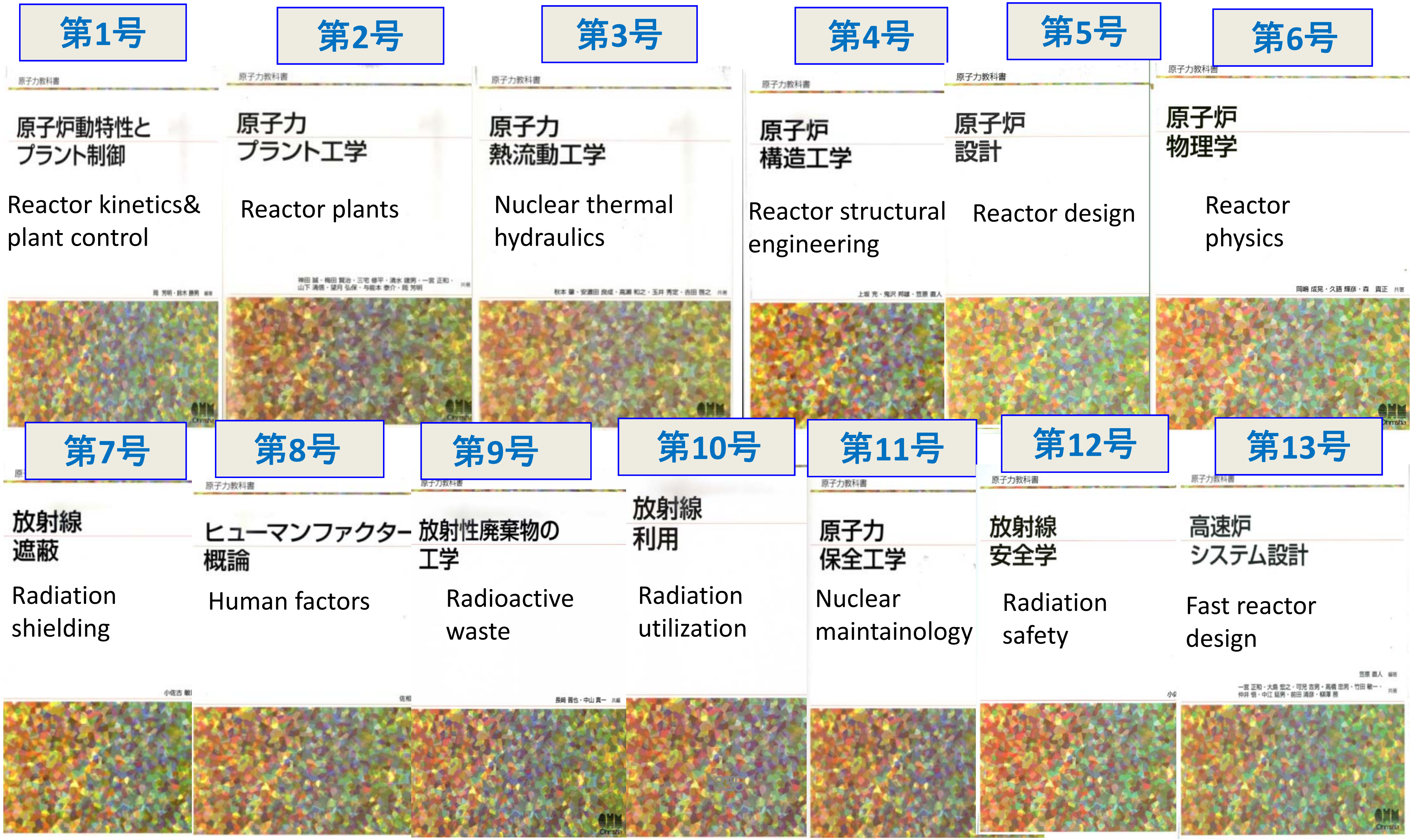


more than 100,000 downloads

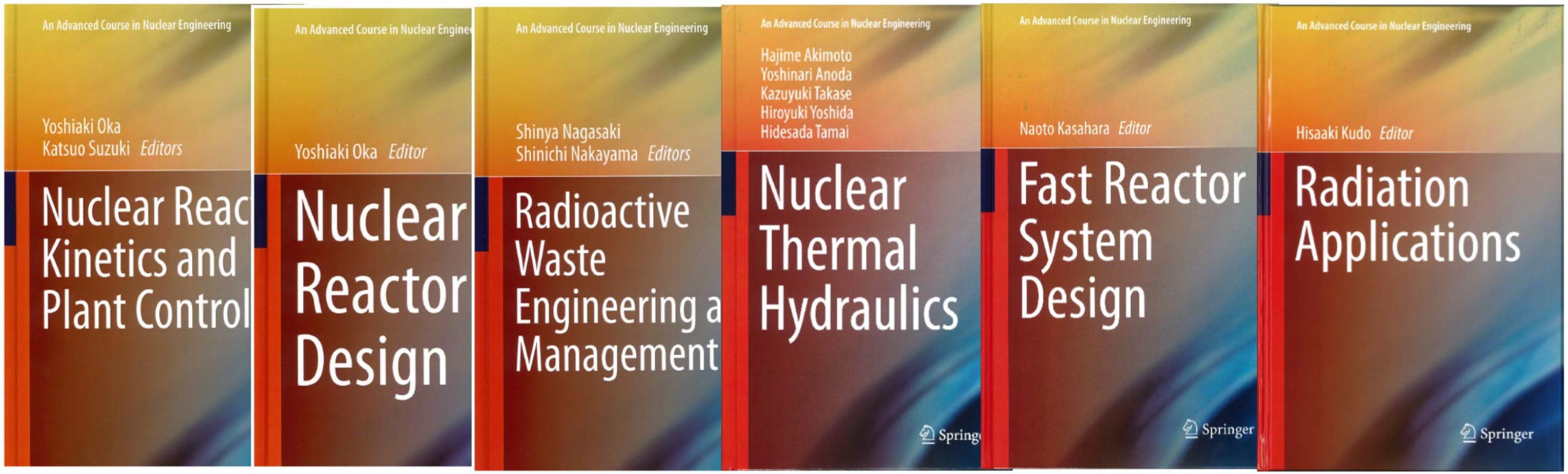
Editors: T.Nakanishi and K.Tanoi, Springer,2013, 2016

Modern textbooks of nuclear engineering

include advances in Japan, 13 books published



Modern textbooks of nuclear engineering
English versions are being published



Lecture notes of Professional Nuclear School of the University of Tokyo were translated and provided to IAEA, now available from IAEA by agreements

