Japan's 'nuclear energy vision' in the 21st century

Marjorie Mazel Hecht, managing editor of Fusion *magazine, reports on Japan's programmatic commitment to develop the most advanced and efficient energy sources available.*

In a report called *Nuclear Energy Vision in the 21st Century,* Japan's Ministry of International Trade and Industry (MITI) announced June 30 that nuclear energy production was expected to more than double by the year 2030, generating 58% of Japan's electrical energy. Nuclear power must become the main source of alternative energy in the next century, the report said.

The program also specifies a schedule for Japan to complete its nuclear fuel cycle, commercializing fuel reprocessing, fabrication, spent-fuel management, and breeder reactors, along with an indigenously developed reactor that is a bridge between conventional light water reactors and fast breeders. Japan already has the independent capability of manufacturing reactors and reactor components, and by the turn of the century, the MITI plan envisions this independence extending to the entire nuclear fuel cycle. Japan will no longer have to import uranium or turn to the United States or France for spent-fuel reprocessing.

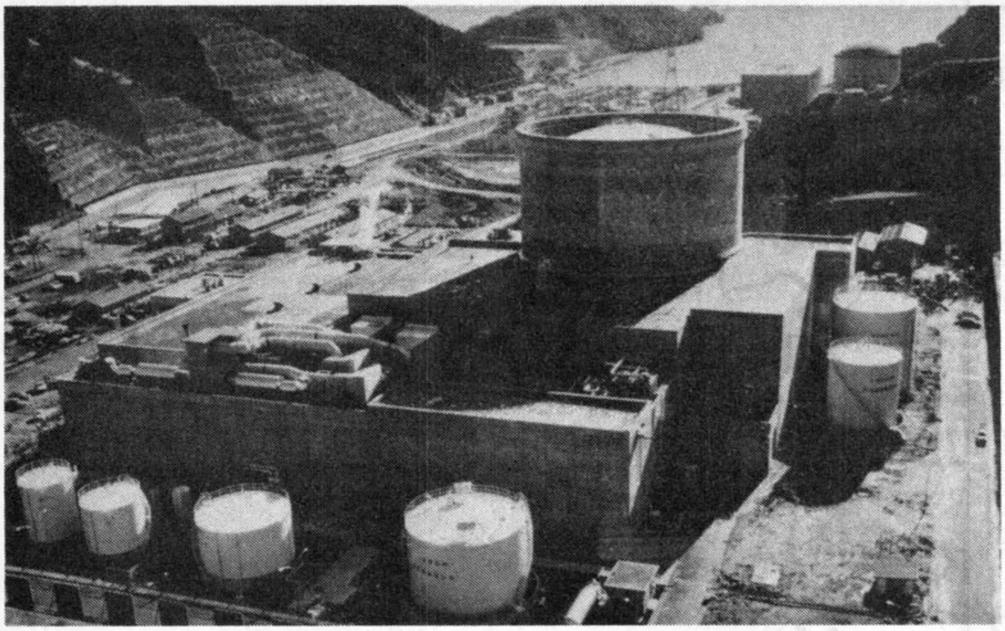
Put forward by MITI's advisory committee on energy, the ambitious nuclear program is no surprise for a country that has no indigenous fossil fuel supplies and a reliance on high-technology, energy-intensive industry. The program merely reconfirms Japan's commitment to develop the most advanced and efficient energy sources available, a commitment adopted in the 1950s. Perhaps the only element of surprise is the timing of the public announcement of a 45-year nuclear program: Most of the rest of the world's nuclear industry has taken to the trenches under the barrage of anti-nuclear propaganda and terrorism that followed the Soviet nuclear accident at Chernobyl April 26.

The MITI plan has two tracks. The first assumes a historically very modest 2.5% annual rate of growth for Japan's gross national product, while the second assumes an even lower growth rate. The more optimistic plan expects to have 87 gigawatts (GW) of nuclear power capacity (3.5 times the present capacity) by the year 2010 and 137 GW (5.6 times the present capacity) by the year 2030, building a total of 122 new reactors during the next 45 years. The plan that assumes a lower growth rate expects to have 77 GW of nuclear power capacity (3.1 times the present capacity) by the year 2010 and 107 GW (4.4 times the present capacity) by the year 2030. In the latter case, 97 new nuclear reactors would be built in the next 45 years.

