Press Release for the 397th Forum on Research Works

February 14, 2007
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World Nuclear Power Generation Markets and Prospects for Nuclear Industry Realignment (Summary)

1. Objective of Study

This study analyzes the background of recent corporate acquisitions, alliances and integrations in the nuclear industry and looks into the impact of these moves on nuclear power generation markets in the world.

2. Key Conclusions

For the world's nuclear power generation industry, nuclear plant makers have played a very important role in supporting a wide range of technologies for plant engineering, construction, and operation and maintenance phases. Realignment of nuclear plant makers in the 1980s and 1990s allowed the world nuclear plant market to come under an oligopoly by a small number of companies that boasted excellent plant concepts and engineering know-how. These companies include General Electric Co. and Westinghouse Electric Co. of the United States and France's Areva Group. Then, the three Japanese nuclear plant makers formed technological alliances with their respective U.S. counterparts. Mitsubishi Heavy Industries Ltd. teamed up with WH. Toshiba Corp. and Hitachi Ltd. tied up with GE. They had no capital tie-up. However, Toshiba acquired WH in 2006, prompting Mitsubishi to announce a strategic alliance with Areva. Hitachi and GE then unveiled an effective integration of their nuclear divisions. The three Japanese companies have thus demonstrated their plans to cooperate with their respective foreign partners in global operations, based on their different business portfolios.

Over recent years, rising energy prices and growing interests in energy security and global environmental problems have prompted many countries to reevaluate the role of nuclear power generation. Particularly, some electricity generators have embarked on nuclear plant construction plans in the United States, where the Energy Policy Act of 2005 called for assistance for new nuclear plant construction projects. Under the circumstance, the question to be addressed is “what nuclear plant type would be selected in the global market in the future?” Indicating the answer to this question would be the acquisition of the Design Certification from the U.S. Nuclear Regulatory Commission (NRC-DC) and U.S. nuclear plant orders. Therefore, nuclear plant makers have given top priority to the U.S. market and have been racing to obtain the NRC-DC and orders for their respective nuclear reactors. Other promising nuclear plant markets include such Asian nations as China and India, as well as European countries where nuclear plants built in the 1960s and 1970s will be replaced in the future.

The key to promotion of nuclear power generation development includes the effectiveness of government support and reduction of relevant private sector enterprises' risk burdens. Particularly, reduction of initial investment burden and of uncertainties on licensing procedures may encourage enterprises to build new nuclear power plants. Even if such risk burden reductions are achieved, business risks and country risks that vary by country and timing may be left by individual enterprises. Nuclear plant makers may have to make the most accurate investment decisions based on their characteristics, capability and clear visions in order to become global top runners.

It is expected that a sound competition between nuclear plant makers based on their reliable technological potentials for manufacturing works may result in improving of technology levels for the whole of the nuclear plant industry. Then it may help invigorate new markets in the United States and Asia and encourage electricity generators to select nuclear energy in the electricity market. From the perspective of the Japanese nuclear industry's global development, this would be a desirable future vision for the nuclear industry that plays a key role in Japan's power generation.

Over

February 9, 2007
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World Nuclear Power Generation Markets and Prospects for Nuclear Industry Realignment

Rising energy prices and growing interests in the importance of energy security and global environmental problems over recent years have encouraged many countries to position nuclear power as a key energy. Under such circumstances, Japanese nuclear plant makers announced their deeper relations with their foreign counterparts in 2006. These nuclear plant makers have played a very important role in nuclear power generation, supporting a wide range of technologies for engineering, manufacturing, and operations and maintenance. This study reviews nuclear power generation markets in the world over the past years, looks into and analyzes the background of nuclear industry acquisition and alliance deals, and considers the impact of such industry developments on the world's nuclear power generation markets.

1. World Nuclear Power Generation Development and Policy Trends

(1) Present state of world nuclear power generation development

① 2005-end

At the end of 2005, 443 nuclear reactors existed in 31 countries with their power generation capacity at 367.8 million kilowatts. Of these reactors, 84%, for a total capacity of 384 million kW, are in OECD (Organization for Economic Cooperation and Development) countries. In 2005, nuclear power generation accounted for about 7% of primary energy consumption and about 15% of electricity output, totaling 2,742 billion kilowatt-hours.

Figures 1 and 2 indicate changes in nuclear power generation capacity and output in the world.

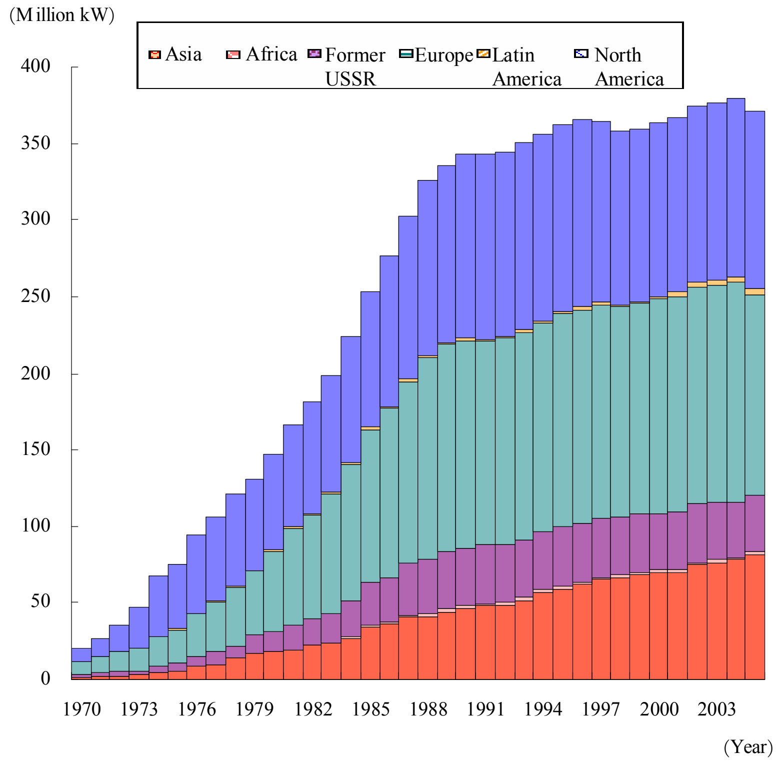


Figure 1. Changes in World Nuclear Power Generation Capacity

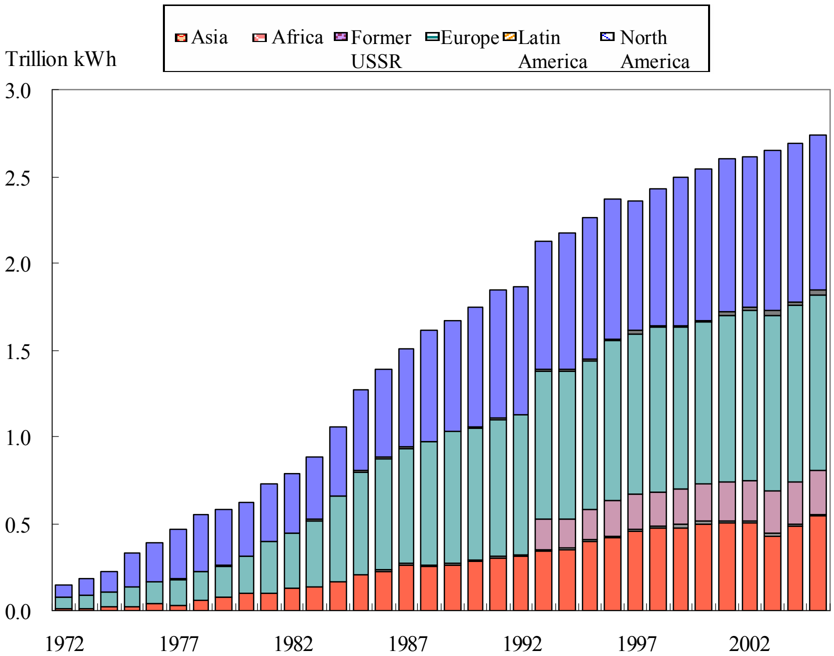


Figure 2. Changes in World Nuclear Power Generation

Sources: "World Nuclear Power Generation Development Trends 2006," Japan Atomic Industrial Forum, Inc.; "World Energy Outlook 2006," IEA

Among regions, Asia has posted remarkable growth over the past years. North America and Europe have slowed growth without recording declines since the 1990s. Power generation companies owning nuclear reactors numbered 86 in the world in 2005, including France's EDF with the world's largest nuclear power generation capacity at 65.8 million kW[1]. The number of nuclear plant makers has declined to less than 10 from a far higher level. These nuclear plant makers, which have great influence over the global market, are analyzed in more detail in Chapter 3.