Source:http://www.springer.com/engineering/energy+technology/book/978-4-431-54194-3

Nuclear utilization in Japan

Nuclear Power Utilization in Japan

LWR plants; BWR and PWR

9 utilities (TEPCO, Kansai, Chubu etc.) by region and JAPC and J-Power(EPDC)

First LWR demo (JPDR, 12MWe BWR) in 1959

First commercial plant (GCR) in 1965, LWR in 1970

Developed ABWR and APWR

3 Manufacturers;, Hitachi/GE, MHI, Toshiba

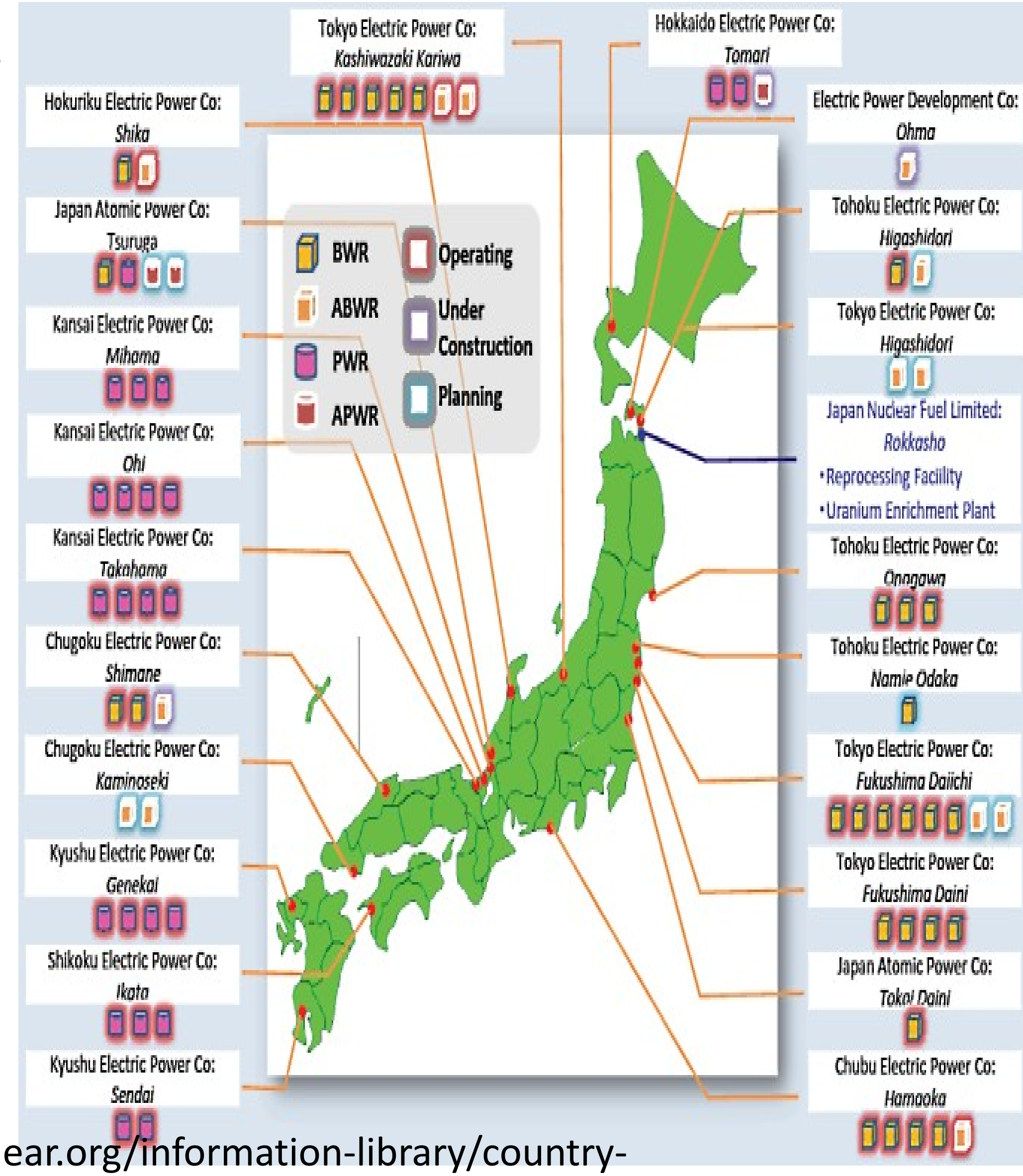
3 nuclear fuel manufacturers; GNF, Mitsubishi NF, NFI