How does this compare with the other nuclear nations? Japan now ranks fourth among the 24 nuclear-power-generating nations (behind the United States, France, and the Soviet Union). At the end of 1985, Japan had 32 plants on line, with a total capacity of 24.52 GW, generating 26% of the nation's electric power. This compares to 85 units with a capacity of 68.867 GW in the United States (generating 13.5% of the nation's electric power), 46 units with a capacity of 22.997 GW in the Soviet Union (generating 9% of the nation's electric power) and 41 units with a capacity of 32.993 GW in France (generating 58.7% of the nation's power), at the end of 1984, according to figures from the International Atomic Energy Agency.

More significant, Japan has steadfastly pursued a goal defined in 1953 by business and government leaders as necessary for the nation's economic growth, without the slowdowns that the other nuclear nations have suffered at the hands of the environmentalists: Nuclear plants have been completed on schedule. The consistent growth in the development and commercialization of nuclear power can be seen in **Figure 1,** which shows the dates Japan's nuclear plants began operating and the cumulative capacity in gigawatts. The location of these plants as well as those under construction and in the planning stage is shown in **Figure 2.**

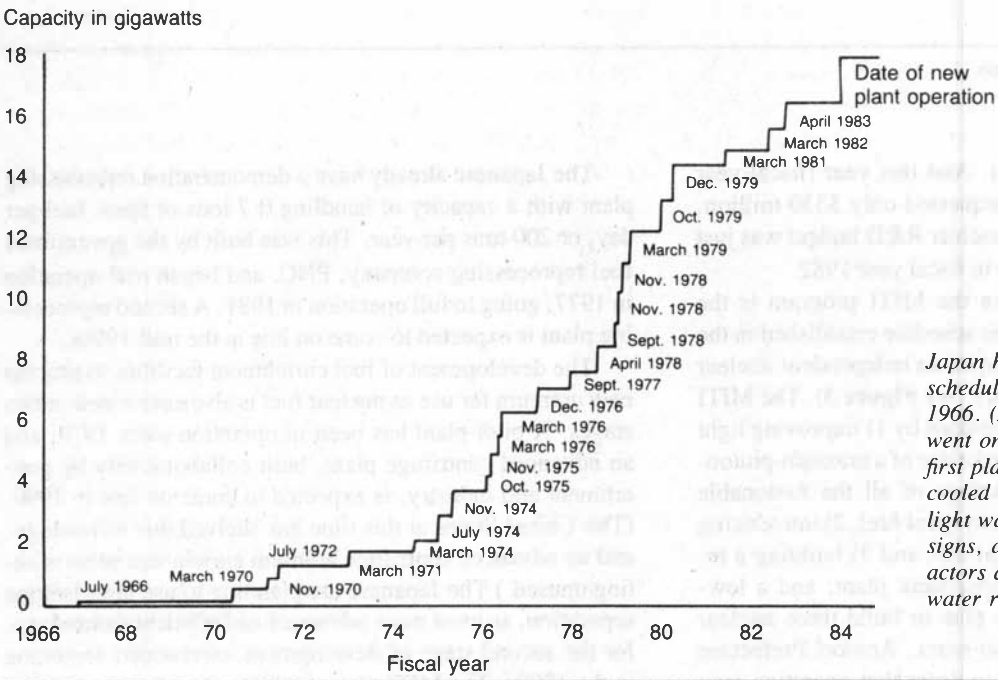
During the next 45 years, MITI expects the total sales of



The "Fugen," an advanced thermal reactor prototype developed in Japan.

