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International Thorium Seminar,
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Thorium and Environmentally Compatible Energy Strategy

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Outline

- Energy Situation in Japan and the World
- Significance of Thorium in Energy Market

Energy Policy Challenges after the Fukushima in Japan

Nuclear

Decommission of Fukushima, Radiation-tainted water problem, Difficulty in restarting, Public acceptance, Waste management, Effective nuclear regulation , Act on Compensation for Nuclear Damages, Development of human resources in nuclear technology

Fossil fuels

LNG import increase, LNG price rising, Asian premium, Trade imbalance

Energy Geopolitics

Middle-East uncertainty, Northeast Asian tension in political issue, Competition over resource equity, Sea-lane security such as in Malacca and Hormuz Strait

Renewables

Feed-in-tariff (FIT) sustainability, Grid connection, Control of surplus power from intermittent sources

Climate Change

Nuclear suspension and CO2 surging, Post-Kyoto dropout

Electricity market

Rising retail electricity price, Power sector reform

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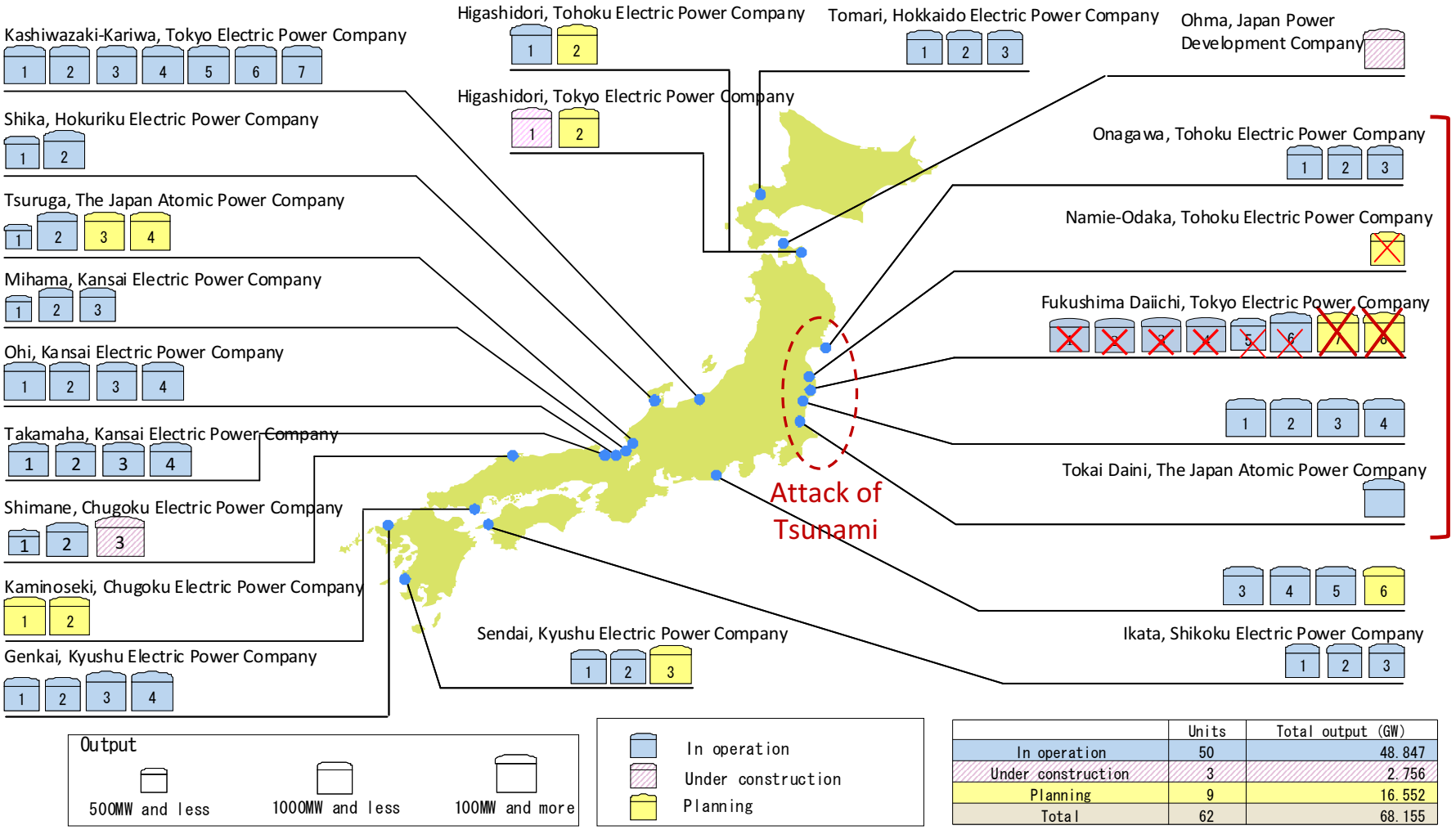
Nuclear Power Plants in Japan after the Fukushima

(As of April 2013)



	Units	Total output (GW)
In operation	50	48.847
Under construction	3	2.756
Planning	9	16.552
Total	62	68.155

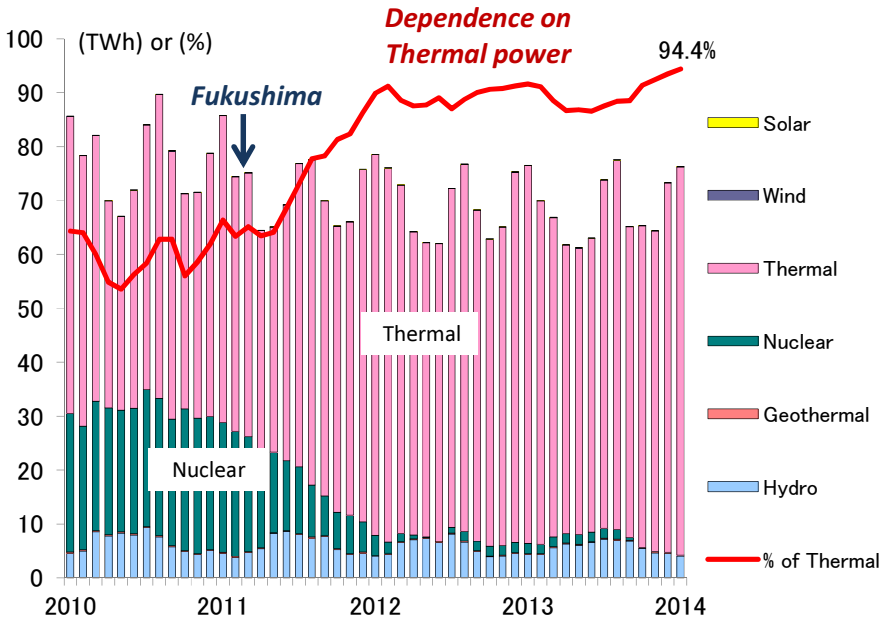
(Source) FEPC(Federation of Electric Power Companies Japan), IEEJ

【Permanent Shutdown】
Tokai:The Japan Atomic Power Company (1998)
Hamaoka No1,No2:Chubu Electric Power Company (2009)
Fukushima Daiichi No1,No2,No3,No4,No5,No6:Tokyo electric power company (2011-2013)

Japan's Power Generation Mix after the Fukushima: Increasing Dependence on Fossil fuel