② Changes in new capacity for construction

Construction of nuclear power plants peaked in the 1970s and 1980s following the 1973 oil crisis. Of nuclear reactors in operation at present, 80% were constructed in those two decades. Construction has slowed conspicuously since the 1979 Three Mile Island nuclear power plant accident. Many nuclear reactor construction plans were cancelled in the United States, while some countries shifted away from nuclear energy. In the 1990s, new capacity for construction declined remarkably and globally due to electricity and gas utility liberalization and earlier overinvestment in nuclear power generation. Supporting new capacity growth for construction then were Japan, France and South Korea.

Nuclear power generation's share of the world's total electricity output peaked at 18% in 1996 and fell to 15% in 2005 due primarily to a fast rise in electricity demand in developing countries where nuclear power generation shares are lower[2]. Nuclear power generation increased by 36% from 1990 to 2005 due to a rise in total capacity and in the capacity utilization ratio.

Policy moves to promote nuclear energy have emerged in such countries as the United States in recent years, while China and India have made steady progress in planning nuclear power generation. In or after 2000, a total of 30 new nuclear reactors for 26.497 million kW launched commercial operations. Asia, including Japan, South Korea, China and India, accounted for 19 reactors (for 13.722 million kW) or some 52% of the new reactors.

In Europe and the United States, reactors constructed in the 1960s have become outdated and will have to be shut down, if they go without any measures to lengthen their service lives. If present nuclear power generation were to be maintained, outdated reactors would have to be replaced. But the number of countries with specific replacement plans is limited. In this respect, future developments will attract attention.

③ Country-by-country conditions (reactors in operation and under construction or planning, and their capacity)

Table 1 provides an overview of the world's nuclear power generation development

[1] Source: "World Energy Outlook 2006," IEA
[2] Source: "World Energy Outlook 2006," IEA

conditions including the number of nuclear reactors in operation and their capacity, the number of reactors under construction or planning and their capacity, and nuclear power generation.

Country	Number of reactors in operation	Capacity of reactors in operation (gW)	Number of reactors under construction or planning	Capacity of reactors under construction or planning (gW)	Power generation (TWh)	Nuclear power share (%)	Number of nuclear power generation firms
Belgium	7	5.8	0	0.0	48	55.2	1
Canada	18	12.6	0	0.0	92	14.6	4
The Czech Republic	6	3.5	0	0.0	25	29.9	1
Finland	4	2.7	1	1.7	23	33.0	2
France	59	63.1	1	1.6	452	78.5	1
Germany	17	20.3	0	0.0	163	26.3	4
Hungary	4	1.8	0	0.0	14	38.7	1
Japan	56	47.8	13	17.2	293	27.7	10
South Korea	20	16.8	8	9.6	147	37.4	1
Mexico	2	1.3	0	0.0	11	4.6	1
Holland	1	0.5	0	0.0	4	4.0	1
Slovakia	6	2.4	0	0.0	18	57.5	2
Spain	9	7.6	0	0.0	58	19.5	5
Sweden	10	8.9	0	0.0	72	45.4	3
Switzerland	5	3.2	0	0.0	23	39.1	4
Britain	23	11.9	0	0.0	82	20.4	2
U.S.	104	98.3	0	0.0	809	18.9	26
OECD total	**351**	**308.4**	**23**	**30.1**	**2,333**	**22.4**	**68**
Armenia	1	0.4	0	0.0	3	42.7	1
Bulgaria	4	2.7	2	2.0	17	39.2	1
Lithuania	1	1.2	0	0.0	10	68.2	1
Romania	1	0.7	4	2.8	5	8.6	1
Russia	31	21.7	5	4.1	149	15.7	1
Slovenia	1	0.7	0	0.0	6	39.6	1
Ukraine	15	13.1	3	3.0	84	45.1	1
Transition Economies total	**54**	**40.5**	**14**	**11.9**	**274**	**17.0**	**7**
Argentina	2	0.9	1	0.7	6	6.3	1
Brazil	2	1.9	1	1.3	10	2.2	1
China	9	6.0	10	9.3	50	2.0	5
India	15	3.0	8	3.9	16	2.2	1
Pakistan	2	0.4	1	0.3	2	2.8	1
South Africa	2	1.8	1	0.1	12	5.0	1
Taiwan	6	4.9	2	2.7	38	16.9	1
Developing countries total	38	18.9	24	18.4	135	2.1	11
Grant total	**443**	**367.8**	**61**	**60.4**	**2,742**	**14.9**	**86**

Sources: "World Nuclear Power Generation Development Trends 2006," Japan Atomic Industrial Forum, Inc.; "World Energy Outlook 2006," IEA

Table 1. Overview of Country-by-Country Nuclear Power Generation Development Conditions

Among countries, the United States has the largest number of nuclear reactors in operation in the world at 103, followed by 59 in France and 56 in Japan. Japan features the largest number of such reactors under construction or planning at 13, followed by 10 in China, eight in South Korea, six in India, five in Russia and four in Romania. However, we must note that these figures are planned ones as published by national organizations and do not necessarily reflect realities. The number of 10 for China means that 10 reactors have been approved by the State Council in 2006. An additional 20 or more reactors may have to be built to achieve the target total capacity of 40 million kW by 2020 as indicated in the medium to long-term nuclear development plan released in 2005 by

CNNC (China National Nuclear Corporation). Construction of 20 or more reactors has yet to be approved, hinting that many more plans could emerge in China. This would be the same case with India and South Korea.

In the United States, nuclear power generation has already been assessed as having market competitiveness. The 2005 Omnibus Energy Act has created new government support measures for nuclear plant construction, prompting electricity companies to announce their respective nuclear reactor construction plans one after another. The number of new reactors and their construction schedules are still uncertain, failing to be reflected in Table 1. As of January 2007, nearly 30 new nuclear reactors were planned for future construction in the United States[3].

④ Analyzing nuclear energy's share of total power generation capacity by country

Countries that have commercial nuclear plants are divided by two axes -- total power generation capacity and nuclear energy's share of the total capacity -- into four categories as shown by Figure 3.