the nuclear industry to be 180 trillion Japanese yen, of which 50 trillion yen would be for new construction, 60 trillion yen for operation of plants, and 70 trillion yen for the completion of the fuel cycle requirements. (For purposes of comparison, 1 trillion yen is about U.S. $6.1 billion.) In 1986, total sales of the nuclear industry are estimated at 1.6 trillion yen per year; by 2010, this is expected to be 4.2 trillion yen, and by 2030, the figure would be 6.7 trillion yen—a fourfold growth. The significant difference in Japan's nuclear outlook and that of the United States can be seen in the fact that, last year, Japan spent 370 billion yen (about $2 billion) on nuclear research and development, while the United States spent

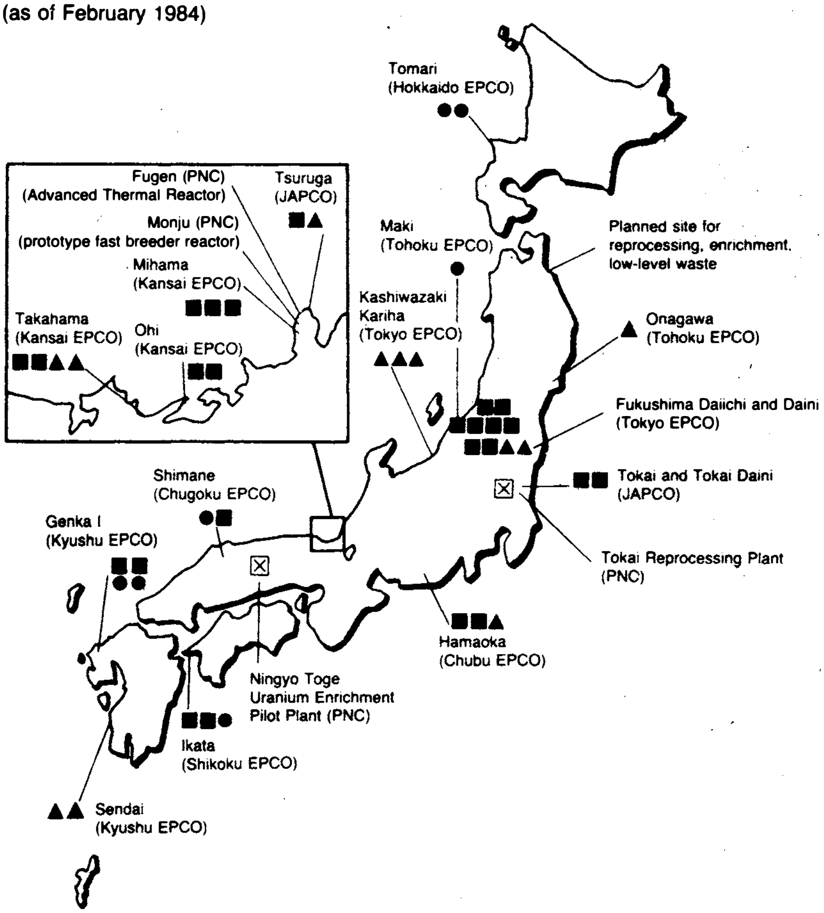
FIGURE 1
Development of Japan's nuclear capacity (as of February 1984)
(electric enterprises only)



Japan has met its ambitious nuclear schedule, putting 32 plants on line since 1966. (Not shown are 3 more plants that went on line in 1984 and 4 in 1985.) The first plant was a British-designed gas-cooled reactor. The others are standard light water reactors based on U.S. designs, about half being boiling water reactors and the other half pressurized water reactors.

Source: Japan Atomic Energy Commission

FIGURE 2
Location of nuclear facilities in Japan
(as of February 1984)



Key

Commercial plants		
■ In operation	25 units	18.277 GW
▲ Under construction	12 units	11.804 GW
● Under preparation	7 units	6.053 GW
Total	44 units	36.134GW
☒ Fuel cycle facilities		

Japan's nuclear plants are shown here with the name of the facility and also the electric power company (EPCO) that operates the plant. PNC is Japan's Nuclear Fuel Development Corporation. At the end of 1985, Japan had 32 nuclear plants on line with a capacity of 24.52 GW, producing 26 percent of Japan's electric power.