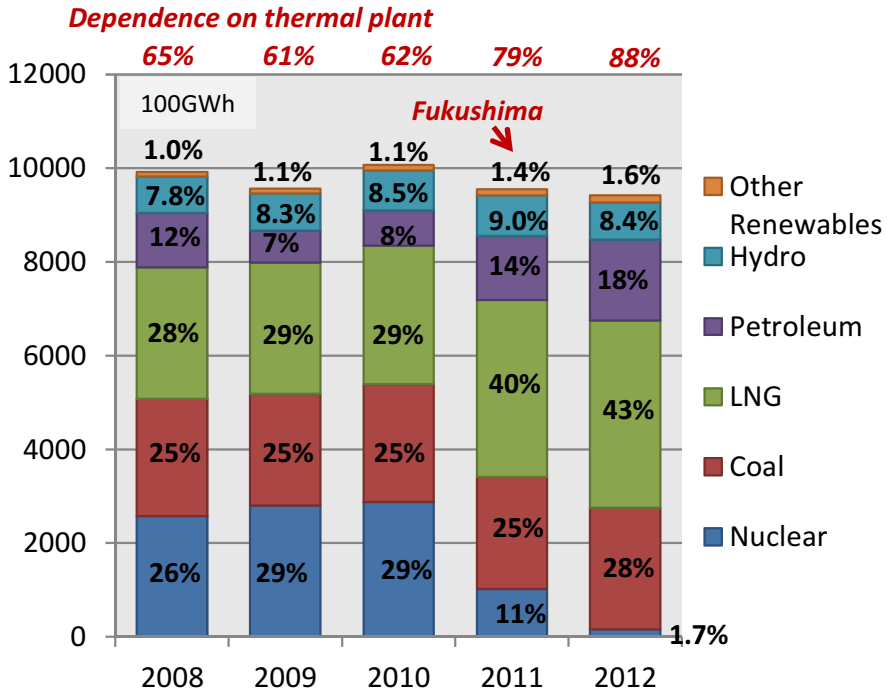
- Since the utilization of nuclear power generation significantly declined after the earthquake due to the accident and the political reason, the fraction of fossil fuel over total power generation reached at the highest level in the last three decades (94.4% in Jan.,2014).
- Nuclear is mainly replaced by LNG and petroleum, expensive fossil fuel.

Monthly Power Generation Mix



(Source) Ministry of Energy, Trade and Industry (METI): Monthly Power Generation Statistics

Power Generation Mix



(Source) FEPC (The Federation of Electric Power Companies of Japan) statistics

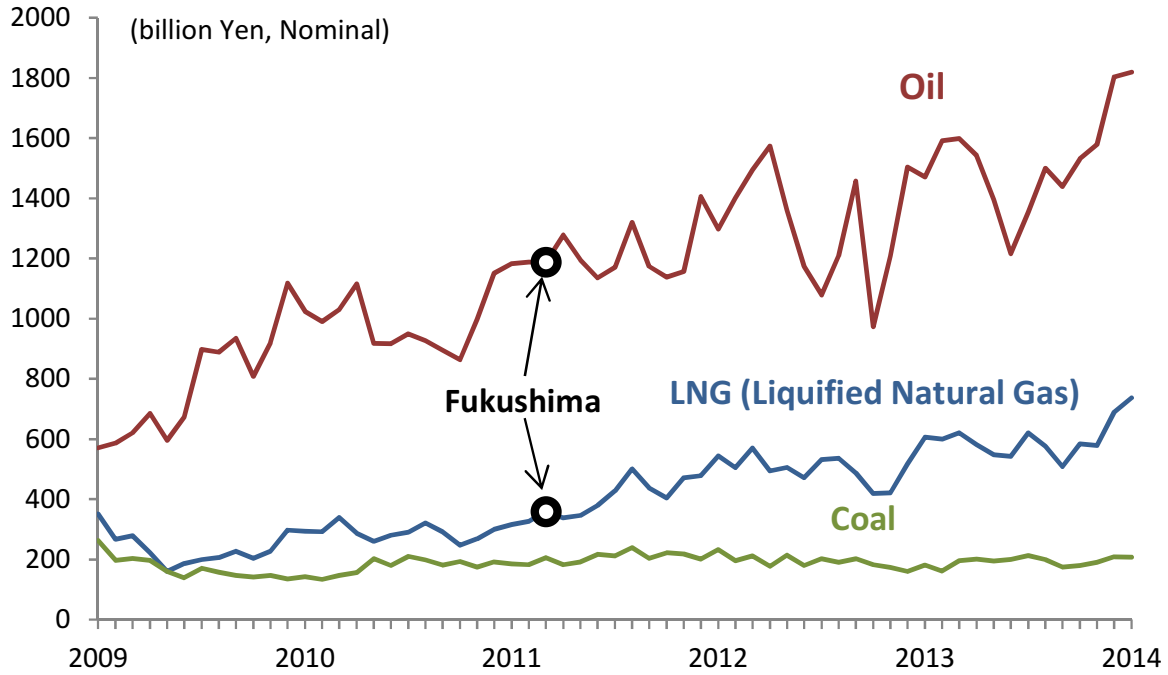
Surging Fuel-Import Cost in Japan after the Fukushima

Nuclear suspension after Fukushima causes soaring fuel-import cost

Fuel import cost in Japan

2009 :	14 trillion yen
2010 :	17 trillion yen
2011 :	22 trillion yen (+5 trillion yen from 2010)
2012 :	24 trillion yen (+7 trillion yen from 2010)
2013 :	27 trillion yen (+10 trillion yen from 2010)

Fuel Import Cost in Japan before and after the Fukushima



(Source) MOF (Ministry of Finance Japan): Monthly Trade Report

**1 $ ≒ 100yen*

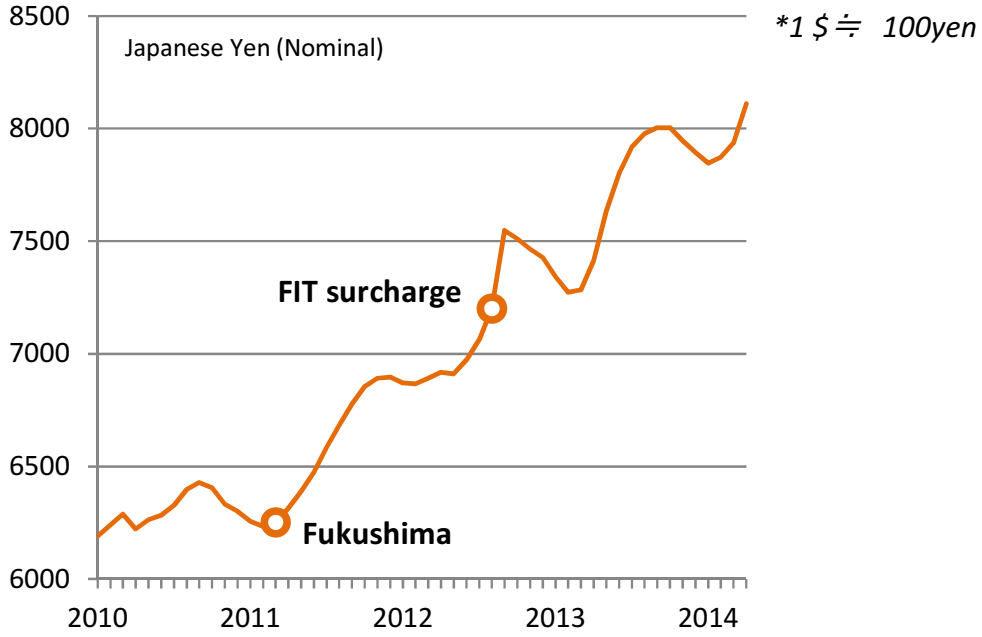
Soaring Electricity Bill in Japan After the Fukushima

