Nuclear Power in Japan: Present and Future

By Yasushi Matsuda

Yasushi Matsuda has been a councillor at the Director General's Secretariat of the Agency of Natural Resources and Energy of the Ministry of International Trade and Industry since October 1982. An atomic energy specialist, he was engaged in energy conservation R&D projects as a senior officer at the Agency of Industrial Science and Technology, 1981–1982.

Japan's energy structure before the oil crisis was especially vulnerable compared with other industrialized nations. Japan depended on imported oil for most of its primary energy needs because it has almost no resources of its own. Naturally, the two oil price shocks in the 1970s had a strong impact on Japan. To establish a stable energy supply system, the government has since promoted a policy to reduce the country's dependence on oil through the development and introduction of alternative energy and by diversifying supply sources.

In particular, nuclear power has priority as a principal oil substitute. This is in part because nuclear energy can be produced domestically on a stable basis and therefore contributes to the nation's energy security. Nuclear energy is also favored because it can be supplied economically in large quantity.

At the end of fiscal 1983, 24 commercial nuclear reactors—with a combined capacity of 18.28Mkw—were in operation in Japan. The number of reactors as of September 1984 was 27 with 19.70Mkw (see Fig. 1). The 24 accounted for about 13% of total generating capacity and about 20% of all power output.

Nuclear power is expected to represent an increasing proportion of power supply through the rest of this century. Capacity is forecast to reach 34Mkw (about 28% of total power output) in fiscal 1990, 48Mkw (about 35%) in fiscal 1995 and 68Mkw (about 39%) in fiscal 2000.

Background

Today, nuclear power is the principal oil substitute in Japan and its development may be divided into three stages.