Source: Japan Atomic Energy Commission

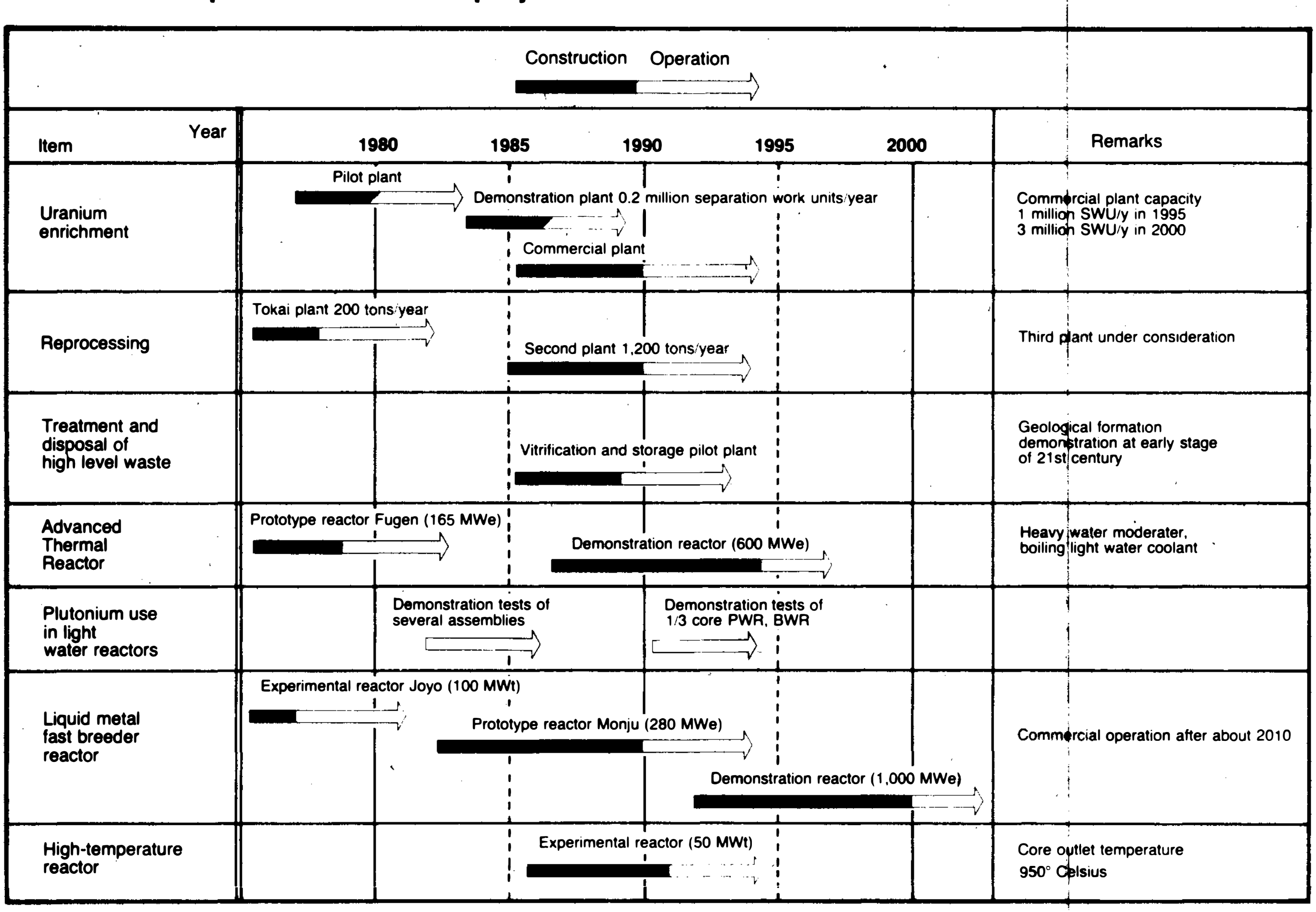
$375 million (fiscal year 1986). And this year (fiscal year 1987), the administration has requested only $330 million. At its height, in fact, the U.S. nuclear R&D budget was just over $1 billion—$1.078 billion in fiscal year 1982.