Commercial nuclear fuel cycle program by JNFL (enrichment, spent fuel reprocessing and low level radioactive waste disposal) in Rokkasho-mura

Only for peaceful use, no nuclear weapon by law

Nuclear Power Plants in Japan (Nov. 2018)

- 9 plants restarted after rigorous safety review of NRA.
- 7 plants passed the review.
- 13 plants are under review.
- 11 plants have not yet applied the review.
- 22 plants were shut down permanently, including 4 plants which were shut down before the TEPCO Fukushima Daiichi accident.

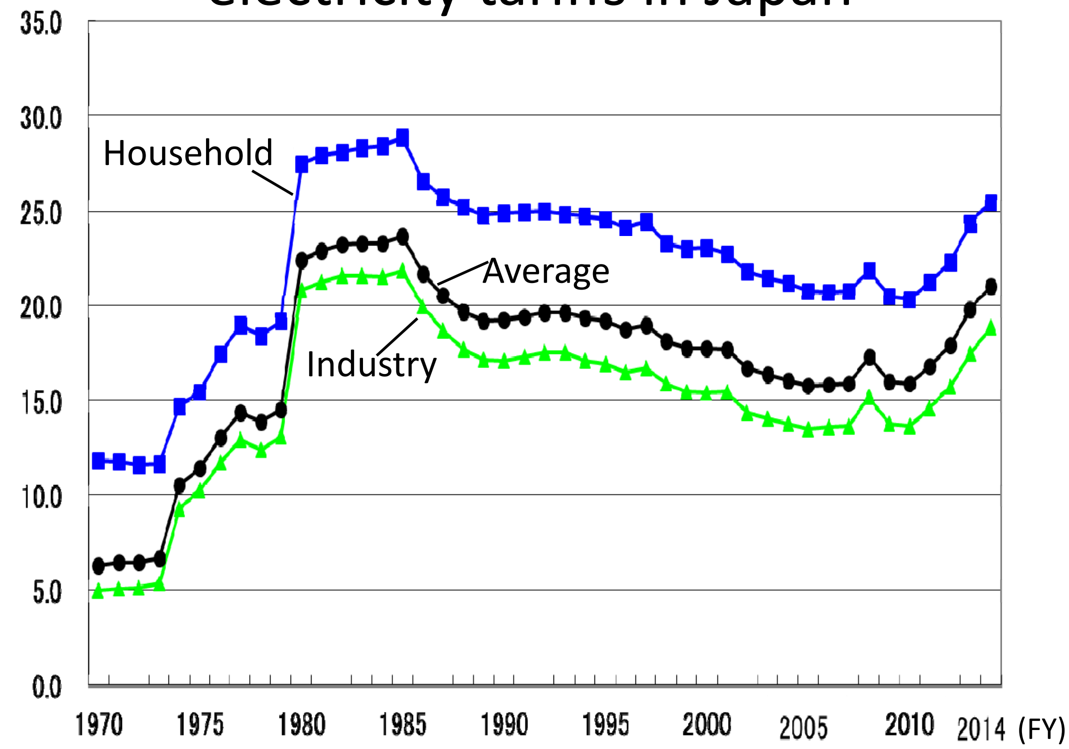


Source: METI and http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/japan-nuclear-power.aspx