Impact of Increasing Electricity Cost on Industry and Household (Source: IEEJ, Apr, 2012)

- **For Industry**
  - If electricity rates increase by **15%** due to continuous shutdown of nuclear**,** the income (operating income margin) of the steel industry will decrease by **0.4%.** Cement and general machinery industries will also suffer from **0.2%** reduction of operating income margin.
  - Higher electricity rates would deteriorate the Japanese industries' competitiveness.
- **For Household (Electricity bill)**

  If electricity rates for households increase by **10%,** the annual additional payment per household will be about **8000 yen**.
- Continuous nuclear suspension will decrease GDP by 0.5% (30 US$ billion) and cause Loss of 50,000 job opportunity

Monthly Household Electricity Bill in Tokyo



(Source) TEPCO (Tokyo Electric Power Company)

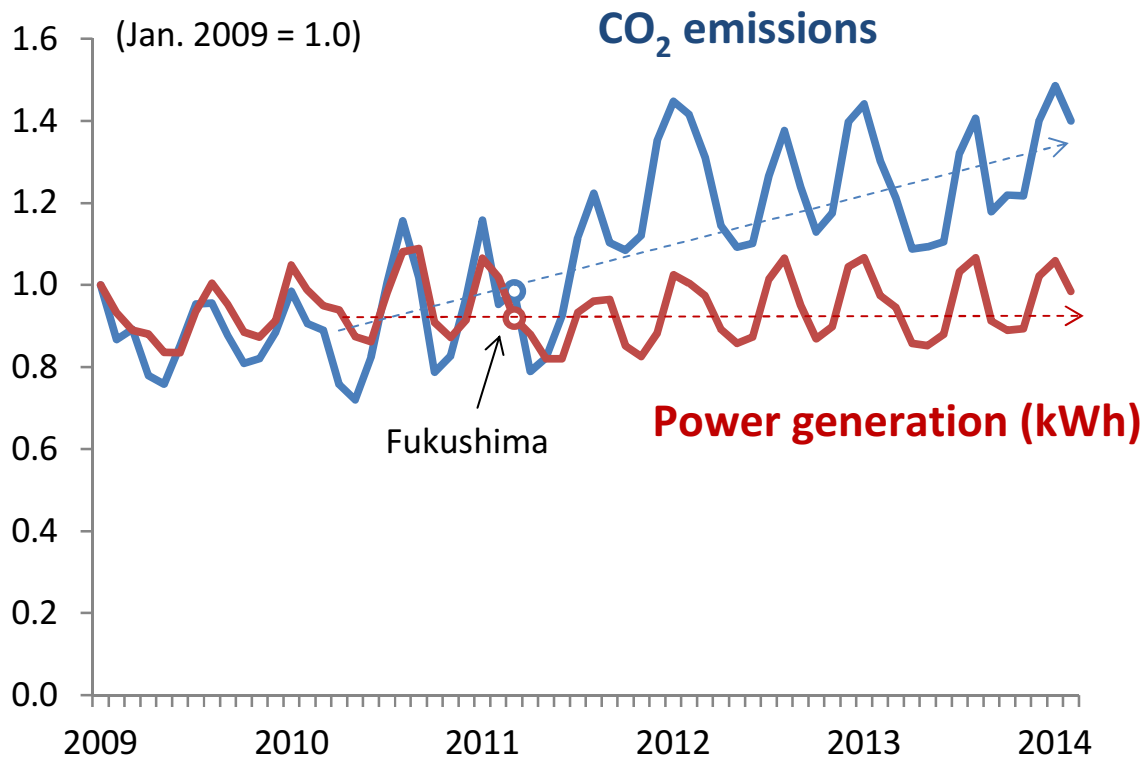
Nuclear Suspension Increases CO_2 in Power Sector After the Fukushima

After Fukushima, CO_2 emissions in power sector rapidly increase, despite of national concerted effort for electricity saving

→ **After Fukushima**

	FY1990	FY2008	FY2009	FY2010	FY2011	FY2012
Electricity demand(TWh)	659	889	859	906	860	852
CO2 emissions from electricity(Mt-CO2)	275	395	353	374	439	486
CO2 intensity (kg-CO2/kWh)	0.417	0.444	0.412	0.413	0.510	0.571

(Source) FEPC(Federation of Electric Power Companies Japan)



(Source) Estimated from "METI: Monthly Electricity Report"