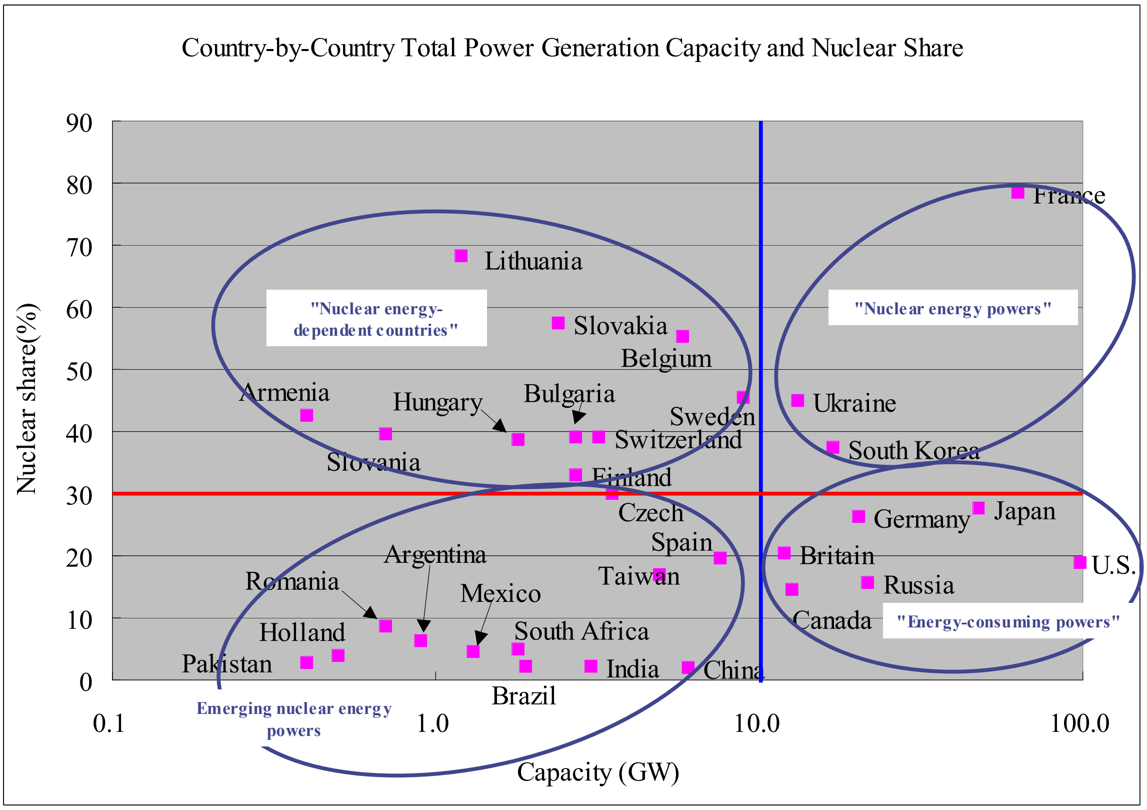


Figure 3 National Characteristics as Seen from Total Power Generation Capacity and Nuclear Share

3 Source: "New Nuclear Power Plants," Nuclear Energy Institute website at http://www.nei.org/index.asp?catnum=2&catid=344

1) Large capacity and a high nuclear share: "Nuclear energy powers"

Countries that launched early nuclear energy development and have established technologies for operation of nuclear plants as the key power source: France, Ukraine, South Korea

2) Large capacity and a low nuclear share: "Energy-consuming powers"

Countries that launched early nuclear energy development and have nuclear power generation capacity above a certain level (10 GW), large economic sizes or electricity consumption, and nuclear shares below 30%: U.S., Japan, Germany, Russia, U.K., Canada.

3) Small capacity and a high nuclear share: "Nuclear energy-dependent countries"

Countries that have taken the initiative in nuclear energy development and have moderate economic sizes, nuclear power generation capacity below 10 GW and nuclear shares above 30%: Sweden, Switzerland, Finland, Belgium and other small European countries; Lithuania, Slovakia, Bulgaria and other East European countries

4) Small capacity and small nuclear shares: Emerging nuclear energy powers

Countries that have nuclear power generation capacity below 10 GW and low nuclear shares below 30% and are likely to step up nuclear energy development in the future: China, India, Taiwan, Brazil, Mexico and Pakistan.

When outlining national nuclear energy policies, it is important to grasp how each country positions nuclear energy. In this respect, the categorization of countries by "total power generation capacity and nuclear share" would be useful. For example, Category 3 countries with small total power generation capacity and high nuclear shares include those that have taken policies to shift away from nuclear energy. The shift away from nuclear energy may be linked to the fact that nuclear shares are higher than indicated by total electricity demand. I would like to take advantage of the categorization for analyzing nuclear energy development conditions on a country-by-country basis.

(2) National nuclear policy review

① U.S.

The U.S. Energy Policy Act of 2005 has positioned nuclear power generation as a key means to achieve energy security and solve the global warming problem and has offered measures supporting construction of new nuclear plants. In February 2002, the United States published the "Nuclear 2010" program for cooperation between public and private sectors regarding clean and easy-to-use energies and has taken various policy measures to construct new nuclear plants by 2010. In response, electric utilities have announced new nuclear plant construction plans in a bid to file construction and operating license (COL) applications with the Nuclear Regulatory Commission. As earlier noted, nearly 30 reactors are subject to plans published by January 2007[4].

② Europe

European countries have had vigorous policy debate on a shift to promotion of nuclear power generation. In May 2005, Sweden closed the second Barseback reactor and increased output at Oskarshamn and Ringhals nuclear power stations. Finland launched construction of the third Olkiluoto nuclear reactor in September 2005.

UK's energy whitepaper in 2003 offered to leave nuclear power generation as a future useful option. In July 2006, an interim review of government energy policy reforms called for more positive consideration of construction of new nuclear plants.

Among other European countries, many are discussing their reconsideration of the earlier shift away from nuclear energy. European countries are diverse, divided into Categories 1, 2 and 3 in the (1) ④ categorization. They have had different goals and timings for their shift away from nuclear energy. We should acknowledge such diversity of European countries.

③ Russia, Eastern Europe, CIS Nations

In Russia, 31 nuclear reactors for a total capacity of 23.55 million kW were in operation as of December 2005, with three units for 3 million kW under construction. The entire Commonwealth of Independent States had 46 reactors in operation for 36.78 million kW and six under construction for 6 million kW. These reactors have all been developed by Russia. European or American nuclear plant makers' nuclear reactors have never been introduced in CIS countries. This is the same case with Eastern Europe. Bulgaria and Kazakhstan as well as Russia plan to build new nuclear reactors, which will all be of the Russia-developed VVER type. No European or American reactors are now expected to be adopted in these countries.

④ China

China's goal is to boost nuclear power generation capacity to some 40 million kW or about 6% of its total capacity by 2020. To this end, China plans to build more than 30 nuclear reactors over the coming 15 years. As of December 2005, 11 nuclear reactors for a total capacity of 6.59 million kW were in operation in China. Including two reactors under construction, the total capacity stands at 8.56 million kW. The State Council has approved construction of 10 new nuclear reactors -- two 1 million kW reactors for Guangdong Province's Lingao (Phase 2), two 1 million kW reactors for Zhejiang Province's Sanmen, two 1 million kW reactors for Guangdong Province's Yangjiang, two 0.65 million kW reactors (additional) for Zhejiang Province's Qinshan (Phase 2), and two 1

[4] Source: "New Nuclear Power Plants," Nuclear Energy Institute website at http://www.nei.org/index.asp?catnum=2&catid=344

million kW reactors for Liaoning Province's Hongyanhe. Nuclear reactor construction approvals and launchings are expected to come one after another in the future. To meet expansion of nuclear power generation, the Chinese government is promoting international cooperation for introduction and joint development of cutting-edge nuclear technologies while proceeding with its domestic development of such technologies.

⑤ India

In Asia, South Korea, Taiwan and India as well as China have aggressively introduced nuclear power generation. Particularly, India had 15 nuclear reactors in operation for a total capacity of 3.31 million kW and eight under construction for 3.92 million kW as of December 2005. It plans to expand its nuclear power generation capacity to 20 million kW by 2020 and to 40 million kW by 2030. India's present nuclear reactors are medium-sized PHWR (pressurized heavy water reactor) units. It has no large-capacity light-water reactors. Responding to fast-growing electricity demand, India signed a nuclear energy cooperation agreement with the United States in 2005 to expand nuclear power generation. In December 2006, the U.S. Congress passed legislation to allow nuclear equipment to be exported to India. In the future, therefore, U.S. nuclear plant makers are expected to position India as one of the new promising markets in promoting business operations.

(3) Nuclear proliferation concerns and international nuclear management initiatives

Nuclear power generation is well expected to expand in the world as global interests have grown over the past years in constraints on fossil fuel resources and in global environmental problems. In the meantime, Iranian and North Korean nuclear problems have grown more serious and limits are cited on the present Nuclear Nonproliferation Treaty regime. Under such circumstances, proposals have emerged for new frameworks to address nuclear proliferation concerns while refraining from impeding peaceful use of nuclear energy.

