World nuclear energy renaissance and Japan's policy

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Abstract: The role of nuclear energy has been revaluated from an energy security and global warming perspective. Many nuclear power generating countries are expanding nuclear power development and a growing number of countries are embarking upon nuclear plant building projects. The world's growing market of nuclear plants has brought about a re-organization of major nuclear power plant vendors. The Japanese government has been developing nuclear power, terming it as an essential pillar to realizing a low-carbon society in the mid- to long- term.

Keyword: nuclear power, nuclear energy, global warming, climate change, energy security, low-carbon energy, low-carbon society

1 Introduction

Facing a pessimistic forecast for the 21st century as characterized by the dilemma of avoiding potential environmental degradation due to global warming via the excessive use of fossil resources while continuing the pursuit of rapid economic growth, the role of nuclear power has been re-evaluated from various aspects depending on each developed and developing country's situation all over the world. This trend of the re-emergence of nuclear power is termed "nuclear renaissance" by many veterans in the nuclear field who remember the long 'ice age' of nuclear energy in 1980-2000 after the TMI-2 and Chernobyl accidents.

In this article, the new world trend of nuclear renaissance will be reviewed from diverse sources of energy information around the world as listed in the references which cover almost all the sources utilized in this article, and thereafter the prospect for Japan's nuclear power policy will be discussed in order to face the nuclear renaissance, where the change of the ruling party occurred after the landslide victory of the Democratic Party of Japan (DPJ) in the general election held in August 2009, against the Liberal Democratic Party (LDP) which had been the ruling party in Japan for over half a century since 1955.

2 Energy and environmental trend

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2.1 Increasing energy and electricity demand

The world's energy demand continues to increase, due to population growth and economic development, especially in the developing countries.

According to the "World Energy Outlook 2008" (WEO-2008) published in November 2008 by the International Energy Agency (IEA), projected world primary energy demand in the reference scenario grows by 45% between 2006 and 2030 - from 11,730 Mtoe to 17,014 Mtoe (refer to Table 1).

The energy demand in the advanced countries; the so-called OECD member countries, increases by a factor of 1.12 in 2006-2030 (*i.e.* annual increase rate of 0.5%), a rather gradual increase compared with the 1.76 factor increase (*i.e.*2.4% per year) of the non-OECD countries, mainly comprising developing countries. The energy demand of Asian countries excluding Japan and Korea increases by as much as 1.96 times (*i.e.*2.8% per year).

As a result of strong economic growth, Asian countries except Japan and Korea account for 59% of the incremental world primary energy demand in 2006-2030, with China and India accounting for 38% and 14% respectively. Many Asian countries depend on energy imports from overseas due to them being relatively poorly-endowed with sufficient energy resources to meet their energy demand. Energy security poses a big challenge.

The world's electricity demand shows a similar trend, but its increase rate is greater than that of the primary energy demand by reason of its convenience.

Projected electricity demand of Asian countries except Japan and Korea grows rapidly in the same way. Electricity demand of China has increased by 14% per year since 2000. Though MWh consumption growth of China is expected to slow in the future, the average annual growth rate is predicted at 7.6% till 2015 and at 4.6% till 2030 (See Table 2).

In order to meet increasing electricity demand, China has been building new power plants with a total output of several dozen GWe every year. New power plants with a total output of as much as 100 GWe started operation in 2006 and by the end of 2009 the total generating capacity in China had reached 874 GWe.

Worth-mentioning, the projected average annual electricity consumption per-capita in developing countries increases by about two-fold in 2006-2030, reaching 2,400 kWh in 2030, whereby China reaches about 4,800 kWh, India about 1,200 kWh and Africa about 700 kWh. The average annual electricity consumption per-capita in developing countries is far less than the present consumption in advanced countries, which is 7,600 kWh.

Electrification ratios (percentages of population with access to electricity) in 2005 are on average 73% for developing countries in Asia (notably, China 99%, India 56%), 38% for Africa, and 90% for Latin America.

Extensive utilization of electricity is indispensable for the improvement of living standards in developing countries. India aims at supplying electricity to all of its households by 2012.

Table 1 World primary energy demand by region

Unit: Mtoe

	Region	2000	2006	2015	2030	2006－2030	
						Increment(share: %)	Increase factor (annual rate: %/year)
OECD	OECD	5,325	5,536	5,854	6,180	644(12)	1.12(0.5)
	North America	2,705	2,768	2,914	3,180	412(8)	1.15(0.6)
	Europe	1,775	1,884	1,980	2,005	121(2)	1.06(0.3)
	Pacific	845	884	960	995	111(2)	1.13(0.5)
Non-OECD	Non-OECD	4,563	6,011	8,067	10,604	4,593(87)	1.76(2.4)
	E.Europe & Eurasia	1,015	1,118	1,317	1,454	336(6)	1.30(1.1)
	Asia	2,191	3,227	4,598	6,325	3,098(59)	1.96(2.8)
	China	1,122	1,898	2,906	3,885	1,987(38)	2.05(3.0)
	India	460	566	771	1,280	714(14)	2.26(3.5)
	Middle East	389	522	760	1,106	584(11)	2.12(3.2)
	Africa	507	614	721	857	243(5)	1.40(1.4)
	Latin America	460	530	671	862	332(6)	1.63(2.0)
	World Total	10,034	11,730	14,121	17,014	5,284(100)	1.45(1.6)

Source: World Energy Outlook 2008, IEA, Nov. 2008

Note: World Total includes international marine bunkers.