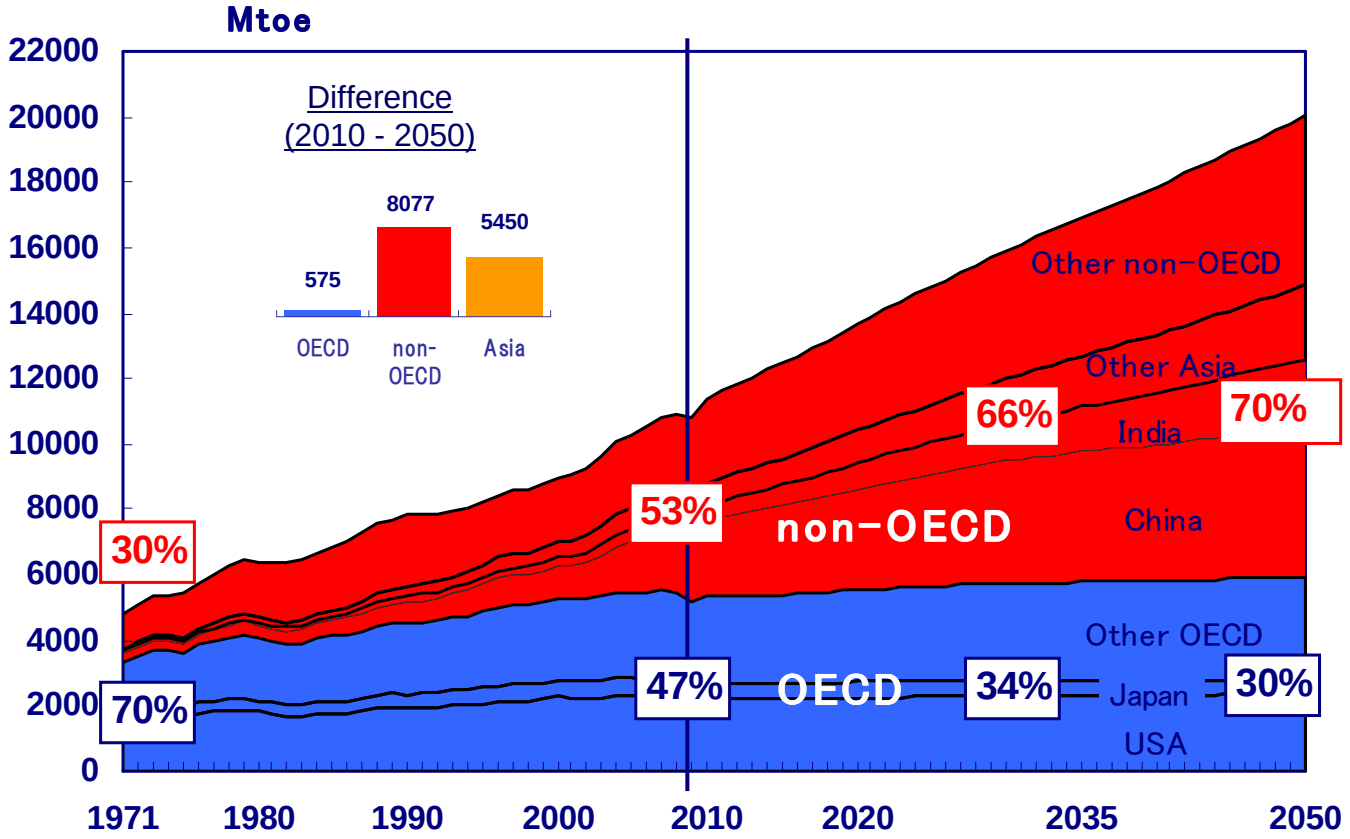
Risks in Global Energy Market

- **Growing energy demand & imports in emerging countries**
- **Competition of access to energy resources**
- **Impact of unconventional fuel (shale gas, tight oil) on global power balance (USA, Middle East, Russia)**
- **Increasing geopolitical risks (*nuclear issues in Iran, political instability in Middle East, …*)**
- **Energy supply constraints**

  - **Investment risks in resource exploration and development**
  - **Instability of energy transportation and sea lane security**
  - **Market liberalization and environmental constraints**

Primary Energy Demand (World)

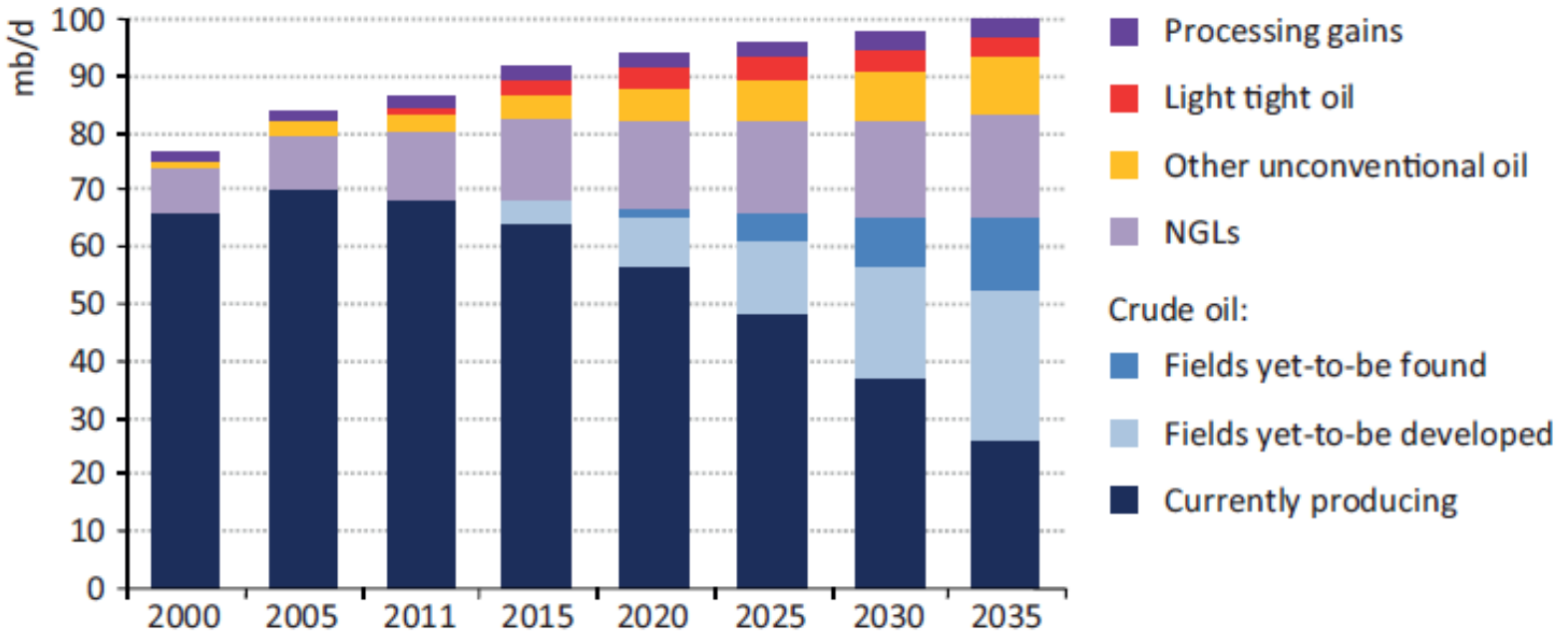
- Energy demand is expected to grow in emerging countries, particularly in developing Asian region including China and India.
- Growing demand will rise concern on energy supply, environmental pollution related to energy use not only for the country but also for international market.



(Source) IEEJ, Asia/World energy outlook 2013, 2013

World Oil Supply by Type

- Crude oil production from existing oil fields will decline by two-thirds by 2035 from the current level.
- World oil production will shift to smaller fields and deep-water developments, where the exploration and development cost is more expensive than conventional fields



(Source) IEA, WEO2012, OECD, Paris

Crude Oil Price

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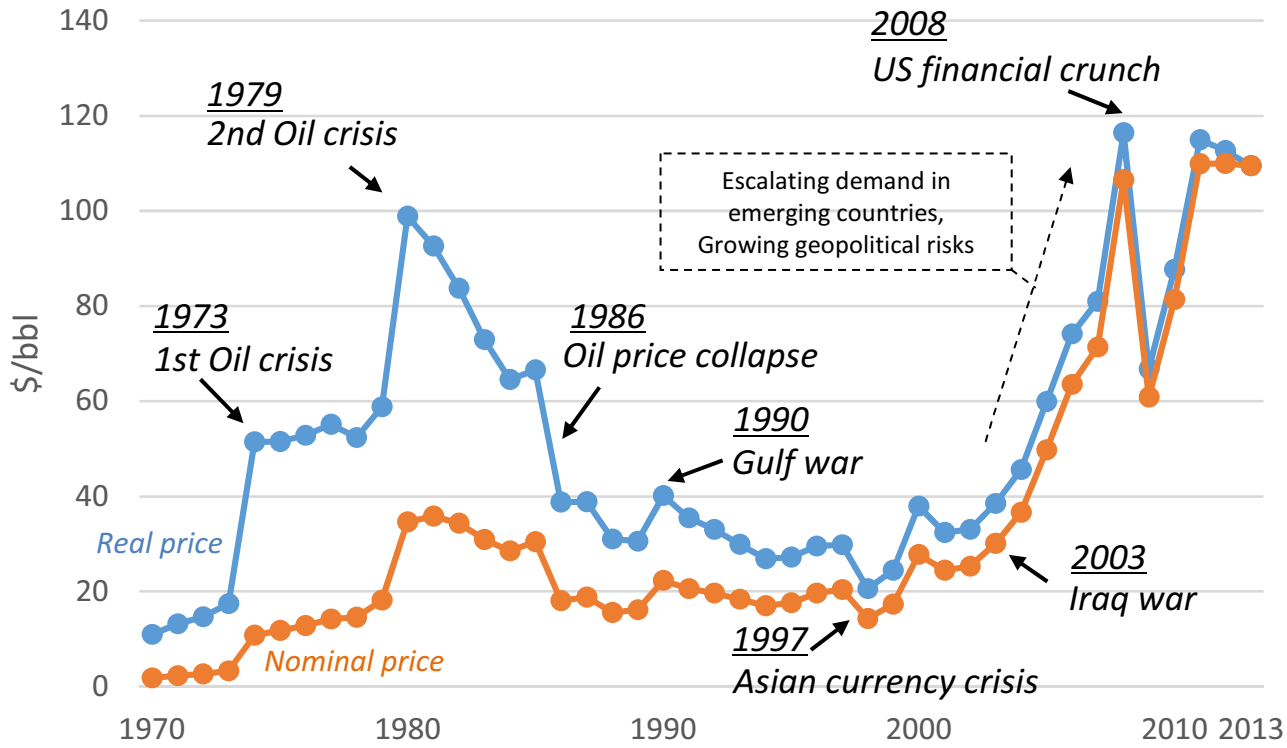
- Crude oil price is one of most influential factors in energy market.
- International crude oil price has largely fluctuated so far and recently shown steep rise, backed by the concern for energy supply constraint and geopolitical risk in Middle East and North Africa.
- Large variation of energy price hinders smooth investment for energy resource development and related infrastructure.