Given the above, the United States and some others have tended to propose various initiatives to support both nuclear nonproliferation and expansion of peaceful use of nuclear power generation.

In September 2003, IAEA Director-General Mohammad ElBaradei proposed his Multilateral Nuclear Approach, or MNA, at a general IAEA meeting. It calls for multilateral management of uranium enrichment and reprocessing, international reprocessing of spent nuclear fuels and international disposal of radioactive wastes.

In February 2004, U.S. President George W. Bush proposed prevention of proliferation of uranium enrichment and reprocessing technologies in his address on nonproliferation of weapons of mass destruction. The so-called Bush Proposal calls on nuclear supplier countries not to provide uranium enrichment and reprocessing technologies and equipment to countries that have no real facilities for uranium enrichment and reprocessing. Given the timing of his speech, the proposal was then interpreted as a warning against Iran. But it was also expected to affect the industrial sector of Japan that has specified a national policy of establishing technologies for a full nuclear cycle. The idea led to the Global Nuclear Energy Partnership, or GNEP, initiative (as described later) that was announced later.

In February 2005, the IAEA announced a recommendation including five approaches for realizing the ElBaradei proposal. The recommendation said that nuclear fuel cycle facilities in nuclear or non-nuclear countries in NPT or non-NPT nations should be put under international management for development of a multilateral nuclear management regime.

In January 2006, Russian President Vladimir Putin announced an international nuclear fuel center concept. In February 2006, immediately after the Russian move, the U.S. Department of Energy released the GNEP initiative. The Russian concept aims to avoid proliferation of nuclear weapons and establish a nuclear fuel cycle, allowing all peaceful users of nuclear energy to receive uranium enrichment and recycling services indispensable for the nuclear fuel cycle. The Russian concept is close to the GNEP initiative. But there has been no evidence indicating prior consultations between the United States and Russia over these proposals. In the future, a proposal could be made for Russia's domestic nuclear fuel cycle facilities under the nuclear fuel center concept to be utilized for demonstrating technologies under the GNEP initiative.

The key point of the GNEP initiative is that "nuclear fuel cycle countries" would guarantee fuel supply to "nuclear power generating countries" while "nuclear power generating countries" would give up developing nuclear fuel cycle technologies. But the GNEP initiative also calls for promoting development of advanced nuclear fuel reprocessing technologies resistant to proliferation and of fast reactors using plutonium. It thus emphasizes international joint research and development operations for demonstration of innovative technologies.

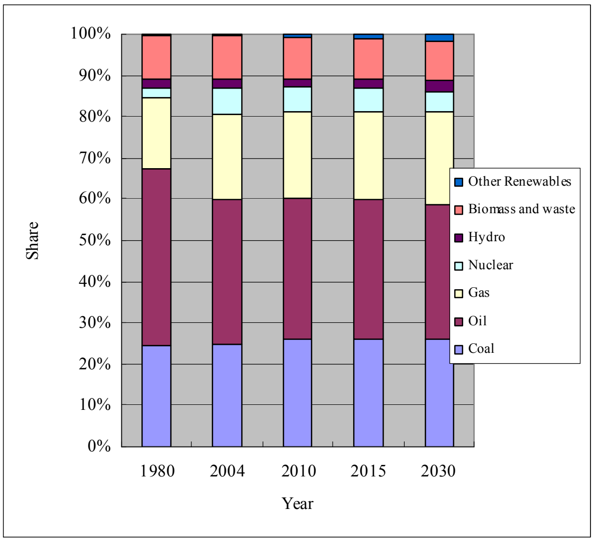
In December 2006, the United Nations Security Council unanimously adopted a resolution for sanctions regarding the Iranian nuclear problem. While the MNA proposal is failing to produce an effective nuclear inspection system, nuclear proliferation concerns are growing. In the future, the IAEA executive board may be required to not only enhance nuclear inspections in countries planning nuclear power generation but also consider an effective inspection regime covering all countries including nuclear powers.

2. Future Prospects for Nuclear Power Generation Development

(1) Prospects for nuclear energy under WEO scenarios

In November 2003, the IEA released the World Energy Outlook 2006 (hereinafter, referred to as WEO2006), forecasting world energy supply and demand through 2030. Figure 3 indicates a world primary energy demand outlook through 2030.

World Primary Energy Demand Outlook (reference scenario)



World Primary Energy Demand Outlook (reference scenario)

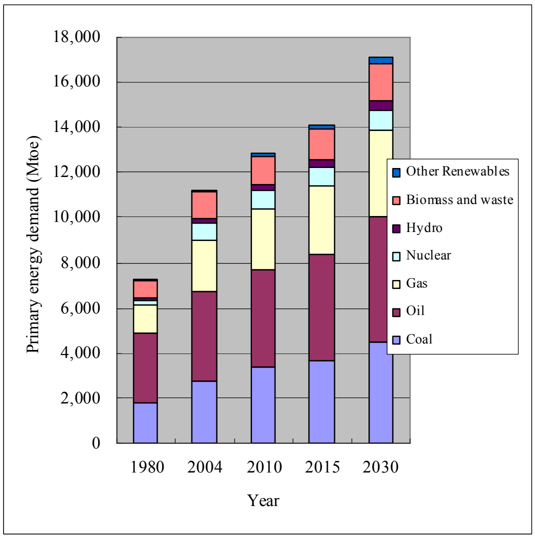
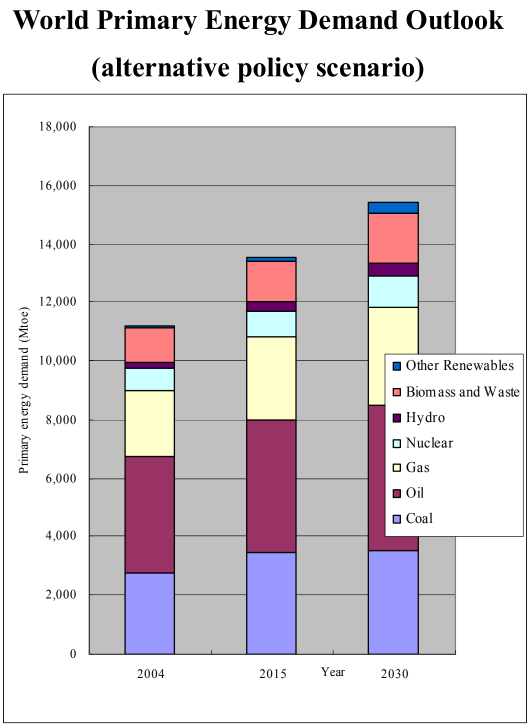


Figure 3 (1) World Primary Energy Demand in the Reference Scenario

The reference scenario, which gives no considerations to any new measures against global warming, indicates that nuclear energy's share of primary energy demand may decline from 6% in 2004 to some 5% in 2030. Although Asian and other developing countries are expected to expand nuclear power generation, Europe and the United States are presumed to replace outdated nuclear plants with non-nuclear power sources.



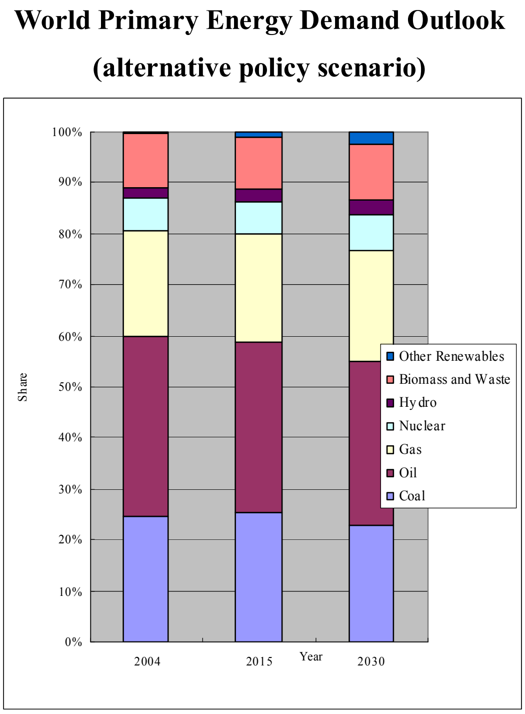


Figure 3 (2) World Energy Demand in the Alternative Policy Scenario

The alternative policy scenario, which takes more measures against global warming into account, indicates nuclear energy's share of primary energy demand may slightly rise to about 7% in 2030, as shown in Figure 3(2). This is not only because nuclear power generation is presumed to grow faster than in the reference scenario, but also because primary energy demand growth in the alternative policy scenario is lower than in the reference scenario due to energy-saving effects.

