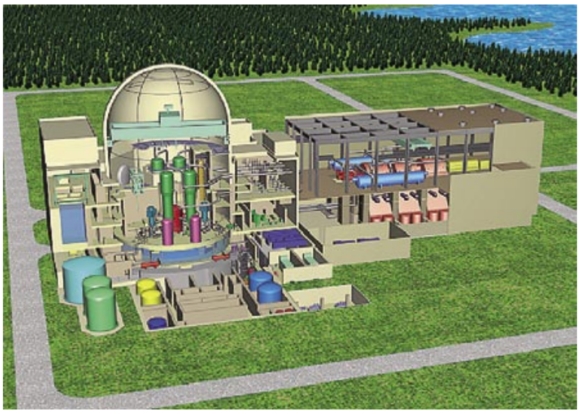


Recent Activities of Nuclear Power Globalization Provisions against Global Warming through the Global Deployment of Technologies as an "Integrated Nuclear Power Plant Supply Company"

KIYOSHI YAMAUCHI*1 SHIGEMITSU SUZUKI*1

Mitsubishi Heavy Industries, Ltd. (MHI) is striving to expand and spread nuclear power plants as an "Integrated Nuclear Power Plant Supply Company" based on its engineering, manufacturing, and technological support capabilities. The company also has ample experience in the export of major components. MHI is accelerating its global deployment through the market introduction of large-sized strategic reactor US-APWR, the joint development of a mid-sized strategic reactor ATMEA1 with AREVA, and a small strategic reactor PBMR. The company also plans to internationally deploy technologies for the nuclear fuel cycle. We present here the leading-edge trends in the global deployment of these nuclear businesses, all of which help to solve the energy and environmental issues in the world.

1. Role of nuclear power generation as a countermeasure against global warming

In December 1997, targets were determined for the reduction of greenhouse effect gas during the Conference on the United Nations Framework Convention on Climate Change (COP3) held in Kyoto. About 90% of greenhouse effect gas from Japan is energy-derived CO_2 generated during energy consumption and energy conversion into electricity, etc. Nuclear power generation, an energy source completely free of CO_2 emission, is thought to be one of the most effective countermeasures against global warming, together with countermeasures to promote energy saving and new energies.

The CO_2 emissions per kWh of energy generated by nuclear power generation are extremely small in comparison to the emissions from thermal power generation with coal and oil, and from natural energy power generation with photovoltaic effects, wind power, and so on (see **Fig. 1**). Thus, nuclear power can help to substantially reduce greenhouse effect gases.

Global warming reduction is a task of utmost importance

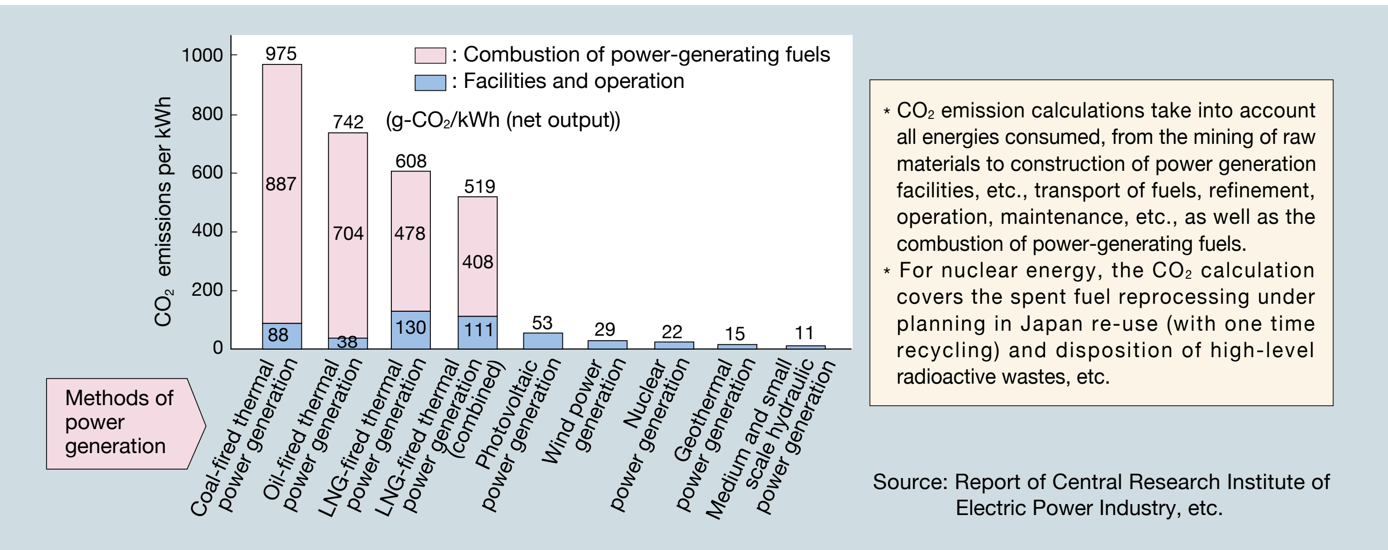


Fig. 1 CO_2 emissions according to various power generation methods
From the website of Federation of Electric Power Companies of Japan, http://www.fepc-atomic.jp/library/zumen/pdf-data/all02.pdf