Crude Oil Import CIF Price in Japan

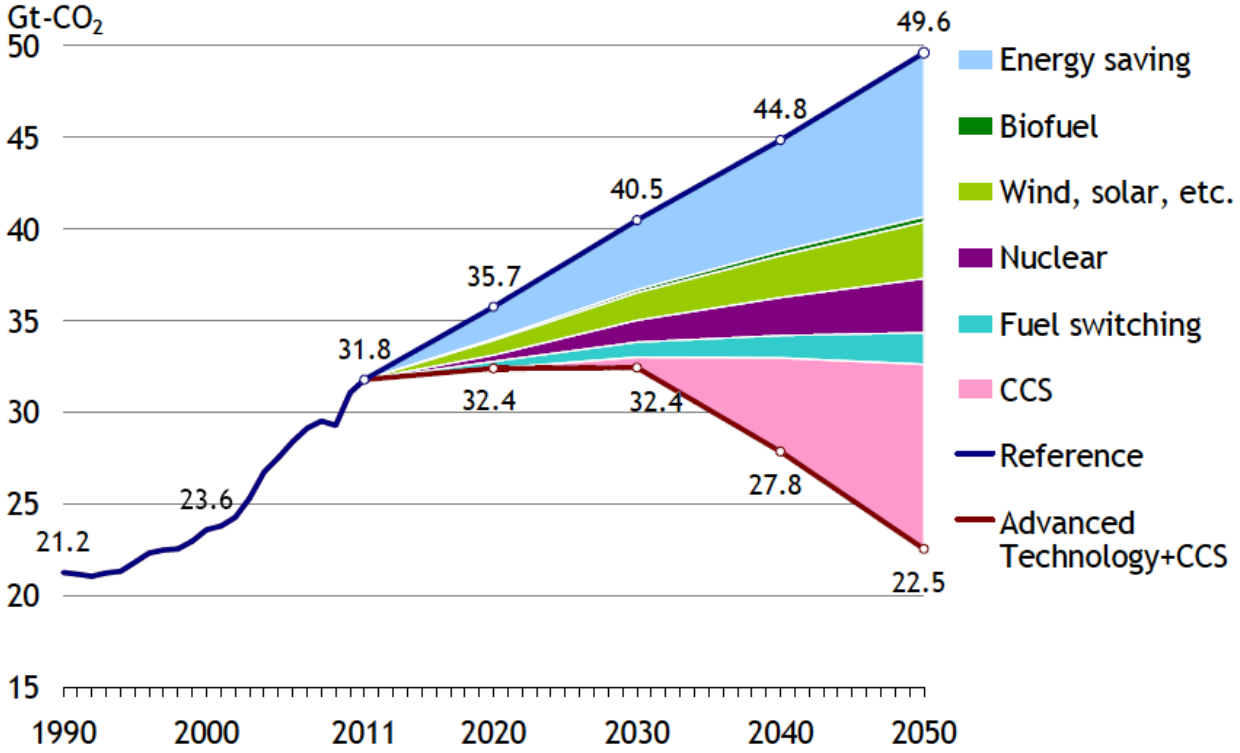


(Source) MOF: Monthly Trade Report

Global CO_2 Emissions (by Reduction Measure)

- Renewable energy, fuel switching (from coal and oil to natural gas), nuclear, energy saving and CCS could potentially play a crucial role to massively mitigate world carbon dioxide emissions.
- In order to halve global CO_2 emissions from present levels, various measures will be indispensable.

⇒ There is no single panacea (solution) for climate change issues, and thorium is considered to be one of important future technologies for addressing it



(Source) IEEJ, Asia/World energy outlook 2013, 2013

Nuclear Power Plant (NPP) in Asia and the World

- In the world, 30 countries possess 429 commercial nuclear power reactors with a total installed capacity of 388 GW, and 76 additional nuclear power reactors (78 GW) are under construction, equivalent to 20% of present capacity, while 97 units are firmly planned equal to one-third of present capacity.
- In Asia 49 nuclear power plants with a capacity of 53 GW are under construction in Asia, suggesting world NPP construction concentrated on Asian regions.
- NPP capacity in Asia under both construction and planning is 103 GW. NPPs 103 GW is equal to 93 million tons of LNG.

*Assumed operating ratio of NPP: 80%, Assumed conv. Eff. of LNGCC: 55%

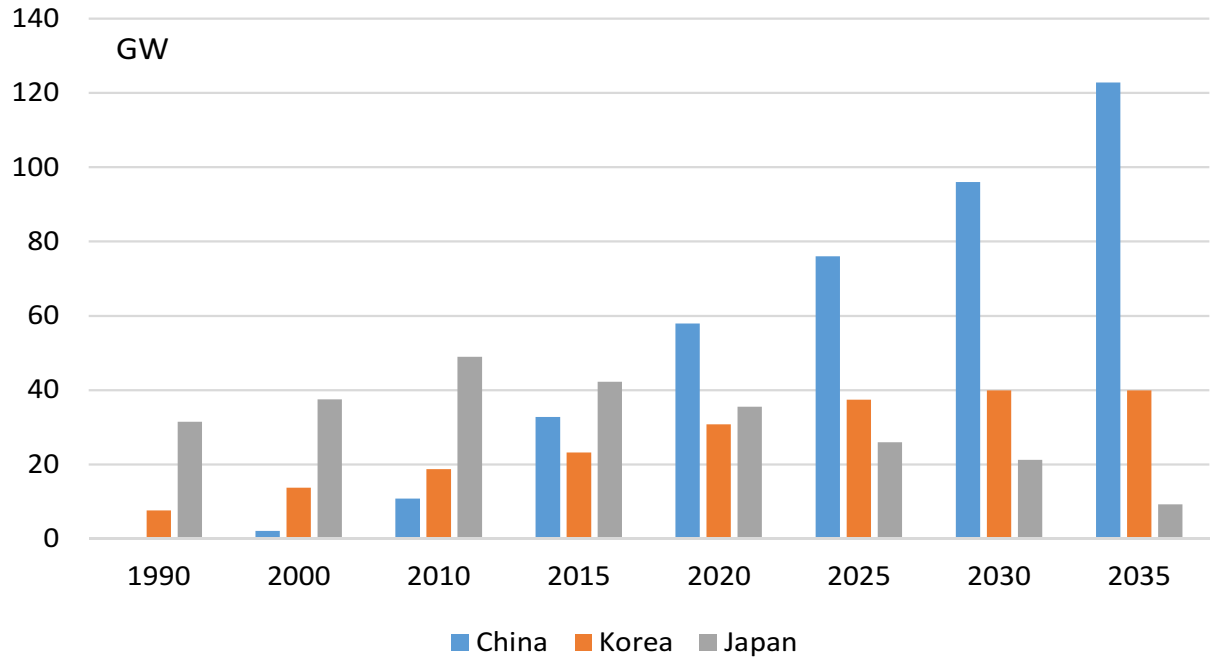
**LNG import (2013): Japan 87 mil. ton, Korea 37 mil. Ton, Asia 167 mil. ton