Electricity Tariffs and Fuel cost

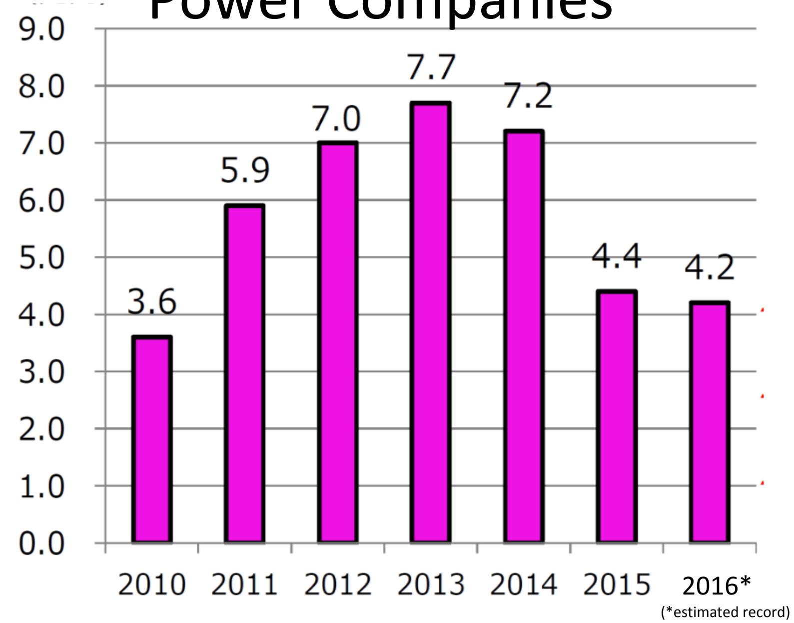
- After the Fukushima accident, **electricity tariffs raised by about 30% for industry and by about 20% for household**.
- **Fuel cost increased by $90 billion due to higher dependency on thermal power generation** as a result of the suspension of nuclear power generation after the Fukushima accident.

(¥/kWh) electricity tariffs in Japan



Source: Energy Annual Report 2015

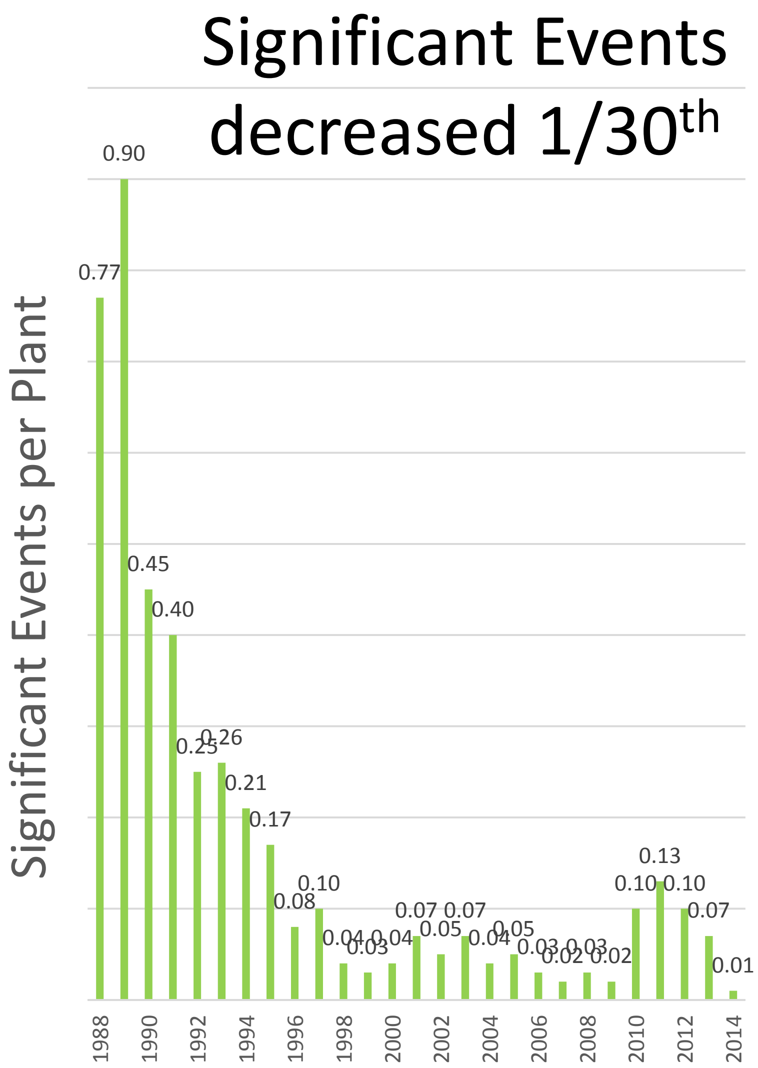
Fuel Cost of Japanese Electric Power Companies