What is most remarkable in the MITI program is the renewed commitment to meet the schedule established in the 1970s and early 1980s to give Japan an independent nuclear fuel cycle in the early 21st century (see **Figure 3**). The MITI program outlines how this will be done by 1) improving light water reactors so that they can make use of a uranium-plutonium oxide fuel that takes advantage of all the fissionable products that can be retrieved from spent fuel; 2) introducing fast breeder reactors for practical use; and 3) building a reprocessing plant, a uranium enrichment plant, and a low-level waste storage plant. "The plan to build three nuclear fuel cycle facilities in Rokkasho-mura, Aomori Prefecture [see map], should be promoted in order that operation may proceed according to schedule," the report says.

The Japanese already have a demonstration reprocessing plant with a capacity of handling 0.7 tons of spent fuel per day, or 200 tons per year. This was built by the government fuel reprocessing company, PNC, and began trial operation in 1977, going to full operation in 1981. A second reprocessing plant is expected to come on line in the mid-1990s.

The development of fuel enrichment facilities to process new uranium for use as nuclear fuel is also envisioned in two stages. A pilot plant has been in operation since 1979, and an advanced centrifuge plant, built collaboratively by government and industry, is expected to come on line in 1990. (The United States at this time has shelved this technology, and an advanced centrifuge uranium enrichment plant is sitting unused.) The Japanese are planning to use laser isotope separation, an even more advanced and efficient technology, for the second stage of development, envisioned sometime in the 1990s. The MITI plan mentions consultation with the AVLIS (Advanced Vapor Laser Isotope Separation) project

FIGURE 3
Schedule of Japan's nuclear R&D projects



MITI's 45-year nuclear development program reaffirms the necessity for Japan to meet these schedules.

Source: Japan Atomic Energy Commission

at Lawrence Livermore National Laboratory in California—a project that was chosen by the Department of Energy as the most efficient technology to pursue, but which is not being funded for accelerated development.

The MITI report discusses a demonstration facility for processing high-level waste that would come on line in the mid-1990s, with the goal of a commercial plant in operation by 2030. Currently, nuclear waste is stored at plant sites, the same way it is done in the United States.

Nuclear fuel independence

The question of becoming self-sufficient in nuclear fuel is a central one for the Japanese, who have very little natural uranium, a fact discovered early in their nuclear program after extensive exploration throughout Japan. An experimental 100-MWe fast breeder plant, Joyo, came on line in the mid-1970s and provided the basic necessary research. A 220-MWe fast breeder pilot plant, Monju, will come on line in 1992-1994; and a site is in construction now for a larger 800-1,000 MWe plant in western Japan that is expected to be ready by 2003, with commercialization planned for fast breeder technology after 2012.

The Advanced Thermal Reactor, or ATR, was planned as early as 1966 as the way Japan would make the most of its reprocessed spent fuel from light water reactors by using not only the uranium that is extracted but also the plutonium. The plan was to have the ATR using the accumulated plutonium from reprocessing spent fuel even before the fast breeder is commercialized. In addition to augmenting the stock of available nuclear fuel, this would lessen the burden of long-term storage of plutonium and the decay of fissionable isotopes of plutonium during storage.

The government operates a prototype 165-MWe ATR plant, Fugen, which has been on line since 1979, and the

Electric Power Development Co., a special corporation set up by the government, is constructing a 606-MWe commercial ATR scheduled for operation in March 1995. Fugen has operated with no problems, and is helping to establish the related technologies necessary for use of uranium-plutonium mixed oxide fuels.

The ATR is a heavy-water moderated light-water cooled reactor of the pressure tube type (**Figure 4**). Pressure tubes are inserted into holes in a calandria tank, each tube housing one fuel assembly. The Japanese describe many advantages to this design. For example, the control rods are immersed in the heavy water moderator, separated from the cooling system, which means that the fuel rods can be in near-atmospheric temperature and therefore have greater reliability in operation.