Output [GW]	In Operation		Under Const.		Planned		Total	
	Output	Units	Output	Units	Output	Units	Output	Units
Japan	46	50	4	4	12	9	63	63
South Korea	21	23	5	4	7	5	33	32
China	13	15	35	32	26	23	73	70
Chinese Taipei	5	6	3	2	0	0	8	8
India	5	20	5	7	5	4	15	31
Asia Total	89	114	53	49	51	41	193	204
USA	107	104	1	1	11	9	118	114
France	66	58	2	1	0	0	68	59
Russia	25	29	10	11	18	17	54	57
World Total	388	429	78	76	111	97	577	602

(Source) JAIF (Japan Atomic Industrial Forum, Inc.), World Nuclear Power Plants, 2013

Nuclear Energy Outlook in East Asia

- Even after the Fukushima nuclear disaster, considerable growth of nuclear energy utilization in the part of Asian countries is projected in the long-term perspective
- The nuclear expansion in Asia is mainly expected in China and Korea. Both countries adopt policies progressively promoting nuclear power.
- China is expected to show the largest growth in nuclear power capacity, adding 114 GW of capacity by 2035, and Korea is projected to add 21 GW of new capacity by 2035.
  - In China, the 12th Five-Year Plan for Energy Development describes targets for the future development of nuclear. The number of nuclear power plants will increase from current 15 to 25 by 2015.
  - The government plans to install nuclear capacity to 58 GW by 2020, while 32 new reactors are under construction and 23 reactors are under firmly planning.



(Source) IEEJ/APERC, APEC Energy Demand and Supply Outlook 5th Edition, 2013

Power Generation Mix to 2100 (World and Asia)

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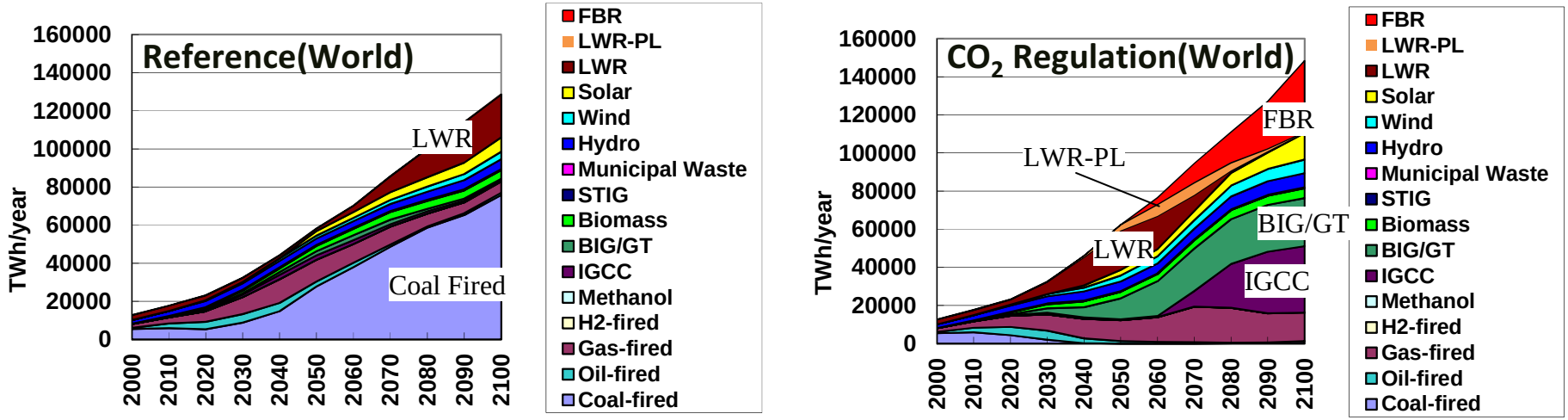
Reference Case: Nuclear will increase in the latter half of the century, reflecting on the depletion of conventional fossil resources.
CO2 Regulation Case: Nuclear will expand due to its economic competitiveness under global CO2 constraints. Biomass and Coal (Coal-IGCC with CCS) become also attractive. Due to the uranium resource depletion constraining LWR usage, nuclear expansion is driven by FBR with nuclear fuel cycle in the latter half of this century.

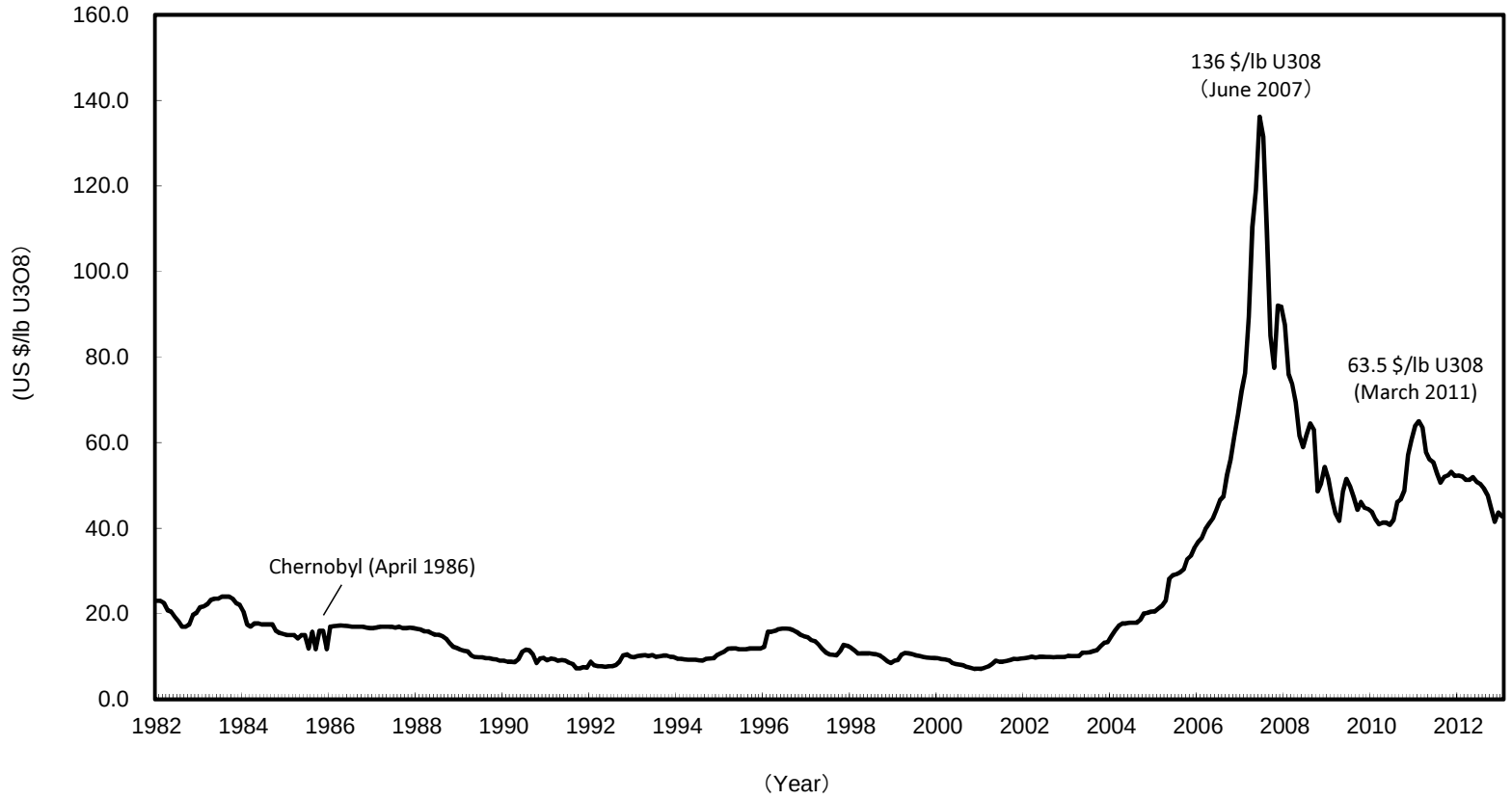
In the last half of the century, uranium resource constraint might potentially pose a challenge for sustainable use of nuclear energy.