(2) Factors for and against Nuclear Development Promotion

Whether nuclear development can be promoted depends on various factors and cannot be simply decided for each country or the entire world. However, a detailed analysis of factors may allow us to assess the feasibility of a nuclear program in a specific country. Factors that support or impede nuclear development include the following:

① Economy (electricity generation cost)

The economy of nuclear power generation has been assessed in various ways. We must understand that cost estimates for any specific nuclear power generation program may differ widely depending on conditions including initial investment (construction cost), fuel purchase cost, operation and maintenance cost, construction lead time and capacity utilization. According to the WEO2006 assessment, nuclear power generation under realistic assumptions regarding the unit construction cost is economically superior to coal thermal power generation, the cheapest of non-nuclear electricity sources. If the unit construction cost is set at a higher level, nuclear power generation may lose its competitiveness to coal thermal and IGCC (integrated gasification combined cycle) power generation systems.

② Initial investment risks (including delays in implementation of plans)

Nuclear power generation facilities feature greater construction costs than other power generation facilities. Even if the unit construction cost over a life cycle of a nuclear power station is lower, a massive initial investment as much as hundreds of billions of yen may be required. The construction period may have to be extended frequently. There are risks that cannot be reflected in the unit construction cost. Solutions to fund-raising and investment-recovering period problems are the key to facilitation of investment in nuclear power generation.

③ CO2 emission credit prices

Many member countries of the European Union take advantage of the EU Emission Trading System to promote trading in CO2 emission credits between businesses. C02 emission credit prices are an important investment factor for a company that is planning to invest in a new nuclear power station and generate income by exploiting the nuclear facility to reduce CO2 emissions. In Britain, which has positioned nuclear power generation as a promising means to fight against global warming and ensure energy security, for example, power generators' decisions on whether to invest in nuclear power generation projects may depend partly on CO2 emission credit prices under the EU-ETS.

④ Security

Uranium fuel, once loaded in a reactor, may not have to be replaced for one year. Refined uranium, once traded, may have two years before being loaded in a reactor. Uranium fuel can thus be stored for a long time. Uranium fuel may be continuously provided from politically stable countries under contracts that last as long as 10 years. In this sense, nuclear energy is far different from oil for which energy consuming nations depend heavily on the unstable Middle East. Spent uranium fuel may be reprocessed for extracting such substances as plutonium that can be used as fuel. Therefore, countries may be able to increase their energy self-sufficiency rates by having nuclear fuel reprocessing and plutonium processing facilities. In countries that depend heavily on fossil fuels or have low energy self-sufficiency rates, promotion of nuclear energy may contribute to stabilization of energy supply. On the contrary, the characteristics of nuclear energy may fail to strongly stimulate promotion of nuclear development in countries that have high energy self-sufficiency rates with abundant mineral resources.

⑤ Nuclear fuel cycle policy

The biggest matter of concern regarding peaceful use of nuclear energy is treatment of spent nuclear fuels. Of the 31 countries engaged in commercial nuclear power generation, only a few have created specific arrangements for treatment of spent nuclear fuels. Most have fixed only a basic policy of reprocessing (or disposing of) spent fuels. Countries that run facilities for reprocessing spent fuels are limited to three -- Britain, France and Russia. No country has run final disposal sites. Whether spent nuclear fuel is reprocessed or directly disposed, factors that we cannot ignore in proceeding with nuclear power development over a long time would include whether the means to treat some 20 to 30 tons of spent nuclear fuels emerging from a 1 million kW reactor annually would be specified and whether the people or investors would support the means.

⑥ Problems involving disposal of high-level radioactive wastes

As well as the above, this is a similarly important matter of concern involving peaceful use of nuclear energy. While spent nuclear fuels as well as high-level radioactive wastes produced through reprocessing of spent fuels generate strong radiation and heat and must be controlled over a long term, few countries have fixed sites for their final disposal. Since spent nuclear fuels can be subject to considerably long interim storage, the problems involving the final disposal of spent fuels are still unrealistic for countries excluding a few. But the problems will have to be addressed eventually.

⑦ Concerns on proliferation of nuclear weapons

While the number of countries using nuclear power generation is likely to increase from the present 31 in the future, nuclear problems in Iran and North Korea are growing more serious. Furthermore, the United States has agreed to provide India, as a nuclear power, with nuclear equipment and technologies. Under such present conditions, the current nonproliferation treaty regime is criticized for having limitations in accomplishing its objectives. The world will have to develop a new framework that would refrain from impeding peaceful use of nuclear energy and from leading to fears of nuclear arms proliferation. At the same time, technologies will have to be developed for rational and precise nuclear inspections. The new framework and technologies are indispensable for realizing both expansion of peaceful use of nuclear energy and nuclear nonproliferation.

⑧ Interests in and understanding about safety

In many countries in the world, barriers are high against promoting construction of nuclear power stations. One problem is a changing public attitude toward nuclear energy. Anti-nuclear movements in some European Union countries have been too strong to allow existing nuclear power stations to be modified for longer services or greater electricity output. Reasons for opposition to nuclear energy are mostly linked to not only fears of nuclear arms proliferation but also the safety of nuclear reactors, and the costs and safety of radioactive waste disposal. Many studies have found that risks involving nuclear reactors and nuclear fuel cycle facilities are not so much higher than other risks (involving automobiles, aircraft, chemicals, etc.). But such findings have yet to be understood widely. Therefore, regional movements against plans for construction of new nuclear power stations or introduction of innovative nuclear technologies are well expected to emerge, causing these plans to be postponed.

This study also deals with how acquisitions and alliances between nuclear energy system manufacturers would affect factors for promotion or interruption of nuclear power generation. See Chapter 3 for specifics.

3. Global Nuclear Industry Developments and Future Japanese Industry

(1) Developments before 2006

In the 1960s, which represented the initial phase of nuclear power generation, nuclear plant makers, nuclear fuel producers and nuclear-related engineering companies prospered, providing machines, fuels and technologies for various nuclear reactors including light-water, graphite gas and heavy-water reactors. As demand declined sharply for construction of nuclear power plants in the 1980s, however, many nuclear industry participants had difficulties in maintaining their sizes, and implemented cross-border realignment and consolidation. As a result, the global nuclear power plant market was oligopolized by a few companies that featured excellent plant concepts and engineering know-how in terms of economy and reliability, including General Electric and Westinghouse Electric of the United States and Areva of France. Areva, as Framatome, acquired nuclear plant makers Babcock & Wilcox Co. of the United States and Siemens A.G. of Germany. Though based in France, Areva is a multinational company with U.S., German and French capital. WH, under British Nuclear Fuel Ltd., acquired Sweden's Asea Browm Boveri, which bought out Combustion Engineering Inc. of the United States. WH is thus also a multinational with nuclear reactor and fuel cycle technologies in various countries.

In June 2005, BNFL decided to sell WH. Soon after the decision, multiple companies in the world indicated their deep interests in WH as a nuclear plant maker with excellent achievements. The nuclear plant maker, which was forced to reduce its size on the global decline in demand for nuclear power stations in the 1980s and 1990s, attracted attention as nuclear plant construction plans grew more feasible in the United States and China. Some within BNFL reportedly doubted the advisability of selling WH, a crown jewel featuring a high profit ratio, stable earnings and an expected rise in corporate values. But others concluded that the time was mature for BNFL to sell WH on growing expectations of a rise in demand for nuclear plant construction[5]. The WH sale price of $5.4 billion indicates that BNFL was successful in selling WH in the most timely manner.