Table 2 World final electricity consumption by region

Unit: TWh

Region		2000	2006	2015	2030	2006－2030	
						Increment(share:%)	Increase factor (annual rate: %/year)
OECD	OECD	8,251	9,035	10,177	11,843	2,808(23)	1.31(1.1)
	North America	4,144	4,413	4,870	5,774	1,361(11)	1.31(1.1)
	Europe	2,694	3,022	3,469	3,980	958(8)	1.32(1.2)
	Pacific	1,413	1,601	1,837	2,089	388(3)	1.30(1.1)
Non-OECD	Non-OECD	4,390	6,630	10,580	16,298	9,668(77)	2.46(3.8)
	E.Europe & Eurasia	1,023	1,165	1,514	1,860	695(6)	1.60(2.0)
	Asia	2,023	3,669	6,574	10,589	6,920(55)	2.89(4.5)
	China	1,081	2,358	4,554	6,958	4,600(37)	2.95(4.6)
	India	369	506	893	1,935	1,042(8)	3.82(5.7)
	Middle East	371	539	793	1,353	814(7)	2.51(3.9)
	Africa	346	479	667	997	518(4)	2.08(3.1)
	Latin America	627	777	1,032	1,498	721(6)	1.93(2.8)
World Total		12,641	15,665	20,757	28,141	1,2476(100)	1.80(2.5)

Source: World Energy Outlook 2008, IEA, Nov.2008

2.2 Global warming issue: challenge for anthropogenic CO_2 emissions reduction

Atmospheric CO_2 concentration increased to 380 ppm in 2005 from about 280 ppm levels early in the industrial revolution in the late eighteenth century, making global warming a big issue.

The fourth Assessment Report released in November 2007 by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, estimates a 6.4ºC rise in global air temperature by the end of the twenty-first century, and warns that global warming could cause irreparable damage unless the temperature rise is limited to within 2-3ºC. The IPCC elucidates the necessity of slashing anthropogenic carbon dioxide emissions by at least half by 2050 in order to mitigate the impacts of global warming. Nuclear energy is among the global warming countermeasure technologies that the IPCC report proposes.

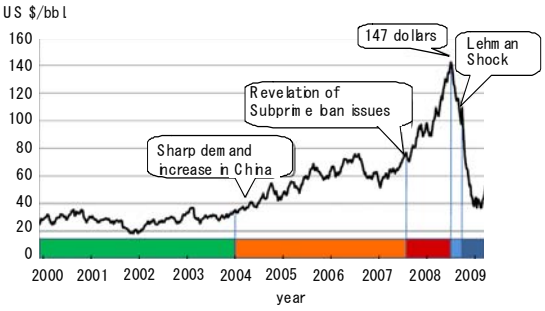
It is a major challenge in the short run to achieve the greenhouse gas emissions reduction targets during the first commitment period from 2008 to 2012 under the Kyoto protocol. A mid and long term response was expected from the Copenhagen COP15 climate change conference held in December 2009, the result of which culminated in an end without consensus, leaving a myriad of global challenges to be solved. The Copenhagen Accord set an objective of a maximum of 2ºC in global temperature increase, but did not stipulate concrete measures for reducing greenhouse gas emissions to attain this objective. Problem-solving was postponed to this year.

2.3 Rising oil price

Global oil demand is envisaged to rise from 4 billion tons (34% of the world's primary energy demand) in 2006 to 5.1 billion tons in 2030 (30%). Fossil fuels including oil, coal and gas, will remain as the major energy sources, accounting for 80% of the world's primary energy mix in 2030.

As seen in Fig.1, oil price had continued to be stable until 2003, being around 20-30 US dollars per barrel, but after 2004 it began to rise due to the outlook for mid- and long-term demand increases in emerging economies such as China, and geopolitical risk factors including the Iraq war. The futures price of crude oil gained high momentum, fuelled by an influx of speculative money, recording a remarkable $147 bbl

in July 2008. It subsequently entered a correction phase and plummeted to $100 in the wake of the financial crisis in September of the same year. It then continued declining to nearly $ 40-50, but currently shows signs of an upward trend. In the medium and long term, concerns about a tight market due to the projected increase in oil demand and concerns about the future supply capacity contribute to higher prices.
Oil price rise adversely affects prices of other fossil fuels, gas and coal. In view of the growing energy demands, economically viable energy sources are being considered extensively.



Source: FY 2008 Energy White Paper, Japan

Fig.1 Changes in the New York crude oil futures market (WTI Crude Oil Prices)

3 Nuclear renaissance

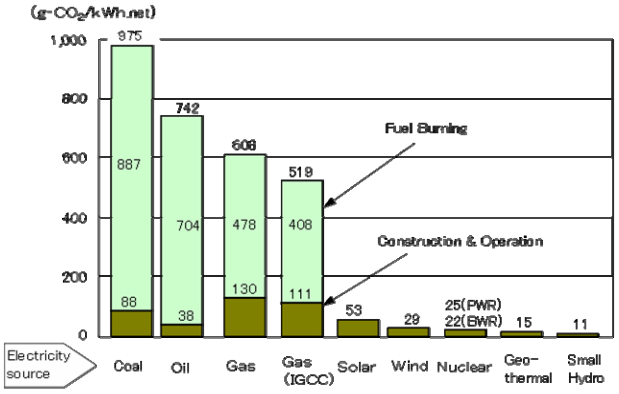
3.1 Features of nuclear power

3.1.1 Green energy (energy not emitting CO_2)

As seen in Fig.2, CO_2 emission per kWh of nuclear power is extremely low, *i.e.* 22g (BWR) or 25g (PWR) in comparison to that of fossil fuel power (about one-twentieth to one-fortieth). For instance, coal-fired plants emit 975g, oil 742g, and LNG 519-608g of CO_2 per kWh. Fossil fuel plants utilize the combustion of carbon, *i.e.* a chemical reaction, whereas nuclear power plants solely utilize a nuclear fission reaction. For this reason, nuclear power is termed a 'zero-carbon' energy or 'zero-emission' power source.