(Source) S.Sharma, R.Komiyama, Y.Fujii, *Journal of Env. Sci. & Eng.*, A1, pp.1215-1232 (2013)

Spot Uranium (U_3O_8) Price

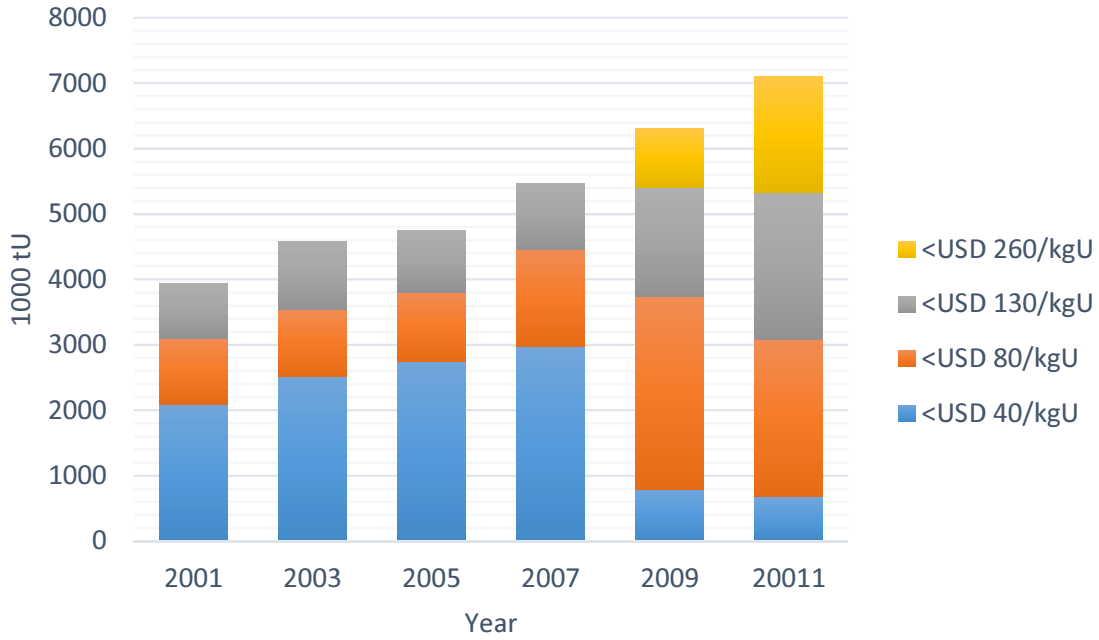
Since 2004, uranium price has considerably increased reflecting on tight uranium supply, decreasing secondary supplies (inventories, weapon), massive procurement of uranium concentrate by China, global intensive quest for uranium equity, speculative fund channeled into spot market.



(Source) International Monetary Fund, Uranium price

Uranium Identified Resources 2001-2011

- Uranium identified resources show a growing trend. However, production cost of uranium have increased and the economically affordable resource (< 40$/kgU) exhibits a decreasing tendency.
- On a resource basis, total identified uranium resources are currently abundant enough to provide a uranium supply more than 100 years based on current uranium production (total uranium production in 2010: 54.7 (1000 tU)).
- Challenge for uranium production countries like Kazakhstan, Canada, Australia, Niger, Namibia and Uzbekistan is to implement an sufficient financial investment for ensuring stable uranium production



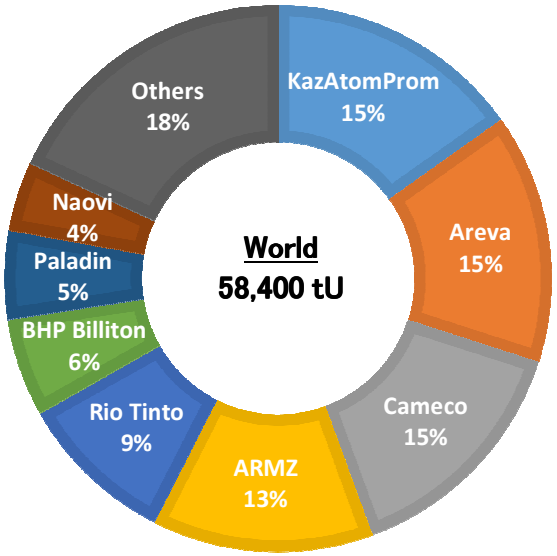
(Source) OECD/NEA "Uranium 2011: Resources, Productions and Demand" 2011 etc.

World Uranium Production and Enrichment by Company

- World uranium production and enrichment are in oligopoly; a small number of companies or countries dominate the market.
- Particularly in enrichment service, only four large suppliers (Rosatom, Urenco, USEC, Eurodif) hold more than 90% of the market.

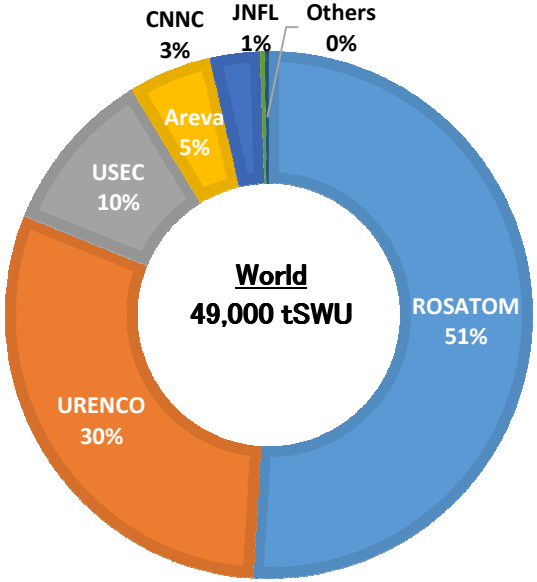
⇒Securing nuclear fuel supply is important agenda. One of important measures to strengthen nuclear fuel supply is developing alternative source like thorium

Grobal Uranium Production



(Source) WNA(World Nuclear Association), World Uranium Mining Production, WNA website