*1 Nuclear Energy Systems Headquarters

throughout the world. This, together with skyrocketing prices for oil, is drawing renewed interest to nuclear power generation in Europe and the United States. The construction of new nuclear power plants in the U.S. has been stalled for almost three decades, since the accident at the Three Mile Island (TMI) Nuclear Power Plant in 1979. But with the passage of the Comprehensive Energy Act, an NPP-friendly piece of legislation, in 2005, there are now newly promoted plans to build 20 to 30 nuclear power plants. The trend to newly build plants is also rapidly spreading in Europe. China and India, meanwhile, are promoting plans for NPP construction to respond to rapidly increasing electricity demand. And the number of countries with plans for nuclear power generation in the mid- and long-term is also increasing in Southeast Asia. In December 2007, ministers in charge of nuclear energy from nine countries adopted a joint communiqué to promote nuclear power generation as a countermeasure against global warming, at a ministerial level meeting at the Forum for Nuclear Cooperation in Asia. The communiqué urges international society to recognize nuclear power generation as a means for reducing greenhouse effect gas in the next framework for greenhouse effect gas reduction (Post-Kyoto Protocol), and to accelerate cooperation in Asia, a region with successive plans to introduce and enlarge nuclear power generation.

Thus, our nuclear technologies accumulated through ongoing plant construction and maintenance activities are expected to serve the growing need for nuclear power generation. MHI has plans to promote the globalization of this business in a coming "Nuclear Power Renaissance."

2. Technologies supporting globalization

Nuclear generation must assure the social needs of "safety and security." Comprehensive technical capabilities covering the whole life of a plant are essential. MHI, as an "Integrated Nuclear Power Plant Supply Company," has come to realize these technologies based on its engineering capabilities, manufacturing capabilities in manufacture and construction, and technological support capabilities mainly in maintenance. MHI is convinced that these capabilities are the technical basis for the global deployment of nuclear power generation.

2.1 Engineering capabilities

MHI possesses technologies revered around the world. Its core design technology and safety analysis technology are essential for nuclear plant engineering. Safety analysis can evaluate and predict how stably a reactor and plant be operated and controlled, and how the safety of a reactor and plant be assured by the actuation of reactor safety and protection systems in when unanticipated events occur.

The company has long experience in using three-dimensional data as technology for plant development and design. The system has been established to correctly and effectively use vast amounts of plant data, and operation and application know-how has been accumulated through its use. This technology has been broadly and effectively used not only for procurement, but also for manufacture with CAM (Computer-Aided Manufacturing), approval in various inspections, construction-process control for short-term construction, and the prevention of human error. Through this use, it has helped establish an excellent quality assurance organization and quality management system (QMS).

MHI has abundant experience in supply and high reliability in the development and design of PWR fuels. MHI has fabricated about 18,000 fuel assemblies by the end of 2007, with a fuel leakage rate at least ten times lower than that of overseas. MHI has also steadily proceeded with the development of high burn-up fuels in response to the needs of utility companies, achieving and applying high burn-up fuels of up to 55 GWd/t for plants. MHI is now tackling the development of what will be the world's highest burn-up fuel ever (70 - 80 GWd/t). The company's fuel development has been continued in the areas of core design, safety evaluation, evaluation of plant effects, design of transport cask, and review on fuel fabrication based on broad experience.

2.2 Manufacturing capabilities

The manufacturing technologies in nuclear power generation cover diverse fields. MHI has adopted, for example, electron beam welding, a new technology for processing large components to assure high precision and enhanced reliability.