Mitsubishi Heavy Industries and Toshiba from Japan, and GE and Shaw Group Inc. from the United States were among companies that made bids for WH and negotiated with BNFL. In December 2005, promising bidders were narrowed down to the four firms for final negotiations with BNFL. In January 2006, BNFL announced a decision to give Toshiba the priority negotiation right, ending more than six months of negotiations with bidders.

Earlier, MHI had maintained a technological alliance with WH. Toshiba and GE had had similar alliances with GE. There had been no capital relations between them. The three Japanese

[5] Source: "BNFL Decides to Sell Westinghouse," JAIF Info Gallery, June 30, 2005, Japan Atomic Industrial Forum (then)

firms' nuclear business divisions had their respective business policies. The situation underwent a turnaround on Toshiba's WH acquisition.

(2) Developments in 2006

① Toshiba's acquisition of WH

On February 6, 2006, Toshiba signed an agreement to acquire WH shares. After U.S. and European antitrust examinations and other procedures over some eight months, Toshiba completed the purchase on October 17. Toshiba eventually acquired an equity stake of 77% in WH, followed by a 20% interest for Shaw and a 3% stake for Ishikawajima-Harima Heavy Industries Co. Toshiba then established holding companies in the United States and Britain to exercise its voting shares and take control of WH management. It was to create a "WEC Coordination Division" at its head office to manage WH operations focusing on pressurized water reactors, or PWRs[6]. Its Nuclear Energy Systems & Services Division was planned to remain responsible for promoting boiling water reactors, known as BWRs. Toshiba now covers the two types of light water reactor which is the world's mainstay nuclear reactor.

② MHI's alliance with Areva

Soon after dropping out of the race to acquire WH, MHI announced a plan to promote its advanced pressurized water light water reactor, known as APWR, throughout the world. On July 3, 2006, MHI founded MHI Nuclear Energy Systems Inc. in the United States to launch operations to obtain the Nuclear Regulatory Commission's design certification for its US-APWR reactor and market the reactor[7]. On October 19, 2006, MHI agreed on and signed a memorandum on a strategic alliance with France's Areva group in nuclear business operations[8]. The alliance covers a wide range of operations from the joint development of a 1 million kW PWR and new-type reactors to nuclear plant and fuel cycle services. Specifics may be negotiated in the future.

③ GE-Hitachi equity alliance

On November 13, 2006, Hitachi and GE signed a strategic alliance agreement for the nuclear energy area and decided to found their joint nuclear business ventures in the United States and Japan in the first half of 2007[9]. The two companies intend to market advanced BWRs and the ESBWR (economic simplified BWR) next-generation large light water reactor through their joint ventures to expand their global market share. ABWR reactors have already been in operation in Japan, while the NRC's design certification has been given to the ESBWR planned for some new

6 Source: Toshiba press release on October 17, 2006.
7 Source: MHI press release on July 3, 2006
8 Source: MHI press release on October 19, 2006
9 Source: Hitachi press release on November 13, 2006

nuclear plant construction sites.

Figure 4 outlines the realignment of the nuclear energy industry including past developments.

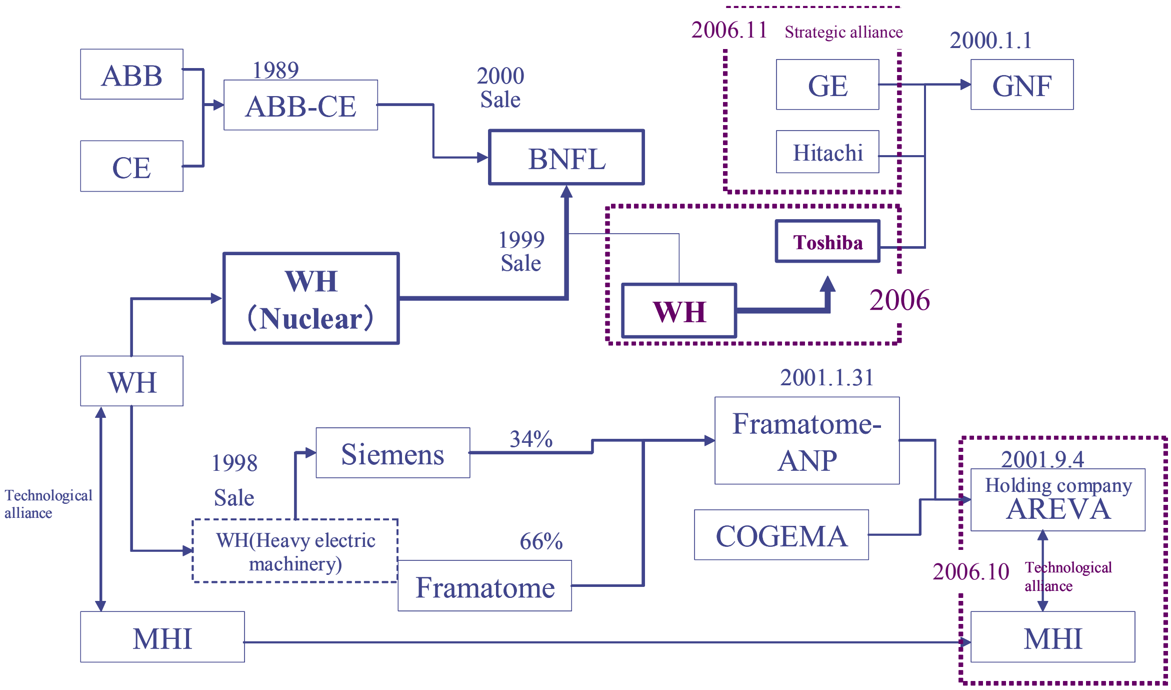


Figure 4 Realignment of Nuclear Industry 1980-2006

(3) Analysis of three Japanese firms' moves

The three Japanese nuclear plant makers have thus adopted different strategies to cooperate with others in the world and develop their operations in the global market. Their objectives and business approaches are also different. Figure 5 indicates cooperative relations between nuclear plant makers and their existing and under-development nuclear reactor types as of January 2007.

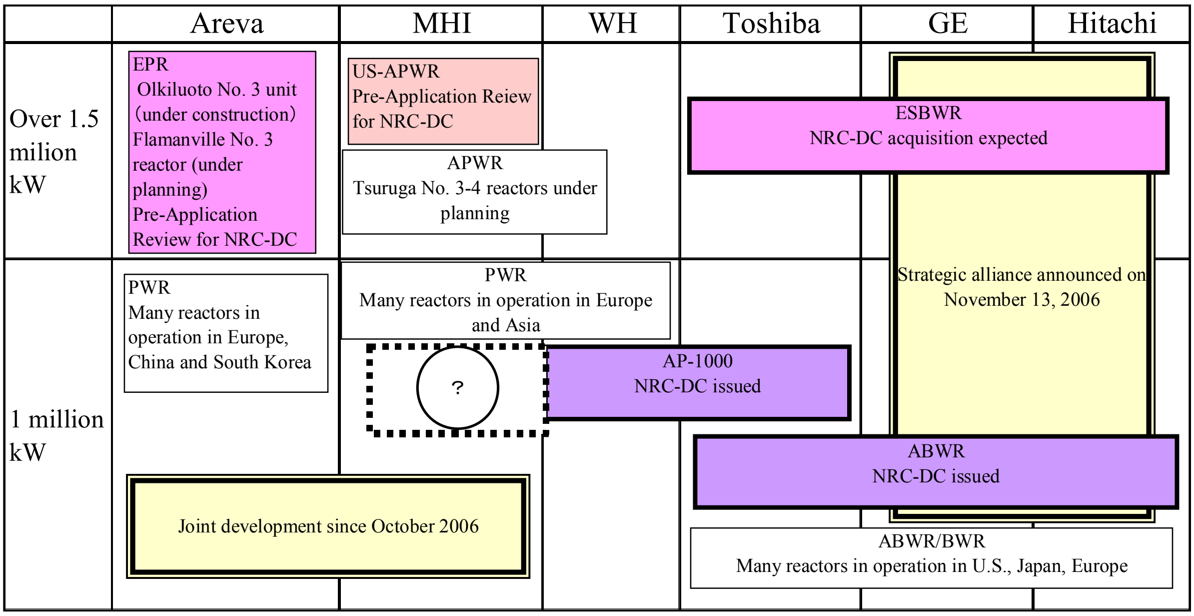


Figure 5 Nuclear Plant Makers and Their Reactor Types (as of January 2007)

WH has not manufactured nuclear plants since its construction of plants ordered in the 1970s. As the prime contractor for nuclear plant projects, it has provided nuclear fuels and plant maintenance services and made some components while ordering major machines from specialized manufacturers. Toshiba's decision to acquire WH for a high price is based on expectations that the WH business model could bring about excellent profitability and promise future growth and that WH and Toshiba's BWR know-how would produce synergy effects. Toshiba aims to obtain a large market share as the prime contractor in China, the United States and other areas where large nuclear plants are expected to be built.