CO_2 emission per kWh is calculated for the whole life cycle - not only during electricity generation but also during mining and transportation of the fuel resources, as well as during the construction and operation of the power plants. Therefore, CO_2 emission per kWh of nuclear power is not zero, but is still lower than for renewable energy sources, *i.e.* solar power (53g) and wind power (29g).
For the operation of a 1 GW power plant for one year, around 7 billion kWh of electricity will be produced assuming a capacity factor of 80%. In this case, a nuclear power plant emits 0.15 million tons of CO_2, a coal plant about 6.8 million tons, an oil plant approximately 5.2 million tons and an LNG plant about 3.6-4.3 million tons per year.

Therefore, the replacement of a 1 GW coal plant by a nuclear plant will contribute to the reduction of CO_2 emissions by more than 6 million tons annually. This figure corresponds to 0.5% of the annual total greenhouse gas emissions of Japan, which is 1,237 million tons of CO_2. In other words, the operation of Japan's 55 nuclear power plants with total capacity of 47GWe will reduce its CO_2 emissions by about a quarter.



Note
* CO_2 emission is calculated based on all the energy necessary for the whole life cycle electricity-generation chain, including mining, transportation and refining of raw fuels, and construction, operation and maintenance of power plants.
* As for nuclear, the currently planned reprocessing of spent fuels, utilization of Pu fuels (MOX fuels, 1 cycle), disposal of high level radioacitive wastes, and decommissioning of nuclear power plants are taken into account.

Source: Central Research Institute of Electric Power Industries (CRIEPI), Japan

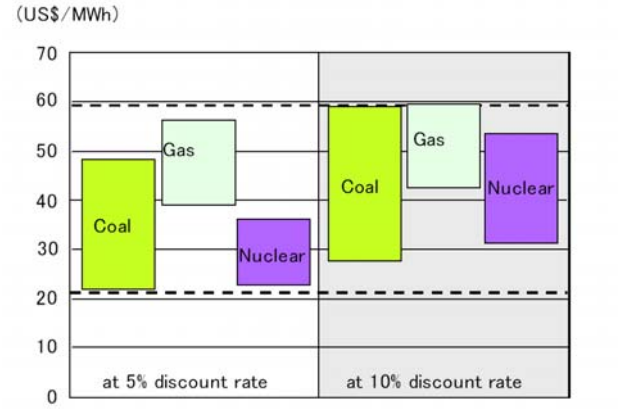
Fig.2 CO_2 emissions of various electricity sources

3.1.2 Supply stability and economics

Unlike oil resources which are located mainly in the geopolitically unstable Middle East region, uranium resources are widely distributed in various countries, having superior supply stability from a political and economical point of view.
The cost of generating electricity has three main components: capital investment, operation and maintenance, and the fuel cycle. Average shares of these components for nuclear electricity are 60%, 25%, and 15%, respectively. The cost of natural uranium itself amounts to only around 5%. Therefore, nuclear power generation cost is very sensitive to the capital cost, but relatively insensitive to its fuel price. In the

case of thermal power, its electricity cost is greatly affected by fuel cost because it occupies a large share, about 70%.

"Nuclear Energy Outlook 2008" published in October 2008 by the OECD Nuclear Energy Agency (NEA) in commemoration of its fiftieth anniversary, explains about nuclear generation cost in one of its chapters under the heading "Providing Electricity at Stable and Affordable Costs". According to a joint NEA and IEA study published in 2005, when oil and gas prices were much lower than today, the cost of generating electricity with nuclear, coal and gas power plants were comparable at 5% and 10% discount rates. (See Fig.3) It can be pointed out that future measures for carbon pricing could further strengthen the viability of nuclear power as compared to fossil fuels.



Source : Nuclear Energy Outlook '08 (OECD/NEA,Oct.2008)

Note
Discount rate: For the purpose of estimating cost-benefit of a long-term investment, the discount rate is used to discount future valuation into the present one. In general, real interest rate or expected rate of return in the process of a project is used for discount rate.

Fig.3 Generation cost by fuel

3.2 Worldwide nuclear renaissance

3.2.1 Nuclear capacity is expected to expand to 470-750 GWe in 2030

The"Atoms for Peace" speech by US President Dwight D. Eisenhower in 1953 triggered nuclear power development for peaceful purposes in the world. The first oil crisis in 1973 and the second crisis in 1978 accelerated nuclear power development, but the US Three Mile Island (TMI) nuclear plant accident in 1979 and the former Soviet Union's Chernobyl disaster in 1986 practically slowed down worldwide nuclear power deployment. World Association of Nuclear Operators (WANO) was established in 1989 and the Convention on Nuclear Safety entered into effect in 1996 to ensure and to improve the safety of nuclear power plants.

In the early part of this century, nuclear power began to be revaluated from the world energy security and global climate change measures viewpoint. Getting out of an 'ice age' period, nuclear renaissance era has begun. An outline of the world's nuclear power development history is shown in Table 3.

The main nuclear-related organizations often release nuclear power capacity projections of the world. Forecast figures for 2030 are shown in Table 4. The figures differ significantly from one another depending on the character of the respective organization.

According to the "Energy, Electricity and Nuclear Power Estimates for the Period up to 2030" IAEA report (2008 edition), the world's nuclear capacity increases to 470 GWe (low estimate) or 750 GWe (high estimate) in 2030, from 370 GWe of 2007. Nuclear power plants of 100 to 380 GWe will be added in 2007-2030 even if aging reactors are not decommissioned. This corresponds to 100 to 380 units of 1 GWe nuclear power plant, - an annual increase of about 4 to 17 units.

As can be seen in Fig.4, the IAEA report predicts that nuclear power expansion of the Far East and the Middle East & South Asia is striking. Asia, especially China and India (including Japan and Korea), plays a pivotal role of a 'traction engine' for nuclear renaissance. It is forecasted that the nuclear generating capacity in the Far East in 2030 will be ranked first in the world, surpassing North America's and Western Europe's nuclear power generating capacity.