The plant construction technologies also require "manufacturing capabilities," including accumulated technologies through plant construction experience. MHI has managed to reduce its on-site construction period by applying steel-plate-reinforced concrete (SC) and large prefabricated blocks. **Figure 2** shows the installation of the upper reactor containment of the Tomari Unit 3 of Hokkaido Electric Power Company, the latest domestic PWR plant. The

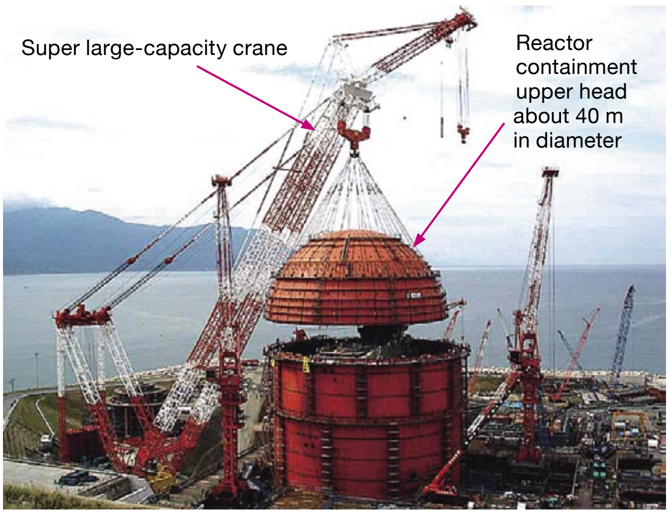


Fig. 2 Manufacturing capabilities (plant construction technologies)
Construction of containment vessel for Tomari Unit 3 of Hokkaido Electric Power Company

upper reactor containment (diameter of about 40 m) was assembled on site, lifted by a super-large-capacity crane, and installed at the precision of several millimeters or less on the perimeter of the cylindrical shell of the reactor containment. The installation was completed in September 2005.

The steam generator delivered to Tomari Unit 3 is the hundredth steam generator manufactured by MHI.

2.3 Technological support capabilities

MHI also has its technological support capabilities to respond to the needs of utility companies, in addition to engineering capabilities and manufacturing capabilities. To maximize the effective use of the existing plants, MHI's technological support capabilities include high-level inspections, proposals for comprehensive preventive maintenance programs, repair works, and component replacements. All of these capabilities enhance plant availability, based on MHI's knowledge and experience on the whole plant.

The replacement of large components requires the careful integration of maintenance technologies. MHI has realized many large component replacement works within short work periods by amalgamating its manufacturing technologies and comprehensive plant engineering technologies. This approach has contributed greatly to the minimization of radiation exposure for working personnel.

3. Experience in exporting major components

Table 1 shows the component export experiences categorized by destination—Europe, the Americas (including Central America and South America), and Asia. For the Americas MHI has provided a number of replacement reactor vessel closure heads and replacement steam generators in existing plants. In Europe, MHI has provided the reactor vessel for the first unit of EPR in Finland, and replacement steam generators for France and Belgium. The company received orders for two turbines from China at the end of September 2007, and a replacement reactor vessel closure head for Centrais Eletricas Brasileiras S.A., in November 2007. As almost 70% of the nuclear power plants in the world are of PWR type, high hopes are placed on MHI's manufacturing technologies and quality assurance systems around the world.

Table 1 Export experiences with major components

	Europe	Americas	Asia	Total
Reactor vessel	1 (1)	–	2	3 (1)
Reactor vessel closure head	3	16 (5)	–	19 (5)
Steam generator	16 (8)	6 (4)	–	22 (12)
Primary coolant pump	–	–	8 (4)	8 (4)
Turbine	2	2	8 (4)	8 (4)

( ): number of components included, under manufacture or before installation.

4. Development and market introduction of world strategic reactors

4.1 Large-sized strategic reactor, US-APWR

The licensing for the US-APWR is now proceeding smoothly in the U.S. The US-APWR, now under a licensing process by NRC, has been introduced into the U.S. market based on the APWR design established for the Japanese domestic market. This will respond to the need for prompt plant construction by U.S. utility companies. The US-APWR, the largest reactor in the world, has a power output of 1,700 MWe class per unit and improved fuel economy. The excellent core design enables 24-month operation and a reduction of uranium consumption to at least 18% less than that of existing reactors (see **Fig. 3**). The US-APWR has achieved highest safety and reliability level by the adoption of safety systems with best combination of passive and active technologies and countermeasures against airplane crashes. To respond to the strong need for construction cost reduction, MHI is targeting a construction period of 41 months and has commenced a study on site conditions with comprehensive technological capabilities being mobilized. The main features of the US-APWR are compatibility between the high power output of 1,700 MWe class and fuel economy, and enhanced safety, reliability, and maintainability.