MHI has chosen Areva as its partner to explore the global nuclear plant market by taking advantage of its own excellent technological potential. Areva has a nuclear power plant concept similar to that of MHI and has never competed with MHI in any specific market. Although MHI's US-APWR may compete with Areva's EPR (European pressurized water reactor) in the market for 1.5 million kW reactors, MHI apparently intends to develop a 1 million kW next-generation reactor jointly with Areva to explore U.S., European and Asian markets. Meanwhile, MHI has offered to consider manufacturing WH-type PWRs if requested by WH.

Hitachi has maintained cooperative relations with GE since they signed a comprehensive licensing contract for BWRs in 1967. The latest capital alliance deal is designed for Hitachi to further deepen and develop its BWR business. In the future, Hitachi is likely to expand marketing not only in Japan but also in the United States and other foreign countries in cooperation with GE. Hitachi has so far had a poor nuclear plant business record in the United States.

While new nuclear plant construction deals are expected to increase primarily in the

United States and Asia, past business achievements cannot allow us to easily conclude that any of the nuclear power plant makers has an advantage over others. As noted in 2. (2), whether nuclear power development could be promoted smoothly depends on nuclear power generation's relative advantage in relevant countries (for specific regions and power utilities), on initial investment risks, on prices of other energies and on public understanding about wastes and safety. Nuclear power plant makers in the private sector may hope that countries subject to their business operations would have sufficient government support for nuclear programs, less initial investment risks, smooth permission and licensing procedures, firm safety regulations and a smaller probability of movements against nuclear plant construction. Countries or regions meeting such hopes may be limited. There may also be time constraints. Nuclear plant makers are left to independently balance initial investment risks with prospects for future market growth in any specific country or region. Initial investment risks may involve possible nuclear plant construction delays and uncertain permission and licensing procedures. In order to become a nuclear industry leader, a maker would have to make the most accurate investment decision based on firm technological capabilities.

Since the Japanese nuclear plant makers have been credited overseas for their excellent manufacturing technology and quality and have a good delivery record, a group that takes more risks and markets than others may have an advantage. But these Japanese firms' profits may vary depending on specific deals. MHI, which has teamed up with Areva, may undertake certain projects for orders that Areva receives. Depending on these projects that MHI undertakes, its profit ratios may vary. How would Toshiba's BWR division be involved in designing and manufacturing PWRs as ordered from WH? Toshiba's profit ratios may depend on answers to this question. In this way, Japanese firms' shares of operations and profits for specific deals may be different.

Profitability of nuclear business operations is not so clear because nuclear plant makers' annual reports provide only limited information. Generally, however, profitability is higher for prime contractors and lower for subcontractors. According to WH's annual reports under the umbrella of BNFL, WH's pretax profit ratio stood at 7.3% in 2004, relatively high within the BNFL group. At GE's energy division (Infrastructure Segment), the ratio of operating profit to revenues in 2005 came to 18.6 percent[10].

The ratio of operating income to revenues at a segment including nuclear operations stood at 2.1% for Toshiba in fiscal 2005, 3.3% for Hitachi, and 5.3% for MHI[11].

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[10] Source: "Summary of Operating Segments," GE Annual Report 2005
http://www.ge.com/en/company/investor/secreport/2006_restatement.htm

[11] Sources:
Toshiba: Investor information>segment information http://www.toshiba.co.jp/about/ir/jp/finance/segment.htm
Hitachi: Business information>Segments>Power & Industrial Systems
http://www.hitachi.co.jp/IR/business/segment/pis/index.html
Mitsubishi: To shareholders and investors>Financial & IR information>Fiscal 2005 results
http://www.mhi-ir.jp/efin/a2006/pdf/annual_2006.pdf

Figures 6 to 9 indicate business portfolios of GE and the three Japanese nuclear plant makers, based on earnings data (segment-by-segment revenues and operating income ratios) for the year to March 2006. The three Japanese firms' segments including nuclear business operations are positioned differently in terms of operating income ratios and revenues. To some extent, these differences may explain why the three firms have teamed up with different foreign partners in different forms.

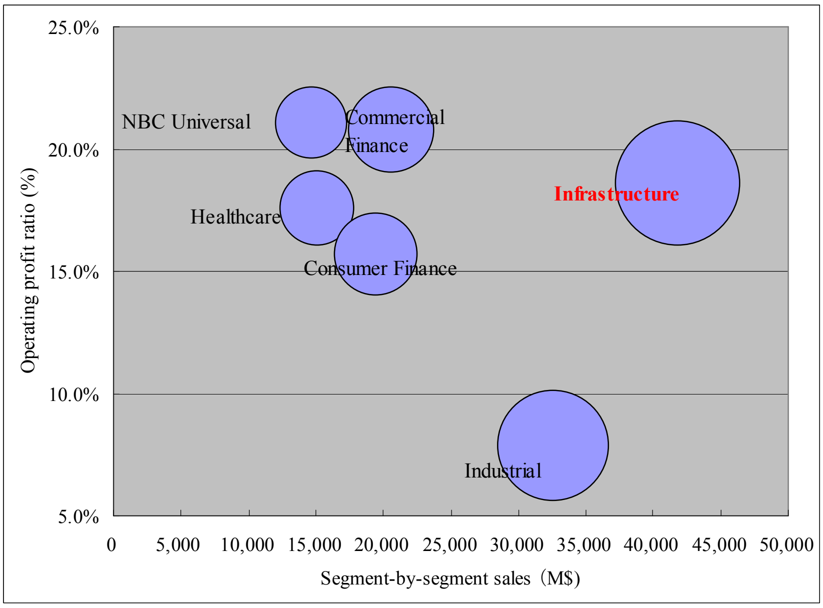

Figure 6 Position of Segment (Infrastructure) Undertaking Nuclear Business Operations at GE (2005)

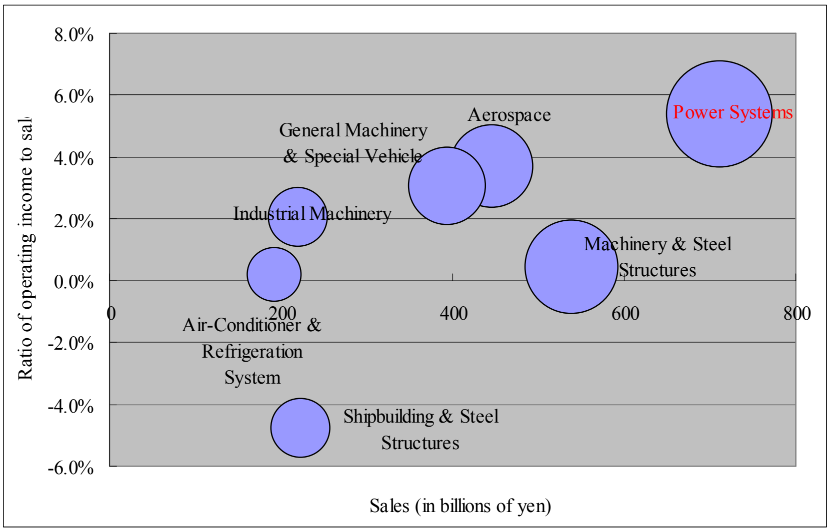

Figure 7 Position of Segment (Power Systems) Undertaking Nuclear Business Operations at MHI (2005)

The segment undertaking nuclear business operations is named Social Infrastructure for Toshiba, Power & Industrial Systems for Hitachi, and Power Systems for MHI.