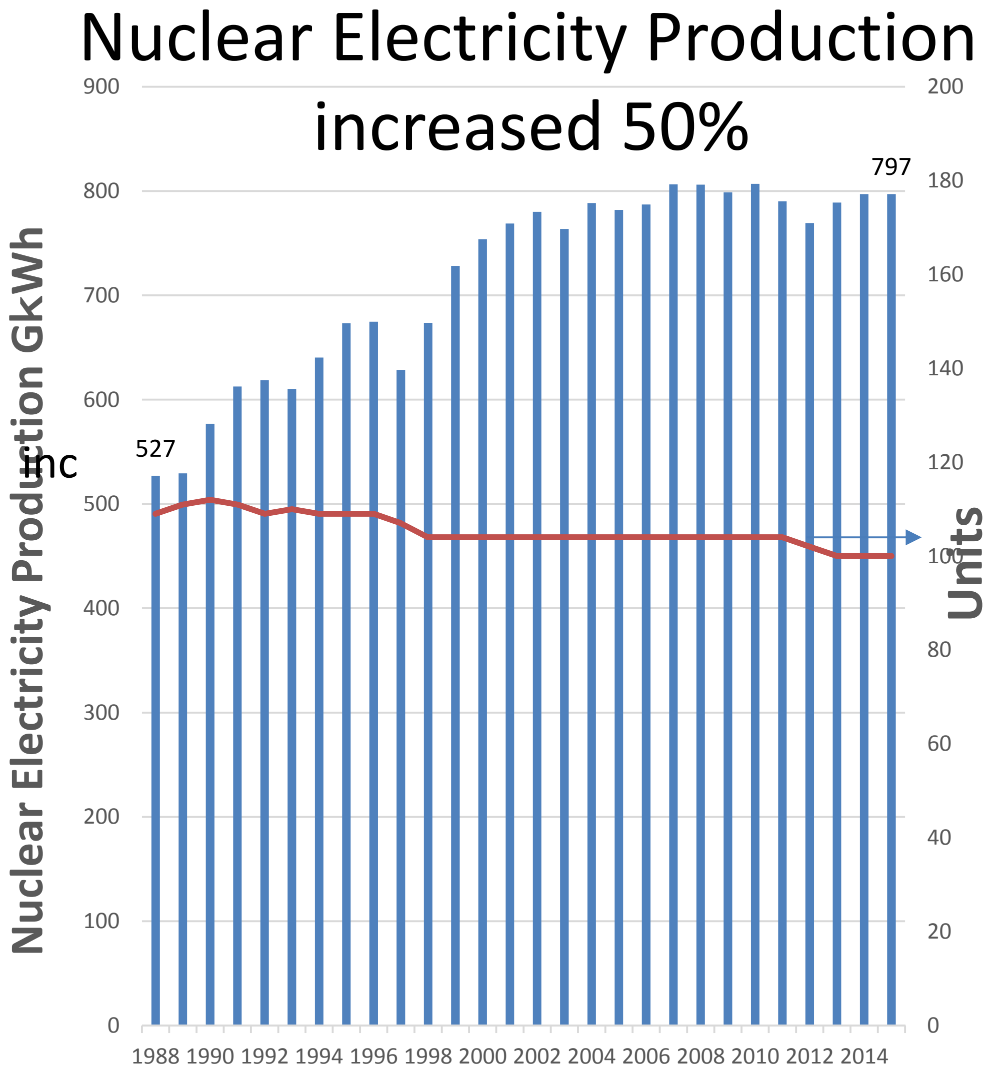


FY	2010	2011	2012	2013	2014	2015
Thermal (%)	61.7	78.9	88.3	88.3	87.8	84.6

Source：Federation of