A pre-application review of the US-APWR for Design Certification (DC) was started from July 2006 with the U.S. Nuclear Regulatory Commission (NRC). Within only a short period, it was recognized as a proven light water reactor through the review. MHI submitted an application for DC of the US-APWR at the end of December 2007. The company is also supporting the preparation of an application to a Combined Construction and Operating License (COL) scheduled to be carried out in parallel.

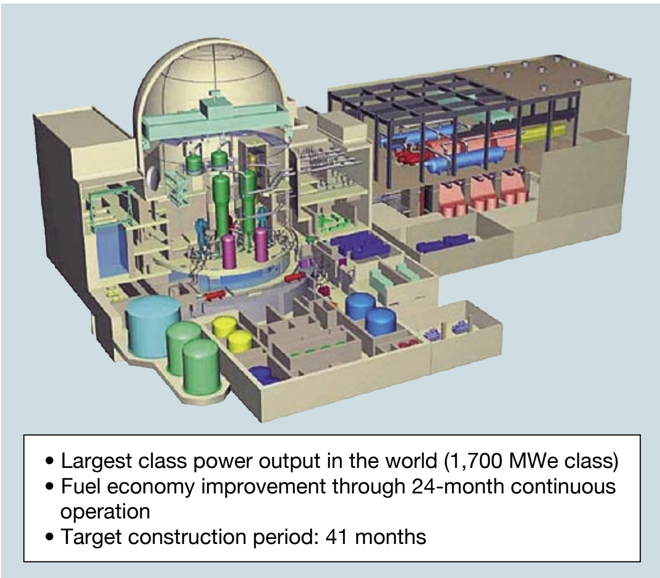
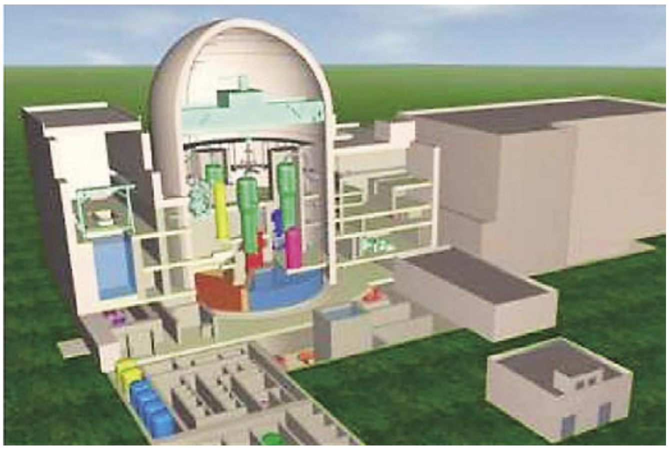
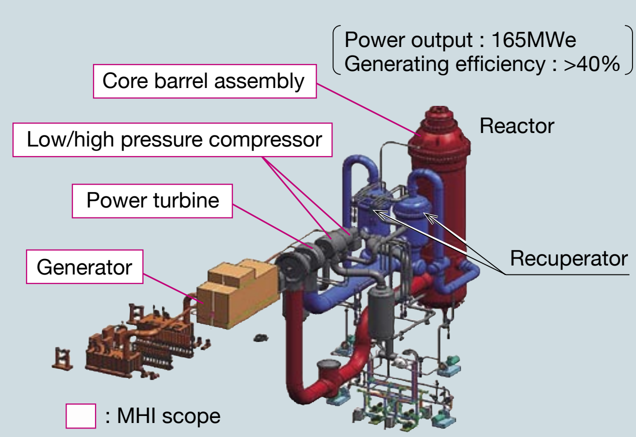


Fig. 3 Large-sized strategic reactor, US-APWR



- Reduction of development period through the synergy effect of MHI and AREVA
- Establishment of joint venture of ATMEA for design and sales: November 2007
- Electric power output: 1100 MWe of net output

Fig. 4 Mid-sized strategic reactor, ATMEA1



- Amalgamation of MHI's gas turbine technologies, design and manufacturing technologies for nuclear components, and PMBR's gas reactor technologies
- Demonstration unit : Koeburg, South Africa (operation start: 2013)

Fig. 5 Small strategic reactor, PBMR

On July 1, 2007, MHI established Mitsubishi Nuclear Energy Systems, Inc. (MNES) as a wholly owned subsidiary in Washington D.C. MNES has commenced sales and marketing activities as a comprehensive center of the nuclear energy business of MHI in the United States pertaining to local affairs of DC application, sales activities for new plants, and replacement large components. MHI expects to commence construction of Luminant Power's first US-APWR at Comanche Peak Site in 2012, and is continuing its efforts to receive orders for succeeding plants in the United States.