Fig. 1 Site of Nuclear Power Stations

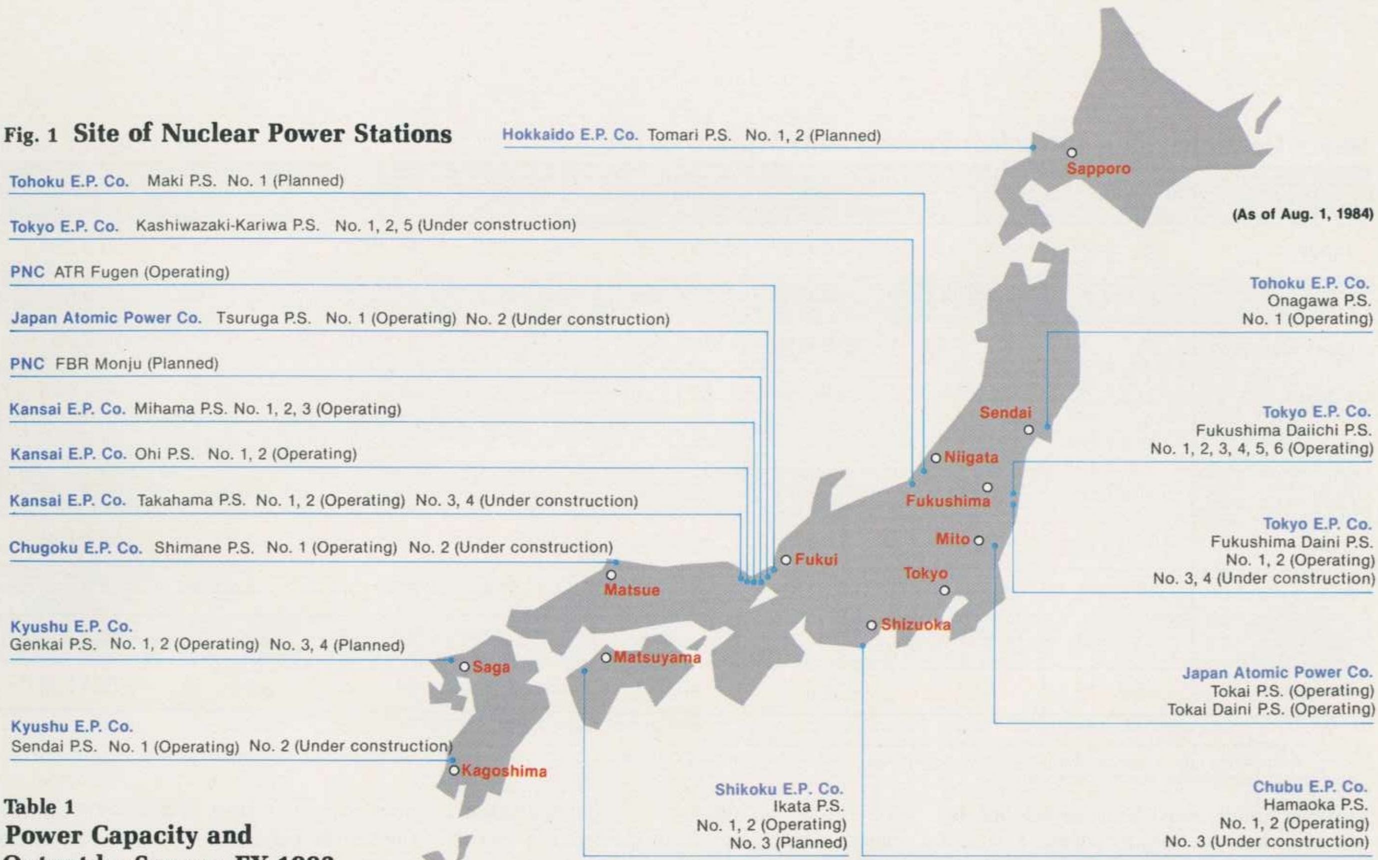


Table 1
Power Capacity and Output by Source, FY 1983

	Hydropower	General	Pumped-up water	Thermal power	Oil	Coal	LNG	LPG	Other gases	Geothermal heat	Nuclear power	Total
Capacity as at end of FY 1983 (1,000kw)	32,400	18,350	14,050	93,580	60,090	8,230	23,380	1,700	—	180	18,280	**144,260**
(%)	22.4	12.7	9.7	64.9	41.7	5.7	16.2	1.2	—	0.1	12.7	**100**
Output (billion kwh)	81.4	76.2	5.2	361.0	202.2	44.1	90.5	3.6	19.5	1.2	113.1	**555.5**
(%)	14.6	13.7	0.9	65.0	36.4	8.0	16.3	0.6	3.5	0.2	20.4	**100**

Notes: 1. LNG includes domestic natural gas, which amounted to 460,000 tons in LNG terms. 2. Other gases are COG, BFG and LDG. 3. Oil consumption is calculated as heavy oil.

(1) Technological introduction

Preparations for nuclear power development in Japan began in the 1950s. These included the passage of the Atomic Energy Basic Law aimed at the peaceful use of nuclear energy and related statutes, and the creation of the Atomic Energy Commission and related agencies. Nuclear power was commercially produced for the first time in 1966 when a gas-cooled reactor introduced from Britain went into operation. Development in subsequent years, however, revolved around light-water reactor technology introduced from the United States. In 1970, the first boiling water reactor (BWR) went into operation at Tsuruga and the first pressurized water reactor (PWR) at Mihama.

(2) Transition

The light water reactors (LWRs) installed in Japan developed a number of technical problems in the years that immediately followed, problems which may be inevitable with any type of new technology. These included stress corrosion cracking in the BWRs and steam generator heat tube leakage in the PWRs. Subsequent efforts to work out countermeasures and develop corrective technology were accompanied by operational difficulties such as the drop in the capacity factor, or operating rates.

In this period, public anxiety over the safety of nuclear power plants increased, making it difficult to construct such facilities. In order to dispel such public apprehensions it was felt that all problems,

Table 2 **Operating Rate of Nuclear Power Plants Worldwide (%)** (As of Dec. 31, 1983)