Electric Power Companies of Japan

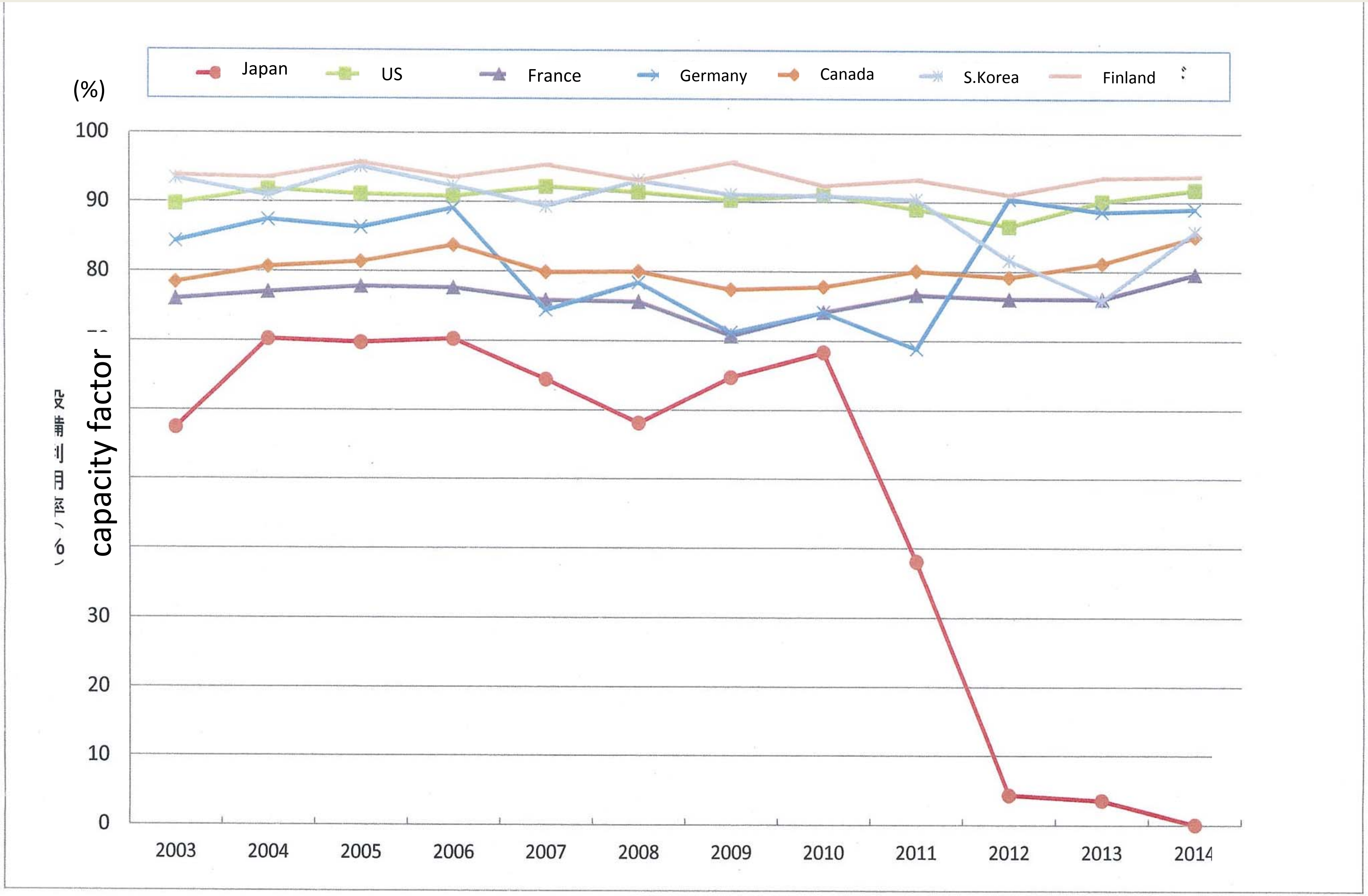
Safety and Economic Improvements after TMI accidents in USA