A wide range of capacity projections for Western Europe in 2030 are influenced by the phase-out policy of some countries, owing to the fact that replacement of all the nuclear power plants coming to the end of operating lifetime may not be completed by 2030 even if phase-out policy is abolished.

For the same period, Eastern Europe focuses on nuclear power development and its capacity also grows steadily.

Table 3 World nuclear power development history

Development Period		Nuclear units & GWe	Main Events	
Introduction	1950s		1953	US president D.D. Eisenhower gave a plenary address on "Atoms for Peace".
			1954	World's first nuclear power plant (LWGR, 6MWe) started operation in USSR.
			1956	World's first commercial nuclear power plant, Calder Hall-1(GCR, 60MWe), began operation in UK.
			1957	International Atomic Energy Agency (IAEA) was established.
Growth	1960s (8 units per year)	85 units 16 GWe	1963	Japan Power Demonstration Reactor (JPDR, 12MWe) successfully generated electricity for the first time.
			1964	China's first nuclear test was carried out.
			1966	Japan's first commercial nuclear power plant (Tokai-1, GCR, 166MWe) started operation.
			1968	The United Nations passed a resolution supporting the Nuclear Non-Proliferation Treaty (NPT).
Acceleration	1970s (26 units per year)	228 units 131 GWe	1970	NPT was enforced.
			1973	The fourth Middle East War broke out, triggering the first oil crisis.
			1974	India's first nuclear test was conducted.
			1977	US President J. Carter announced a freeze on reprocessing and deferment of FBR development.
			1977	The International Nuclear Fuel Cycle Evaluation (INFCE) was implemented. (～1980)
			1978	The second oil crisis broke out.
			1979	Three Mile Island nuclear power plant accident happened in USA.
Deceleration	1980s (11 units per year)	425 units 335 GWe	1980	Sweden adopted a policy of phasing out nuclear power by 2010 based on a referendum.
			1986	World's worst nuclear accident happened at Chernobyl nuclear power plant in the Ukraine of the USSR.
			1986	IAEA General Conference adopted the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.
			1987	Convention on the Physical Protection of Nuclear Materials came into force.
			1988	Italian government passed a resolution to shut down nuclear plants and to halt construction of new units based on a referendum in 1987.
			1989	World Association of Nuclear Operators (WANO) was established.
Stagnation	1990s (3 units per year)	425 units 359 GWe	1990	Reunification of East and West Germany.
			1991	The Soviet Union collapsed.
			1995	NPT Review and Extension Conference agreed on the indefinite extension of NPT.
			1996	Convention on Nuclear Safety entered into force.
			1997	Kyoto Protocol was adopted at the Third Conference of the Parties to the UNFCCC (COP3).
			1997	IAEA Board of Governors adopted the Additional Protocol.
Renaissance	2000s (5 units per year)	447 units 378 GWe	2005	Construction of a new nuclear plant (Olkiluoto-3) started in Finland. (The first new plant to be built in Europe in 15 years.)
			2008	Italian government confirmed the suspension of the nuclear plant moratorium.
			2008	UK government's White Paper approved nuclear plant construction.
			2008	The declaration of Leaders of G8 Hokkaido Toyako Summit emphasized the importance of nuclear power.
			2009	Swedish government announced the abolition of the nuclear phase-out policy.
			2009	US President B. Obama's speech in Prague on nuclear non-proliferation and disarmament.

Note: Parenthesis means average annual new build. Nuclear units & GWe shows the total number and capacity of operating nuclear power units at the end of the period. As for the 2000s, the numerical figures are those as of February 11, 2010.

Table 4 Estimates of the world's nuclear power capacity in 2030

Organization : Report	GWe
International Energy Agency (IEA) : World Energy Outlook 2006 (WEO 2006)	416 ～ 519
US Department of Energy's Energy Information Administration (DOE/EIA) : International Energy Outlook 2008 (IEA 2008)	498
International Atomic Energy Agency (IAEA): Energy, Electricity and Nuclear Power Estimates for the Period up to 2030, 2008 edition	473.2 ～ 747.5
Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA): Nuclear Energy Outlook 2008	404 ～ 619
World Nuclear Association (WNA): WNA Nuclear Century Outlook	604 ～1289

Note: Nuclear power capacity at the end of 2007 is 372.2GWe. (Data by IAEA)

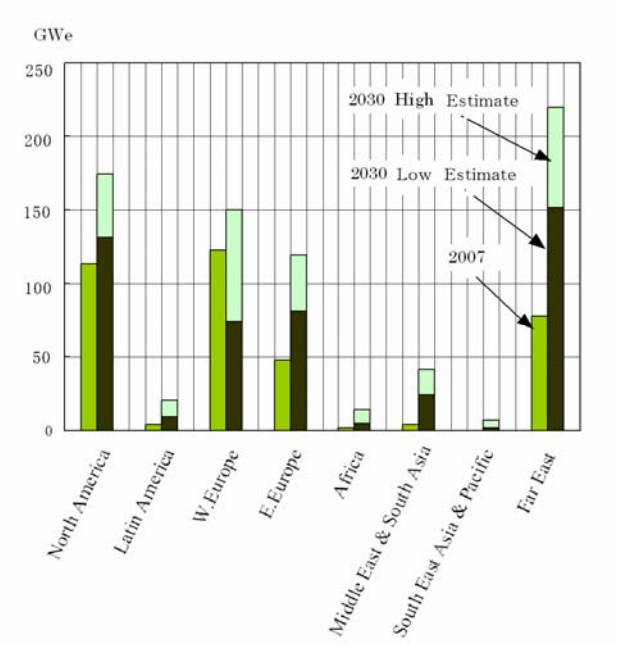


Fig.4 World's nuclear power capacity by region (IAEA 2008)

3.2.2 Twenty-five to sixty newcomer countries

According to the Nuclear Energy Outlook of the OECD-NEA, 25 countries either announced plans or are considering building nuclear power plants, 21 of which are developing countries. Vietnam and Turkey are proceeding with a construction program of nuclear power plants. Thailand, Bangladesh, Egypt, Philippines, and Nigeria are considering or have expressed intentions to build nuclear power plants. Many of these countries aim to obtain fresh water via desalination of seawater, in addition to meeting increasing energy demand and reducing GHG emissions through the construction of nuclear power plants.