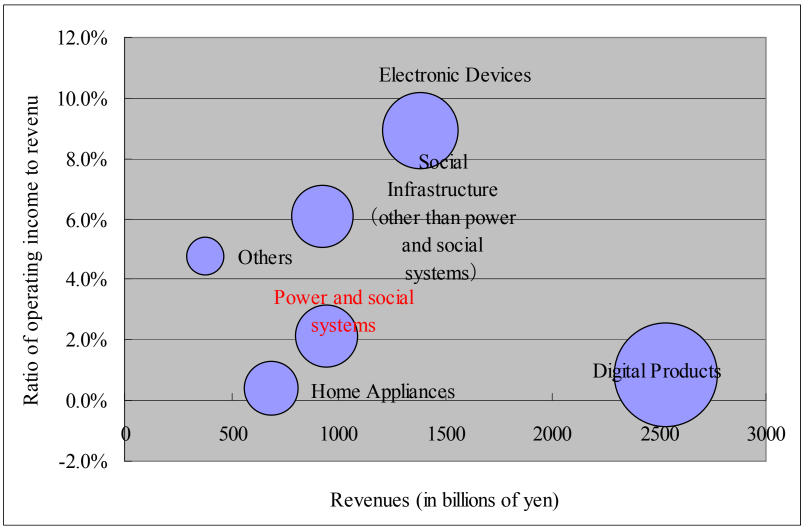

Figure 8 Position of Segment (Social Infrastructure) Undertaking Nuclear Business Operations at Toshiba (2005)

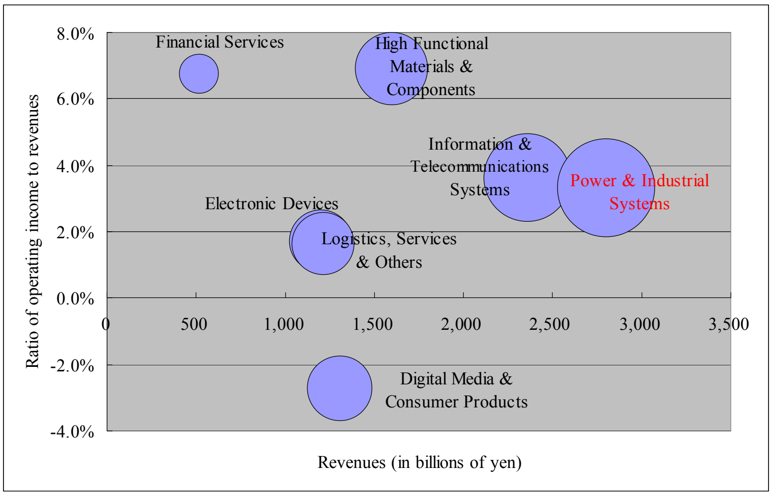

Figure 9 Position of Segment (Power & Industrial Systems) Undertaking Nuclear Business Operations at Hitachi (2005)

Operating income ratio gaps among the three Japanese firms have changed year by year and cannot be viewed as significant. But GE's ratio is clearly higher than the Japanese firms'. This may be because GE has basically followed the same business model as WH, as noted earlier, and pursued higher added value and profitability while liquidating low-profitability divisions under its traditional business culture. Under its business model, GE or WH has sold excellent concepts, undertaken engineering operations as a main contractor and ordered equipment from other firms. The Japanese companies have never adopted such business model in overseas operations. How they would develop cooperative relations with their respective foreign partners will attract attention along with these groups' business territories and market shares.

(4) Goals in "Nuclear Energy National Plan" and nuclear industry realities

Japan has been undertaking a national project to develop a next-generation light water reactor for overseas markets as well as the domestic market where existing reactors will begin to be replaced around 2030[12]. For this national project, Toshiba and Hitachi have agreed to cooperate in the BWR area. The three Japanese nuclear plant makers are also positively engaged and cooperate in a project for a commercial fast breeder reactor cycle system. The project calls for launching operations of a demonstration FBR and relevant cycle facilities around 2025 toward commercial operations of the FBR cycle system starting around 2050.

Achievements of the joint government-private projects may depend on the three nuclear plant makers' future distances with their respective foreign partners. As far as they have developed equity alliances in addition to technological cooperation and exchange of information, it would be unrealistic for them to bar their foreign partners from these national projects. Rather, it may be significant for them to appropriately cooperate with their foreign partners in a bid to develop new reactors that could be accepted globally. As long as the national projects' objective is stable electricity supply over a long term, Japanese power utilities may have to realistically respond to the realignment and globalization of the nuclear industry and take full advantage of nuclear plant makers' technological potential for power generation achievements.

[12] Source: "Nuclear Energy National Plan," Agency for Natural Resources and Energy, August 2006. http://www.meti.go.jp/report/downloadfiles/g60823a01j.pdf

4. Future Prospects and Implications for Japan

Nuclear power generation is expected to grow more important for energy security and measures against global warming in the long run. How each country would promote development of nuclear power generation may depend on the effectiveness of government support and reduction of risks for private businesses. In countries where power utilities select generation sources based on market competitiveness and deregulation, a key point may be whether nuclear power generation can retain a competitive advantage regarding CO_2 emission credit prices and non-nuclear energies. Smooth permission, licensing and construction processes will also be important factors for promotion of nuclear power generation. In general, countries should reduce uncertainties about costs and permission and licensing procedures as much as possible.

Construction of new nuclear power plants is expected to make progress in China, which has set specific numerical targets for nuclear energy promotion, as well as the United States which has enacted legislation for government support for nuclear plants. Only based on the past achievements, we cannot make conclusions on any promising nuclear plant maker or any promising reactor type. Although China is viewed as a big market for nuclear plants with a plan to expand its nuclear power generation capacity to 40 million kW by 2020, the Chinese government is proceeding with domestic production of nuclear reactors. Foreign nuclear plant makers' future share of the Chinese market is very uncertain, while permission and licensing procedures are unpredictable for foreign firms. These points could be viewed as risks. East Asian countries other than China, South Korea and Taiwan have just begun to consider introducing nuclear power generation. We cannot deny that there may be some risks regarding permission and licensing procedures and immature regulations in these countries.

It is difficult to predict any specific type of reactor that would become the global standard. Conceivable criteria for the prediction include the design certification by the U.S. Nuclear Regulatory Commission and construction records in the United States. In this sense, WH and GE have obtained the NRC DC and may be viewed as top runners in the world. But even other nuclear plant makers are expected to make a breakthrough in expanding market shares by clinching first orders in the United States. Therefore, nuclear plant makers are now racing to obtain plant orders primarily in the United States. Sound competition between nuclear plant makers with excellent manufacturing technologies should promote improvement of technological levels and economic efficiency in the entire industrial world to invigorate markets for construction of new nuclear plants in the United States and Asia and replacement of outdated plants in Europe and secure selection of nuclear energy for power generation. This is the direction that should be pursued by the nuclear industry forming the key part of Japan's nuclear power generation operations.

Another key point is that technologies and systems for preventing proliferation of nuclear weapons should be expanded as nuclear facilities increase in the world with a growing number of countries launching nuclear power generation. National research and development organizations have independently or jointly been tackling technological measures, while nuclear nonproliferation systems are still under discussion at the IAEA. Multiple proposals that are sensitively different are on the table, including the U.S. GNEP initiative, the IAEA MNA proposal and the Russian international nuclear fuel cycle center concept. Based on such present situation, Japanese companies must be aware of country-by-country conditions and tackle exploration of nuclear power generation markets in line with Japan's steady vision.

End

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