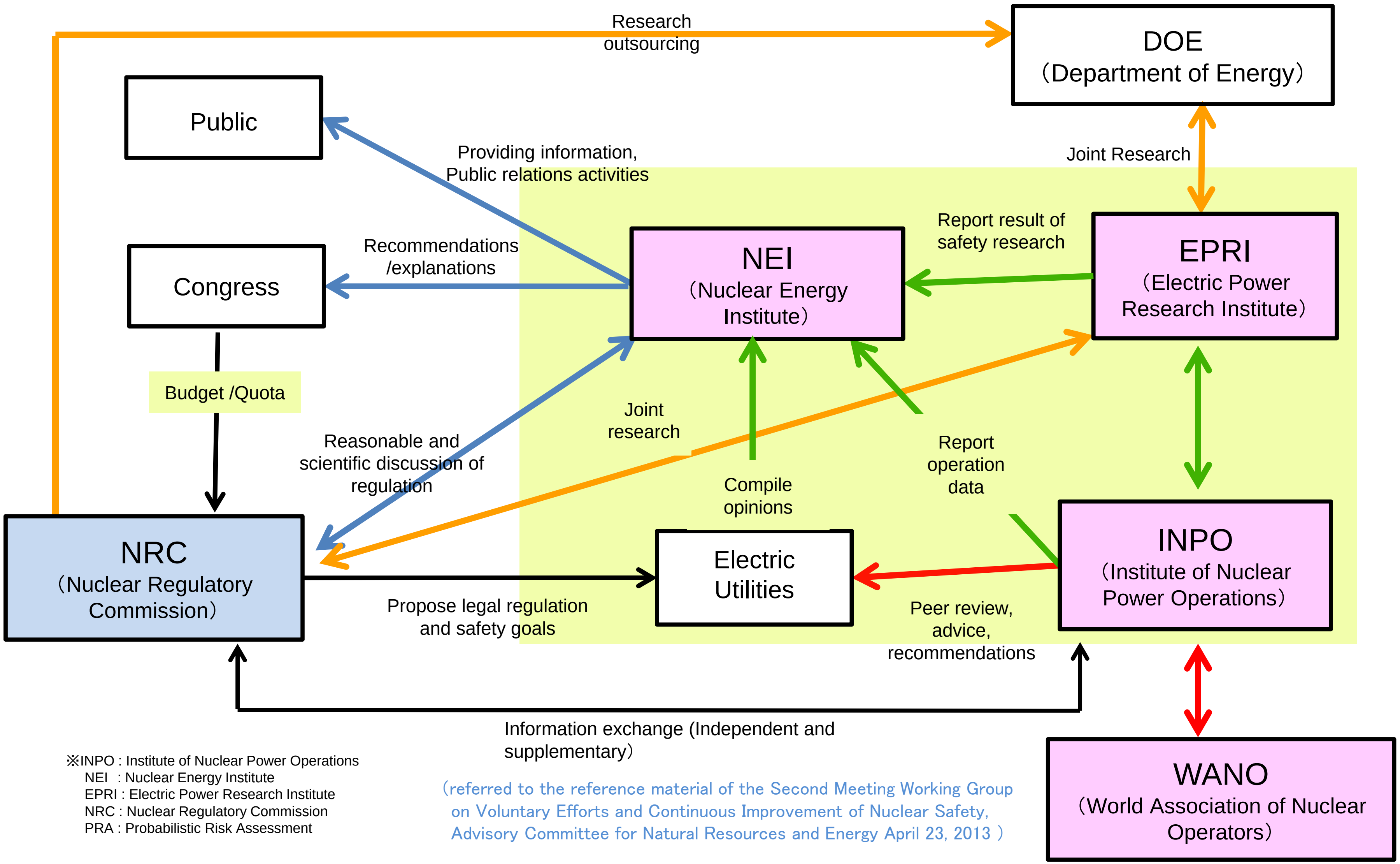
Source: NEI

International comparison of capacity factors



Source：IAEA,Power Reactor Information System(PRIS)

Risk Management Mechanism in US Industry



※INPO : Institute of Nuclear Power Operations
NEI : Nuclear Energy Institute
EPRI : Electric Power Research Institute
NRC : Nuclear Regulatory Commission
PRA : Probabilistic Risk Assessment

(referred to the reference material of the Second Meeting Working Group on Voluntary Efforts and Continuous Improvement of Nuclear Safety, Advisory Committee for Natural Resources and Energy April 23, 2013)