According to the WNA Nuclear Century Outlook, 43 countries are planning or considering the introduction of nuclear power. At the International Conference on Nuclear Energy held in Beijing in April 2009, Mohamed ElBaradei, then incumbent director-general of IAEA, cautioned that the global economic crisis could delay the implementation or expansion of nuclear power programs in some countries for a limited period. ElBaradei noted that "most of the 30 countries already using nuclear energy plan to expand their output. More than 60 countries – mostly in the developing world – have informed the IAEA that they might be interested in launching nuclear power programs. Of these, 12 countries are actively considering nuclear power."

Table 5 shows the efforts by the main nuclear electricity expanding countries and newcomer countries.

3.3 Global recognition of the role of nuclear power

3.3.1 Sharing recognition at the G8 Toyako Summit

The Declaration by leaders of the G8 Hokkaido Toyako Summit held in July 2008 reads as follows: "We witness that a growing number of countries have expressed their interest in nuclear power programs as a means to addressing climate change and energy security concerns. These countries regard nuclear power as an essential instrument in reducing dependence on fossil fuels and hence greenhouse gas emissions." Through this declaration, the G8 leaders for the first time shared a common recognition of the pivotal role of nuclear power.

The declaration also stresses the importance of the so-called "3S" concept: safeguards, safety and security, for expanding nuclear energy utilization. "We reiterate that safeguards (nuclear non-proliferation), nuclear safety and nuclear security (3S) are fundamental principles for the peaceful use of nuclear energy. Against this background, an international initiative proposed by Japan on 3S-based nuclear energy infrastructure will be launched. We affirm the role of the International Atomic Energy Agency (IAEA) in this process."

Table 5 Current status and prospect of the world's nuclear power development

(1) Main Nuclear power generating countries

country	NPP in operation		Current status and outlook
	units	MWe	
USA	104	100,683	・There have been absolutely no new NPP construction for nearly 30 years since the TMI accident of 1979, but owing to power uprates and the extraordinarily good performance of NPPs, electricity generation by NPPs has increased substantially, with an increased generation output corresponding to 19 new 1000 MWe plants. ・17 applications for joint construction and operating licenses on 26 units have been filed with the NRC since late 2007. It is expected that there will be significant new nuclear capacity by 2020.
France	58	63,130	・France derives about 80% of its electricity from nuclear energy. ・Surplus and cheap electricity generated by NPPs is exported to neighbouring countries. ・In 2007, the construction of the first EPR started at Flamanville, and the second EPR is planned for Penly. ・France is expanding aggressively, exporting activities of NPP and the fuel cycle globally.
Japan	55	47,069	・Nuclear energy has been a national strategic priority, particularly since the oil-crisis of 1973. ・An important basic policy is the establishment of a nuclear fuel cycle and the development of FBR. ・There are 3 units under construction and 10 units set for construction. ・ Zero-emission carbon-free electricity sources including nuclear energy are targeted to supply more than 50% in 2020 according to an action plan for a low-carbon society.
Russian Federation	31	21,743	・The basic policy is to increase nuclear electricity share and to decrease gas-fired electricity. ・Russia plans to double its nuclear capacity to 43 GWe by 2020, with nuclear generation share rising from the current 16% to 25-28% in 2020. ・An 800 MWe FBR (BN-800) is under construction, with commissioning expected in 2014. ・A small floating nuclear power plant (FNPP) is also under construction, with the goal of start-up by 2012.
Korea	20	17,705	・Of the 6 units currently under construction, four are improved OPR-1000 designs, and two rank first among the advanced APR-1400 designs. ・ Korea plans to build 12 units by 2022, with nuclear electricity share increasing to 48%. ・ Korea succeeded in brokering a deal to export 4 APR-1400 units to the UAE late 2009.
United Kingdom	19	10,137	・19 reactors supply one-fifth of the electricity in UK, but 18 gas-cooled reactors among these will be retired by about 2020 because of aging. ・Early in 2008, the UK government embraced nuclear energy as the core of its response to the need for secure, safe and affordable low-carbon energy supplies, in the new White Paper. ・The first of some 16 GWe in new-generation plants are expected to be on line in about 2017.
Sweden	10	8,992	・According to the 1980 referendum, Sweden decided to phase out nuclear power by 2010, but it has abandoned its plans to prematurely decommission nuclear power plants, and is currently investing heavily in life extensions and uprates. ・In February 2009, the Swedish coalition government said it planned to abolish the act banning the construction of new nuclear power plants.
China	11	8,438	・Mainland China has 11 nuclear power reactors in commercial operation, 20 under construction, and more to commence construction soon. These include the Chinese-designed CPR-1000, the Westinghouse-designed AP-1000 and the Areva-designed EPR units. ・Nuclear capacity is expected to increase to 70,000 MWe by 2020.
India	18	3,984	・India has been developing a unique nuclear fuel cycle to exploit its abundant thorium reserves. ・Until 2009, India was excluded from the trade in nuclear plants and materials, because of non-NPT membership and its nuclear testing in 1974. ・India has an ambitious nuclear power program and expects to have 20,000 MWe nuclear capacity on line by 2020 and 63,000 MWe by 2032.
Finland	4	2,696	・ Finland started construction of a large nuclear unit (Olkiluoto-3) in 2005, as the first new one in 30 years in the country and in 15 years in Europe, and plans are underway for another large one to follow it.

(Data of operating nuclear plants are as of February 2010.)