Country \ Calendar Year	1976	1977	1978	1979	1980	1981	1982	1983
Japan	95.1 (13)	39.2 (14)	54.8 (18)	49.3 (21)	61.2 (21)	61.3 (22)	70.2 (24)	70.0 (24)
U.S.A	59.8 (52)	64.6 (59)	65.7 (62)	57.6 (65)	55.7 (67)	57.5 (71)	55.1 (75)	56.0 (72)
West Germany	68.7 (8)	63.7 (9)	60.5 (9)	53.5 (10)	56.6 (10)	67.8 (10)	74.0 (11)	71.6 (11)
France	57.2 (7)	61.7 (7)	70.5 (9)	56.4 (13)	58.7 (20)	57.8 (28)	52.7 (30)	64.4 (30)
Canada	85.2 (5)	86.8 (7)	78.7 (8)	78.4 (9)	82.2 (9)	88.4 (9)	82.2 (12)	84.6 (12)
Italy	67.6 (3)	61.3 (3)	71.0 (3)	20.1 (4)	16.9 (4)	20.5 (4)	58.4 (3)	62.3 (2)
Spain	77.0 (3)	66.7 (3)	78.1 (3)	68.4 (3)	52.9 (3)	64.9 (4)	48.9 (4)	52.7 (4)
Switzerland	85.3 (3)	86.6 (3)	89.6 (3)	66.5 (4)	80.3 (4)	85.2 (4)	84.2 (4)	87.3 (4)
Sweden	55.0 (5)	61.6 (6)	70.5 (6)	62.4 (6)	71.5 (8)	64.1 (9)	62.0 (10)	64.3 (10)
Belgium	65.3 (3)	77.6 (3)	81.8 (3)	74.4 (3)	81.5 (3)	84.0 (3)	83.5 (5)	79.1 (5)

Notes: 1. The figures in parentheses show the number of nuclear power reactors installed at each power station with terminal output greater than 135Mw taken for the calculation of the capacity utilization rate.
2. Operating rate = [output (kwh)/authorized output (kw) x number of hours (h)] x 100 (%)
Sources: Nucleonicsweek, Nuclear News, etc.

however small, must be resolved one by one so that no major accident would occur. In other words, the best assurance of nuclear safety was thought to lie in the accumulation of operational data proving that nuclear plants are indeed safe. As a result, concerted efforts were made both at the official and private levels to ensure nuclear safety and improve the reliability of nuclear power generation.

These efforts involved not only measures to resolve specific technical problems but also systematic studies in the form of technological improvement and standardization programs. From 1975 to 1980, the first and second such programs were carried out, producing results of great technological importance and contributing significantly to the establishment of domestic nuclear power generating technology.

Aside from these efforts to establish Japanese technology, the government promoted demonstration tests in order to deepen public understanding of nuclear plant safety and reliability. These tests were conducted on major components of a nuclear power plant, with conditions equal to or even more tough than actual operating conditions. Demonstration tests, which have been carried out since 1975, have produced useful data.

The Japanese nuclear power industry was jolted by the accident at Three Mile Island in the U.S. in 1979. And in 1981, one of Japan's plants, at Tsuruga, Fukui Prefecture, experienced an accident. These incidents offered important lessons plants and they sparked efforts to strengthen safety precautions. As a result, the safety and reliability of nuclear power generation increased.

(3) Crystallization

This is a period in which the nuclear power industry has learned from its operational experiences and in which design improvements of the past are bearing fruit. At the same time, operational and administrative refinements, combined with the learning process, are producing an effect. As a result, rapid improvement in the capacity factor attests to the establishment of nuclear generating technology in Japan.

The operating capacity of nuclear power plants stayed at 40%–50% during the second period of development, due to initial technical problems such as stress corrosion cracking. In and after fiscal 1980, however, the capacity factor exceeded 60%. In 1982–83 the rate remained at the 70% level (see Table 2). This is very high compared with other nuclear power countries, considering that Japanese plants undergo regular inspection once a year for three to four months.

The major reason behind this is that these facilities are subject to stringent official safety regulation at all stages from planning to operation (see Fig. 2). In addition, the following four reasons may be cited:

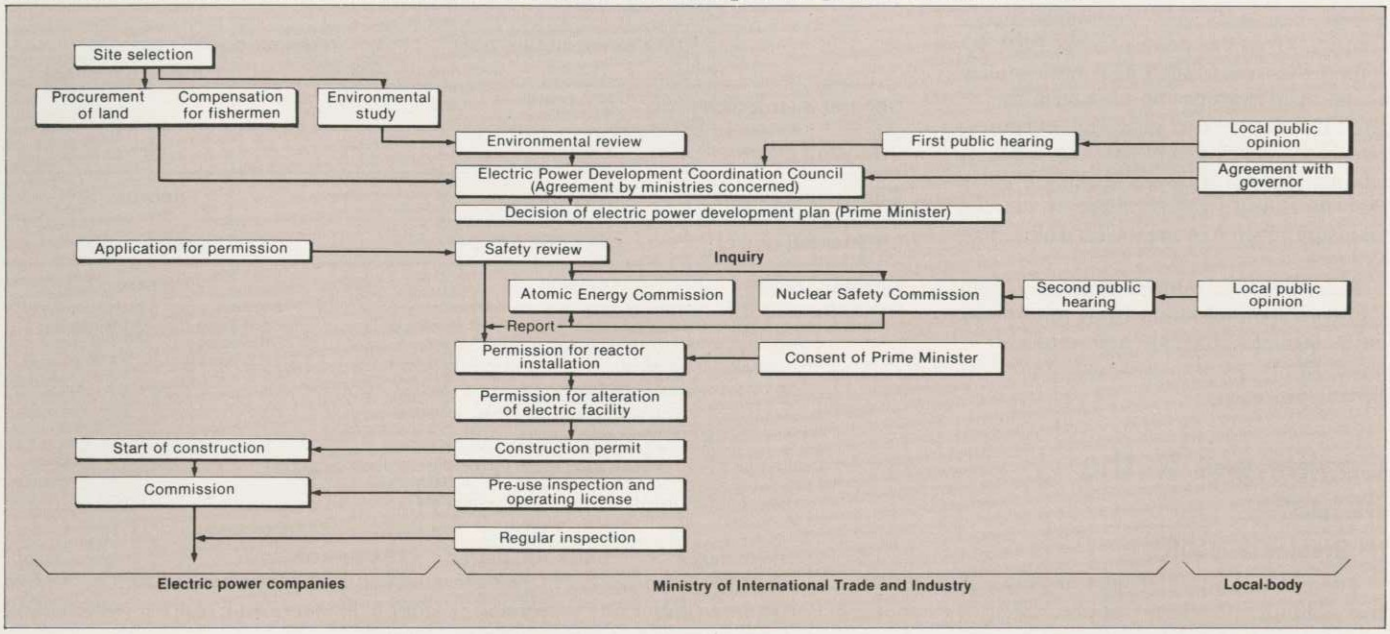
1) Cutting regular inspection periods

Repair and modification work to resolve technical problems has been substantially reduced. At the same time, the operating process and system have been improved through introduction of automated and remote-control devices. Consequently, the period of regular inspection has been steadily reduced.

2) Extending continuous operation

The reliability of nuclear power plant

Fig. 2 **Outline of Nuclear Power Construction Permit and Operating License Proceedings**



machinery and equipment has been increased through design improvements and effective quality control. Also, design changes have been made in the fuel system. As a result, the period of continuous operation has been stretched to about 10–12 months from about 8–10 months.

3) Reducing non-scheduled shutdowns

Japanese-style quality control, technological improvements, more thorough training of operating personnel, and better automatic safety control systems have all helped to reduce both the frequency and duration of non-scheduled shutdowns caused by technical faults. The frequency of such shutdowns—the average yearly number of disruptions per reactor—is less than one-tenth of that in the United States.

4) Resolving technical problems

Such problems can now be prevented more effectively than before, and, in the event, can be resolved quickly and accurately. This has been facilitated by the introduction of a qualifying examination system for operating managers and the strengthening of operation control and supervision systems, such as the posting of a nuclear power operating administrator at each plant.

One conclusion may be drawn from all this: LWR development is now taking root in Japan, 15 years after its introduction from the United States. And this is happening in ways suited to the characteristics and systems of Japanese technology and industry.

The changing environment

So far the circumstances surrounding the LWR seem to have developed in favor of the Japanese nuclear power industry. Among them are a sharp rise in primary energy demand in the early period of reactor development, the explosion of oil prices during the first and second oil crises, and the growing realization of the need to develop alternative sources, including nuclear power, as a means of enhancing energy security.

Now that LWR technology has entered a period of consolidation, the energy position is again faced with major changes.

First, with the world economy, as well as Japan's, entering a period of slower growth, energy demand, too, is going through a period of slower expansion. Now in progress are structural changes in energy demand stemming from alterations in the industrial structure and progress in energy conservation.

Secondly, there is a social imperative to stabilize energy costs. The two energy crises of the past decade have sent energy costs soaring, creating a tremendous impact on Japan's economy, including basic materials industries. It is clearly in the interest of the national economy to stabilize energy costs. Price stability is also essential for national security. The share of electric power supply in the nation's total energy supply is expected to continue expanding. In order to stabilize costs, therefore, it is especially important to stabilize the cost of electric power, particularly of nuclear generation, which is expected to be the main source of power supply in the future.