Source: adapted from METI

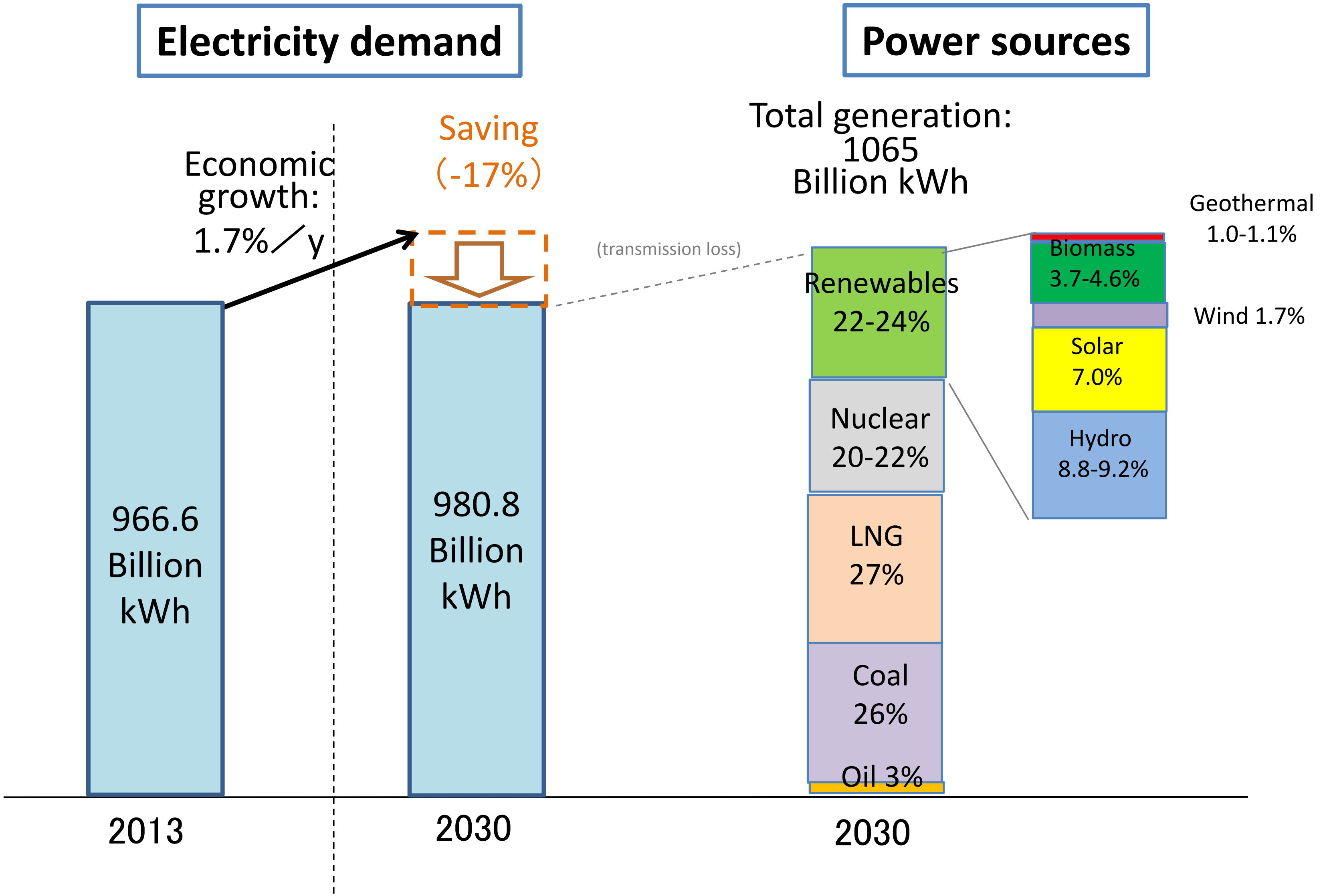
Improvement of risk management and regulation in Japan

Established Nuclear regulatory authority/agency (NRA)
Separation of promotion and regulation
Independent regulatory body

Safety is primary responsibility of utilities
Improvement by Japanese industries:
Established JANSI (Japan Nuclear Safety Institute)
NRRC (Nuclear Risk Research Center)
ATENA(Atomic Energy Association)

Reactor oversight process (ROP) started at NRA

Electricity demand and supply outlook in 2030 in Japan



Source; Long-term energy supply and demand outlook, July 2015 METI

Administrative Organizations for Nuclear Energy Policy

Cabinet Office

Japan Atomic Energy Commission (JAEC)

Discuss and form a plan on:

- Policy on nuclear energy research, development and utilization
- Important policy matters on nuclear energy utilization e.g., coordination among relevant ministries on nuclear energy research, development and utilization

Basic Guidelines, Decisions, Statements, Views etc.

↓

Ministries that own individual policy matters

Cabinet Office
- *Nuclear Disaster Prevention*

MOFA
- *Foreign policy on nuclear science and Peaceful use of nuclear energy*

MEXT
- *Policy on nuclear science*
- *Nuclear fusion and nuclear applications*

METI
- *Policy on nuclear energy*
- *Nuclear fuel cycle*
- *High level RW*
- *Fukushima Daiichi*

MOE
NRA
- *Nuclear regulation*
- *N. Security Safeguards*

Thank you