(2) Emerging nuclear energy countries

Region	country	Current status and outlook
Europe	Italy	・According to a national referendum in 1987 triggered by the Chernobyl accident, the government resolved to halt all nuclear construction and shut down all the operational reactors by 1990. ・Recently over 10% of its electricity is derived from nuclear power - all imported. ・In May 2008, the new government confirmed that it will commence construction of new nuclear power plants within five years, aiming at having 25% nuclear electricity by 2030. ・An EDF-ENEL joint venture plans to build 6400 MWe of nuclear capacity in the next decade.
	Poland	・The Polish cabinet decided early 2005 that it should move swiftly to introduce nuclear power for energy diversification as well as CO_2 emissions reduction. ・In January 2009, the state-owned electric power company (*i.e.* PGE) announced plans to build two nuclear power plants, each with a capacity of 3000 MWe, at least one of which will be built by 2020.
	Lithuania	・Lithuania's Ignalina nuclear power plant consisting of two large Russian RBMK reactors supplied nearly 70% of electricity and exported some of the electricity, but the first unit was closed in late 2006 and the second in late 2009 at the EU's insistence. ・ The government is proceeding with the Visaginas project for a new 3200-3400 MWe nuclear power plant in conjunction with energy companies from Latvia, Estonia and Poland.
Asia	Indonesia	・The government in 1989 initiated a study focused on the Muria Peninsula in central Java, and had planned to call tenders in 2008 for two 1000 MWe units, Muria 1&2, leading to a decision in 2010, with construction starting soon thereafter and commercial operation from 2016 and 2017 respectively, but this schedule has slipped behind. ・A pre-feasibility study for a small reactor for power and desalination on Madura Island and the consideration of a floating nuclear power plant on Sulawesi has been reported.
	Vietnam	・The National Assembly approved a pre-feasibility study in November 2009, and a comprehensive feasibility study will be undertaken soon. ・ Two sites in Ninh Thuan province have been earmarked for the construction of nuclear power plants, each site fitted with two nuclear units of 1000 MWe each. They are expected to begin operation from about 2020.
	Thailand	・In June 2007, the Energy Minister announced that the Electricity Generating Authority of Thailand (EGAT) will proceed with the plans to build 4000 MWe of energy in nuclear power plant. The government plans to have 1000 MWe on line by 2021 and another 1000 MWe a year later. ・In October 2008, Burns & Roe engineering consulting firm was commissioned to undertake a study to recommend siting, technology and the reactor size for the first plant.
	Bangladesh	・ Since a proposal to build a nuclear power plant in 1961, a number of feasibility studies have been carried out. ・ In May 2007, the Bangladesh Atomic Energy Commission(BAEC) proposed two 500 MWe nuclear reactors for Rooppur by 2015.
	Philippines	・Construction of Bataan Nuclear Power Plant (BNPP) began in 1976 and it was completed in 1984, but it was not loaded with fuel and thus never operated due to financial issues and safety concerns pertaining to earthquakes. ・In the 2008 update of the National Energy Plan, a 600 MWe reactor was projected to be on line in 2025, with further 600 MWe increments in 2027, 2030 and 2034 to yield a total output of 2400 MWe. ・ In 2008, an IAEA mission advised the government on the possibility of having the Bataan plant refurbished in order to enable it to be operated economically and safely for 30 years. According to a feasibility study conducted by the Korea Electric Power Corporation, Bataan plant will be able to start operation at a cost of about one billion US dollars.
	Malaysia	・In July 2008, the government directed the state-owned utility TNB to set up a task force to investigate on the feasibility of introducing nuclear power plants. In September of the same year, the government announced that it had no option but to commission nuclear power plants due to high fossil fuel prices, and set 2023 as the target date
CIS	Kazakhstan	・The Russian BN-350 fast breeder reactor at Aktau (formerly Shevchenko) successfully produced electricity and heat for desalination until it was closed down in mid-1999. ・ Nuclear power plans are proposed for the southern and western parts of the country as well as for the regional cities. A feasibility study on building a new 600 MWe plant at Aktau or near Lake Balkhash is being undertaken, with operation expected to commence in 2016.
	Belarus	・In mid-2006, the government approved a plan for the construction of an initial 2000 MWe nuclear power plant in the Mogilev region of eastern Belarus. ・Russia's Atomstroyexport is the most likely supplier for the 2×1000 MWe nuclear power plant. Operation of the first unit is envisaged for 2016 and the second in 2018.

Region	country	Current status and outlook
Middle East & North Africa	Turkey	・Several nuclear power projects have been proposed since around 1970. The Akkuyu site on the Mediterranean coast and the province of the port city of Sinop on the Black Sea have been deemed as potential nuclear power project sites. ・The Turkish Electricity Trade & Contract Corporation (TETAS) called for tenders in March 2008, inviting bids for the first nuclear plant at Akkuyu, the first unit of which was expected to come on line in 2016. Only one bid was received from Rossian Atomstroyexport. TETAS recently cancelled the Russian proposal due to some legal issues. A new tender will be launched soon.
	Iran	・In the mid-1970s, construction of two 1200 MWe PWR units was started at Bushehr by Siemens KWU, but it was suspended in 1979. ・In 1994, Russia agreed to complete unit 1 of the Bushehr nuclear power plant with a VVER-1000 unit, using mostly the infrastructure in place. It is expected to start electricity generation in 2010.
	6 GCC countries (Saudi Arabia, UAE, Kuwait, *etc*.)	・In December 2006, the six member states of the Gulf Cooperation Council (GCC) announced that GCC was commissioning a study on the peaceful use of nuclear energy. ・In April 2008, the UAE independently published a comprehensive policy on nuclear energy, embracing nuclear power as a proven, environmentally promising and commercially competitive option for the UAE's economy and future energy security. It aims to operate 5000 MWe of energy in nuclear plants by 2020. ・Late in December 2009, the UAE signed a contract with a Korean group led by Korean Electric Power Corporation for four APR-1400 reactors.
	Jordan	・Jordan imports about 95% of its energy needs. Jordan's Committee for Nuclear Strategy has set out a program for a nuclear power plant to provide 30% of its electricity by 2030-2040. ・ Jordan Atomic Energy Commission (JAEC) has announced that a nuclear tender is likely in mid-2010 with construction of a nuclear power plant, initially 750 to 1100 MWe, starting in 2013 and operation by 2020.
	Egypt	・Several nuclear power projects with desalination have been proposed since 1964 and in 1983, El-Dabaa site on the Mediterranean coast was selected for a nuclear plant. ・In May 2009, the Energy & Electricity Ministry signed a contract with Worley Parsons to support the establishment of a 1200 MWe nuclear plant. The ministry confirmed that Egypt aims to begin generating nuclear electricity in 2017.
	Morocco	・ The government has plans to build an initial nuclear power plant in 2016-17.
	Algeria	・ In February 2009, the government announced that it planned to build a nuclear power plant to be operating in about 2020.