4.2 Mid-sized strategic reactor, ATMEA1

Next comes the introduction of mid-sized strategic reactor, ATMEA1, under joint development with AREVA. Both MHI and AREVA are leading nuclear suppliers engaged in all fields of nuclear development, design, manufacture, construction, and maintenance. Through this cooperation between two large companies with the world's most advanced comprehensive capabilities, the development period up to the market introduction of the ATMEA1, an attractive nuclear power plant can be drastically reduced with an expected synergy effect. The two companies own and operate twelve nuclear energy factories, enough to avoid bottlenecks in component manufacturing and other processes. The ATMEA1 will have a power output of around 1,100 MWe, will be flexibly adapted for the power grid conditions of various sites, and will be flexibly designed to adjust various regulations of the IAEA, United States, Europe, and Japan. This will become possible through an integration of experience and know-how from the 120 or more nuclear power plants produced by these two companies. With its design concept, the reactor will have resistance and durability against airplane crashes, and the reactor containment integrity will be assured for long periods during severe accidents. This durability and integrity will make the reactor suitable for construction and operation anywhere in the world. The conceptual design for the plant has already been completed, and development and sales activities will be accelerated by the newly formed joint venture ATMEA, established in November 2007 (see **Fig. 4**).

4.3 Small strategic reactor, PBMR

The small strategic reactor PBMR is a reactor-adopted pebble bed fuel with a helium gas coolant using nonradioactive medium. Its major advantage is zero risk of reactor core dissolution. The pebble bed fuel is a mixture of uranium oxide particles and graphite powder compaction-molded into a spherical shape of about 6 cm in diameter. MHI has participated in the project from 2001, promoting the project by amalgamating its own gas turbine technologies and nuclear component design and manufacturing technologies with the gas reactor technologies of PBMR Ltd. The 165 MWe reactor is designed as a module type that will be extendible to meet electric demand in various regions, in the expectation that it will be installed close to the site of power demand. PBMR is scheduled to be constructed by ESKOM, a power company of South Africa, at the Koeberg Power Plant site west of Cape Town. Startup is planned by 2013 (see **Fig. 5**). There are also plans for U.S. deployment, and a pre-application review for the DC is being carried out with the NRC.

5. Establishment and international deployment of nuclear fuel cycle

Finally, we introduce MHI's activities and developments in the area of nuclear fuel cycle. The company has broad and long-term experience in this area. The fast breeder reactor (FBR) and nuclear fuel cycle at the Rokkasho Reprocessing Plant is a culmination of many thousands of state-of-the-art technologies.

5.1 Establishment of the nuclear fuel cycle

MHI has been actively engaged in FBR development and played an important role in the projects for the Experimental Reactor "Joyo" and the Prototype Fast Breeder Reactor "Monju," aiming at practical use of the FBR. As the FBR has recognized to have the compatibility with both safety and economy, MHI was selected to serve as the core company in FBR development in Japan. In response, MHI established Mitsubishi FBR Systems, Inc. (MFBR), a new engineering company to engage in the development and design of the demonstration reactor and commercial reactor. MFBR commenced operation in July 2007.

5.2 International deployment of the nuclear fuel cycle

A joint proposal submitted by MHI with AREVA and the Japan Nuclear Fuel Ltd. was selected to become part of a "Global Nuclear Energy Partnership (GNEP)" overseen by the U.S. Department of Energy. Under this proposal, the Advanced Recycling Reactor (ARR) fueled by plutonium, etc. will be operated jointly with the Consolidated Fuel Treatment Center (CFTC) to reprocess and reuse spent fuels in the United States. This proposal was based on the intentions of the Japanese Government, which had earlier decided to participate in the partnership originated in the United States. MHI is taking part in this project in the hopes of developing its concept of a fast breeder reactor in Japan as a world standard.

6. Conclusion

As the need for nuclear power generation rapidly grow around a world, Japanese nuclear suppliers will be playing a more global role. MHI believes that "safety and security" are of top priority in nuclear power generation, and will continue to supply reactor facilities, plant systems, components, nuclear fuels and turbines with its own technologies, responding to the needs of the world, based on its own experiences. The company also believes it can surely cooperate with overseas companies during the overseas deployment based on the know-how accumulated from its experiences. MHI is keenly aware of the importance acquiring global design certifications and accumulating overseas construction experience, to respond to the reliability requirements of domestic utility companies. As an "Integrated Nuclear Power Plant Supply Company," MHI will take part in the globalization of nuclear energy using the experiences it has gained through its work to comply with the high-level regulations and quality requirements in Japan, and work to solve the world's energy and environmental issues with its own technologies.


Kiyoshi Yamauchi


Shigemitsu Suzuki