Global Enrichment Capacities

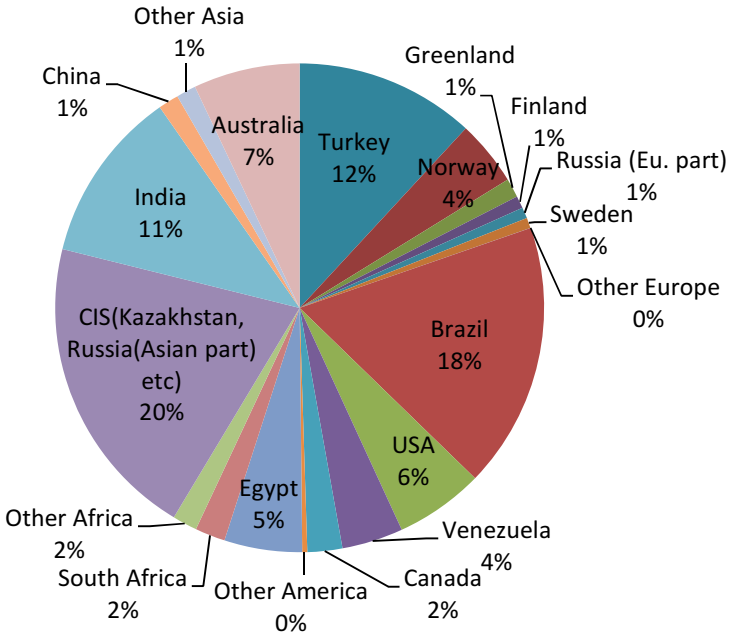


(Source) WNA(World Nuclear Association), Uranium Enrichment, WNA website

Thorium Resource in the World

- Identified thorium resource is estimated to be from 673 mil. ton to 759 mil. ton, which is comparable to total identified uranium resources (reasonably assured and inferred resource), 533 mil. tU (OECD/NEA(2011)).
- Thorium resources are widely spread in the world; the situation is totally different from crude oil which resource is heavily concentrated on Middle eastern countries.
- Among thorium-rich countries, USA, Australia, Brazil, Canada, Norway, Russia and Kazakhstan are major countries which are endowed with large oil and natural gas reserves, while India faces domestic rapidly-increasing energy demand.

Global Thorium Resource Endowment by Country

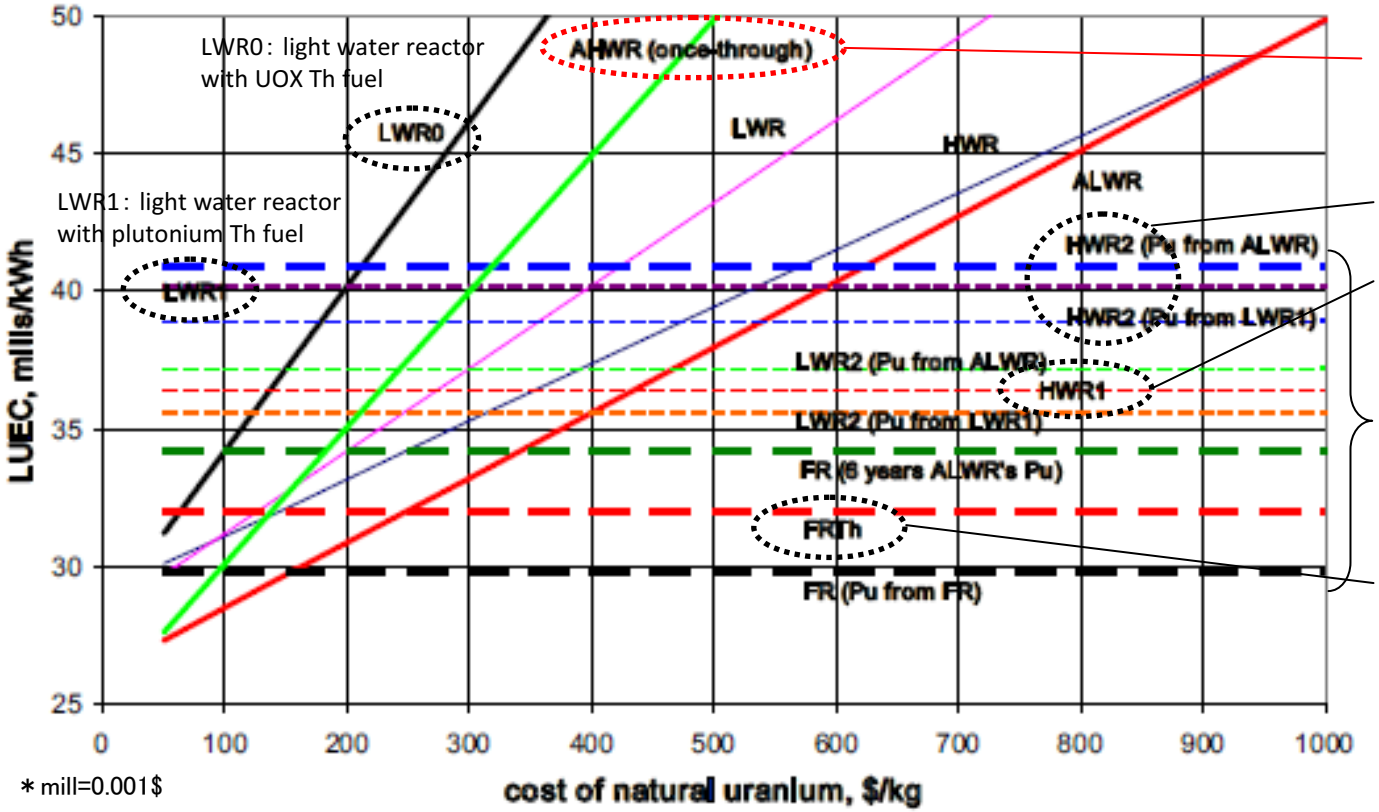


(Source) OECD/NEA "Uranium2011:Resources, Productions and Demand" 2011

Power Generation Cost of Thorium

- A thorium reactor, AHWR, in a once-through fuel cycle is potentially economically competitive with conventional nuclear reactors, depending on the cost of natural uranium.
- If the cost of natural uranium significantly increases, thorium fuel cycle technology is estimated to be cost-competitive against conventional once-through fuel cycle technology

Levelized unit energy cost (LUEC) of Nuclear depending on Uranium Cost



AHWR : advanced heavy water reactor with plutonium, U233, thorium fuel (Once-through)

HWR2 : heavy water reactor with plutonium, Th, 233U fuel

HWR1 : heavy water reactor with plutonium thorium fuel

Reactors using reprocessed fuel (LWR1, LWR2, HWR1, HWR2, FR and FRTh)

FRTh : fast reactor with plutonium, depleted uranium fuel, and thorium in blankets

* mill=0.001$

(Source) IAEA, Role of Thorium to Supplement Fuel Cycles of Future Nuclear Energy Systems, No. NF-T-2.4, 2012

Conclusion: Significance of Thorium Technology Development

- **Thorium technology development has a significance in following contexts:**
  - **Alleviating the resource constraint of fossil fuel and uranium**
  - **Potentially preventing energy price escalation (theory on backstop technology)**
  - **Realizing sustainable energy development**
  - **Encouraging the advancement of new industry**
  - **No single panacea (solution) for energy security and climate change, and technological portfolio is important**

⇒ Thorium is one of various important technological options in global energy market

- **Continuous elaborate effort for R&D and public acceptance is indispensable for the actual future deployment of thorium technology in energy market**

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Thanks for your kind attention.

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