Japan is committed, at both official and private levels, to promote development of a fast breeder reactor (FBR) as the prototype to succeed the LWR. This is necessary to ensure both effective use of energy resources and national energy security. From this point of view, FBR development is envisaged as a basic policy aimed at promoting the long-term use of nuclear energy for peaceful purposes. However, development of the FBR is tending to lag worldwide, making it likely that the LWR will continue to be the mainstay reactor in Japan for some time to come.

Therefore, it is more necessary than ever for Japan to put its LWR technology on a stronger footing and establish it more firmly as the principal source of electric power.

Table 3 Power Costs by Source, FY 1983

	Unit construction cost (¥/kw)	Terminal power cost (¥/kwh)	Fuel cost share
General hydropower	610,000	20	—
Oil-fueled power	130,000	17	approx. 75%
Coal-fueled power	230,000	14	approx. 40%
LNG-fueled power	180,000	17	approx. 65%
Nuclear power	300,000	12.5	approx. 25%

Notes: 1. Power costs are calculated from hypothetical model plants on the basis of power plants that began operation or were scheduled to begin operation around fiscal 1983.
2. The capacity utilization rate is estimated at 70% (40% for hydropower plants).
3. Prices, approximations, are those prevailing in the first year of operation.
4. Model plants are assumed to have the following capacities:
General hydropower (dam, water conduit type)...10,000-40,000kw
Oil-fueled power ... 4 generators of 600,000kw class
Coal-fueled power...4 generators of 600,000kw class (using foreign coal)
LNG-fueled power...4 generators of 600,000kw class
Nuclear power...4 generators of 1.1 million kw class

Challenges to the industry

(1) Greater reliability

The growing share of nuclear power in the nation's electricity supply makes it essential that LWR development be promoted with greater emphasis placed on reliability. This is indispensable not only for stable, long-term supply of electric power, but also for cost stability.

One major challenge is to strengthen measures for the maintenance of nuclear power plants and prevention against accidents and other technical faults. To do this, effective use must be made of information collected in the course of plant operation in other countries as well as Japan's 15 years of experience in the operation of LWRs.

Efforts in this direction are being made by electric power companies. For its part, the government is planning to set up in fiscal 1984 an information center designed to collect and use information conducive to more efficient safety regulation.

Another major challenge is to train qualified people, such as plant operators and maintenance workers, to run the increasing number of reactors. It is important that power companies themselves make steady efforts to meet such needs in the long term. Ultimately, such efforts should contribute to improving autonomous maintenance systems.

The pursuit of higher reliability for the LWR also depends on progress in technology. Particularly important is technological development aimed at higher reliability (e.g. through plant maintenance and accident prevention), simplified operation and greater ease of maintenance, and higher operating rates. All such improvements can be made on the basis of past experience in nuclear plant operation and maintenance and Japan's high-level industrial technology. To make this possible, it is necessary to establish a technological development system based on government-industry cooperation and to promote information exchange and research cooperation with other advanced nations.

(2) Cost reduction

Until now, the high cost of constructing a nuclear power plant has been overshadowed by the sharp rise in oil prices. Thus, nuclear power has maintained its advantage over other sources of electric power (see Table 3). The fact remains, however, that plant construction costs, accounting for nearly 80% of nuclear power generating costs, have sharply increased over the years. In order to minimize the cost of nuclear power, it is vital to reduce construction costs. This can be achieved by the following methods:

1) Construction

This involves standardization, design rationalization, and shorter construction periods.

2) Improvement of capacity factor (from the present 70% to 80–85%.)

The operating rate could be raised by such measures as making regular inspection more efficient, lengthening the period of uninterrupted operation, and promoting technological development aimed at preventing accidents and other technical failures.

Japan's nuclear power generating technology is now established, as shown by the satisfactory utilization record of recent years. It can be said, therefore, that the Japanese industry is now well prepared to seek better economy of nuclear power generation.

Nuclear power generation in Japan has reached the stage where greater emphasis is placed on reliability and economic merit than on quantitative expansion. Therefore, Japan should take appropriate measures from a long-term perspective. At the same time it should be remembered that Japan is now required to play an international role as an advanced nuclear energy country. ●