Source: Home pages of WNA and IAEA.

3.3.2 Annual 32 new build to address global warming

In June 2008, the IEA published a report "Energy Technology Perspective" as a reference study for the G8 Hokkaido Toyako Summit.

The Intergovernmental Panel on Climate Change (IPCC) has concluded that only scenarios resulting in a 50% - 80% reduction of global CO_2 emissions by 2050 compared to the 2000 levels can limit the long-term, global mean temperature rise to 2.9-2.4 ºC. In the absence of new policies, global energy demand and CO_2 emissions will more than double by 2050. In this case (*i.e.* baseline scenario), the global CO_2 emissions grow rapidly, oil and gas prices are high, and energy security concerns increase as imports rise. The IEA reviews two scenarios; the ACT scenario whereby worldwide emissions can be brought back to today's level by 2050, and the BLUE scenario halving worldwide emissions by 2050.

Table 6 Annual investment in the electricity sector in the ACT and BLUE scenarios (compared to the Baseline, 2005-2050)

Power generation	ACT - BLUE Scenarios
Coal(CCS)	30 - 35 CCS coal-fired plants (500 MW)
Gas(CCS)	1 - 20 CCS gas-fired plants (500 MW)
Nuclear	24 - 32 nuclear plants (1000MW)
Hydro	1/5 of Canada's hydropower capacity
Biomass	50 - 100 biomass plants (50MW)
Wind (onshore)	2,900 - 14,000 wind turbines (4MW)
Wind (offshore)	775 - 3,750 wind turbines (4MW)
Geothermal	50 - 130 geothermal units (100MW)
Solar (PV)	115 - 215 square km(PV)
Solar (CSP)	45 - 80 CSP plants (250MW)

Note: ACT Scenario: Limit global CO_2 emissions in 2050 at the same level as in 2005.
Blue Scenario: Halve global CO_2 emissions in 2050 from the 2005 level.
CCS: CO_2 Capture and Storage (carbon sequestration)

Source: Energy Technology Perspectives, IEA, June 2008

Table 6 above shows additional investment in the electricity sector in the ACT and BLUE scenarios, compared to the baseline scenario in 2005-2050.

Both scenarios are of course based on the optimum use of energy efficiency and energy conservation. They also make use of fossil fuel power with CCS (CO_2 capture and storage) sequestration technologies, nuclear power and renewable energy. An annual 24 units (ACT scenario) to 32 units (BLUE scenario) of 1 GWe nuclear power plants need to be constructed.

4 International expansion of nuclear industry

The worldwide nuclear renaissance has lead to the international re-organization and cooperation among nuclear plant vendors. During the worldwide lull period when the rate of construction of new nuclear power plants was sluggish, the construction of nuclear power plants in Japan has remained steady, albeit the constructions involved in a small number of units. Japan's nuclear manufacturers have maintained and improved high-technology and project management capability in design, engineering and construction, through such continuous new-build projects. Against this background, Japanese firms have played a key role in the worldwide re-organization and cooperation among nuclear industries.

Toshiba bought Westinghouse Electric Company of the US in October 2006 and established a business partnership with the state-owned nuclear power corporation of Kazakhstan in August 2007. Hitachi established a joint venture nuclear company with General Electric Company of the US in June 2007. Mitsubishi Heavy Industries (MHI) established a joint venture with the French state-owned nuclear company, Areva SA, for developing mid-sized nuclear reactors, in September 2007, and merged operations in the processing of nuclear fuel, in April 2008.

For the future global expansion of nuclear power, infrastructural development to ensure the "3S" concept to be adhered to in the new emerging countries is essential and securing the supply chain, including the front-end of the nuclear fuel cycle such as uranium resources, enrichment services, and fuel fabrication is also crucial.

French and Russian nuclear corporations have front- and back-end industries for global marketing within their own organizations, and promote the export of nuclear power plants to foreign countries with strong state-support. The role of electric power companies of nuclear generating countries has recently gained greater importance because their knowhow and experience in the operation and maintenance of nuclear power plants are valuable to newcomer countries.

The business activities of Japan's nuclear companies have mainly been limited to the domestic market. Japanese firms have entered the crucial phase of entering the world stage.

For reference, nuclear plant suppliers in the world and their reactors are listed as follows.

- Areva NP (Areva 66% stake, Siemens 34%): PWR (EPR, US-EPR), BWR (SWR-1000) (note: In January 2009, Siemens announced its withdrawal from Areva NC.)
- Westinghouse Electric Company (Toshiba 67%, Shaw group 20%, IHI 3%, Kazatomprom 10%): PWR (AP1000, AP600)
- Toshiba: BWR (ABWR)
- GE-Hitachi Nuclear Energy (GEH) (GE 60%, Hitachi 40%), Hitachi-GE Nuclear Energy (Hitachi 80.01%, GE 19.99%): BWR (ABWR, ESBWR)
- Mitsubishi Heavy Industries (MHI): PWR (APWR, US-APWR, EU-APWR)
- ATMEA (a joint venture between Areva and MHI): Atmea-1(mid-sized PWR)
- Atomstroyexport (a subsidiary company of the Russian State Nuclear Energy Corporation Rosatom): VVER-1000 (AES-92), VVER-1200 (AES-2006)
- Atomic Energy of Canada Limited (AECL): CANDU (CANDU-6, CANDU-9, ACR)
- Doosan Heavy Industries & Construction Co., Ltd. (Korea): PWR (OPR1000, APR1400)
- China National Nuclear Corporation (CNNC): PWR (CPR-1000)

5 Japan's nuclear policy

5.1 Japanese government's nuclear energy policy

The Atomic Energy Commission (AEC) of Japan formulates basic concepts and guidelines for the research, development and utilization of nuclear science and engineering approximately every 5 years. The latest one called "Framework for Nuclear Energy Policy" was formulated and endorsed by the cabinet in October 2005.

The AEC specifies the following three basic concepts in the framework.

1) Generation of 30 to 40% or more of total electricity from nuclear power even after 2030.
2) Promotion of the nuclear fuel cycle (*i.e.* uranium enrichment, reprocessing of spent nuclear fuel and utilization of recovered plutonium)
3) Commercialization of the fast breeder reactor (FBR) by 2050.

The Ministry of Economy, Trade and Industry (METI) published "Nuclear Energy National Plan" in August 2006 as a specific action plan in order to achieve the above concepts.

5.2 Action plan for low-carbon society

In May 2007, Prime Minister Shinzo Abe announced a proposal called "Invitation to Cool Earth 50" as a measure to counter global warming. He proposed a long-term target of cutting down global emissions by half from the current level by 2050 as a common goal for the entire world. It is difficult to realize the long-term target enshrined in the "Cool Earth 50" proposal through the utilization of current technologies. The development and utilization of innovative technologies is essential. In view of this, METI identified 21 innovative technologies and formulated a development roadmap in March 2008. Advanced nuclear power generation was identified among them.

On 29th July 2008, the "Action Plan for Achieving a Low-carbon Society" was approved in a Cabinet meeting. The action plan defines a framework for transforming the whole country into a low-carbon society, the development of innovative technologies, and changes of business practice and lifestyle. It also set a long-term CO_2 emissions reduction target of up to 50% for the whole world and 60%-80% for Japan as long-term. It advocates a 14% reduction from the present situation as Japan's mid-term goal. Regarding electric power sources for realizing the mid-term target, it aims to achieve 50% of electricity energy share by zero-emission power sources. Though solar energy and wind power play important roles, their contributions are limited. Nuclear power is expected to fulfill a key role.

In June 2009, then Prime Minister Taro Aso announced a 15% reduction compared to the 2005 level, as a mid-term target for 2020. In response to this, the METI's committee for nuclear energy in the same month put together a set of measures for facilitating the promotion of nuclear power development. To realize the mid-term target, nuclear power needs to have around 40% share of the total electricity generation by 2020, METI recommends. The nuclear power promotion measures envisage that 9 nuclear power units will start commercial operation by 2020, and that nuclear plant fleet capacity factor will improve from 70% in 2005 to 81% in 2020.

5.3 The energy and environment policy of the new government

The new administration led by the Democratic Party of Japan (DPJ) assumed power in September 2009 after a land slide victory over the Liberal Democratic Party (LDP) of the DPJ in the general election. In fact, it is the first time in the postwar era for a change in government to take place.

At the UN summit meeting on climate change held in the same month, Prime Minister Yukio Hatoyama did not hesitate to officially announce an ambitious mid-term target of reducing GHG emissions by 25% by 2020 compared to 1990 levels. According to the DPJ manifesto, this promise is hinged on the condition that the international community establishes a transparent international framework for GHG reduction, the participation of all major GHG-emitting countries accompanied by the respective countries setting aggressive goals. The DPJ government's commitment to a 25% reduction, corresponding to a 30% reduction compared to 2005, is being criticized in various industrial circles as being unrealistic.

The government plans to propose a draft law on global

warming countermeasures that includes the mid-term target by the spring of 2010. The Basic Energy Plan for 2030 currently under deliberation, is expected to be formulated around June 2010, and subsequently to be adopted by the Cabinet. Concrete measures to achieve the government's commitments are expected to be provided by then.

As for the basic stance of its nuclear energy policy, the DPJ advocates for active utilization of nuclear power for a stable energy supply, with public understanding and trust. During the recent environmental impact assessment (EIA) on the construction of Sendai Nuclear Power Station (Unit 3), Environment Minister Sakihito Ozawa submitted the opinion that the Sendai-3 plant can greatly contribute to the reduction of global GHG emissions. It was the first time that an Environment Minister clearly supported the promotion of nuclear power plants. The Sendai-3 plant will be the third APWR (Advanced PWR) in Japan to be constructed on the south-western coast of Kyushu island by Kyushu Electric Power Co., Ltd. The Sendai-3 plant with its 1590 MWe nuclear power generation capacity will be the largest nuclear power plant in Japan to be in commercial operation in 2019.

6. Conclusions

In this paper, the contemporary worldwide trend of what is termed "nuclear renaissance" is first reviewed based on a wealth of references. It can be said that in many countries, the role of nuclear energy is being positively revaluated from the perspective of energy security and global warming issues. Many nuclear generating countries are expanding nuclear power development programs, and a growing number of countries worldwide are embarking on plans to build new nuclear power plants, which has brought about reorganization of major nuclear manufacturers over the some nuclear developed countries. The Japanese government has been developing nuclear power, and the new DPJ-led government, which recently took over from the conservative LDP, seems to be positioning nuclear power as a key pillar in the quest for a low-carbon society.

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