Internationalization

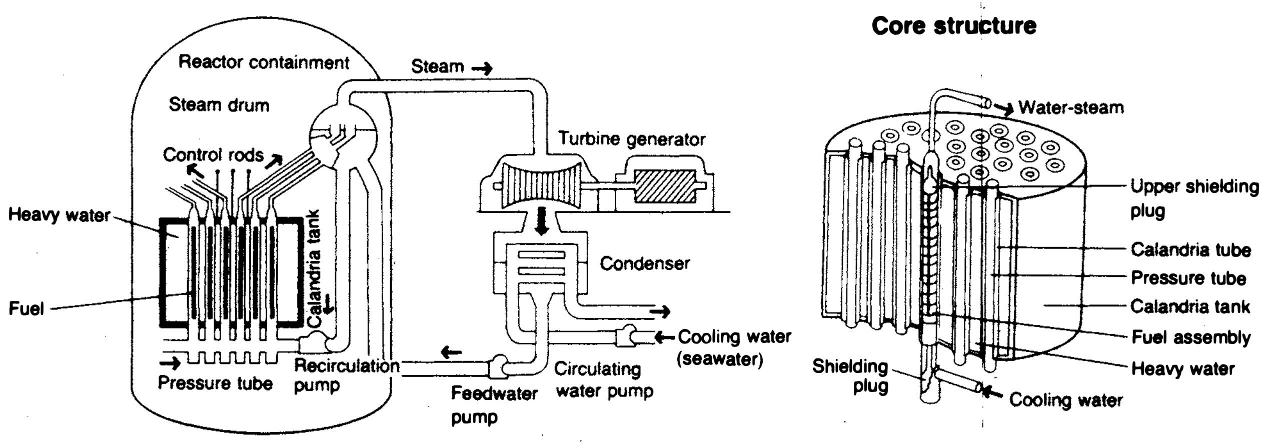
A section of the MITI report stresses "internationalization" of nuclear technology—or export policy. The emphasis here is on promoting nuclear technology by collaborating not only with Europe and the United States but with developing countries, by sending out nuclear experts and by training developing-sector representatives. Such collaboration is envisioned to include the fast breeder reactor and the full nuclear fuel cycle. There was also mention of small and medium size reactors for internationalization.

The Washington, D.C. representative of Japan's electric power industry commented that Japanese companies are very eager to export nuclear reactors (Japan's nuclear manufacturers are now operating at perhaps 40% to 50% of their 6,000-MWe annual reactor-production capacity), but that government policy was more cautious. Personally, he said, he was "truly afraid" after Chernobyl at the attitude toward safety in the Soviet Union as well as China. For the developing nations, he said, we have to make sure that they have plenty of experience with large power plants and that they are ready with emergency planning.

Americans cannot help but be impressed by the Japanese vision in planning for a nuclear future since the 1950s and, more important, the commitment to carry through on their plans. Despite the impressive scope of the Japanese 45-year plan, however, the program has not escaped unscathed by the worldwide economic decline. The MITI report, for example, made no mention of the High Temperature Gas Cooled Reactor (HTGR), which the Japanese had helped develop in collaboration with GA Technologies in San Diego. The advanced design of the HTGR and the high-temperature process heat it made available, were seen as essential for development of the nuclear steelmaking industry of the future. Now, however, because of the slowdown in Japan's steel and iron

FIGURE 4

Schematic of Japan's Advanced Thermal Reactor



Japan's unique Advanced Thermal Reactor (ATR) is designed to make use of a mixed plutonium-uranium oxide fuel. The inclusion of plutonium, a product of reprocessing spent fuel, is aimed at enhancing Japan's nuclear fuel independence by reducing reliance on uranium. The ATR uses heavy water as a moderator and light water (boiling) as a coolant.

Source: Courtesy of Electric Power Development Co., Ltd.

industry, the HTGR is on hold. Ten years ago, when the market was more optimistic, an HTGR was scheduled to be on line in about 1990 (see Figure 3).

Energy demand in Japan's industrial sector has declined since the 1973 Oil Crisis, even though Japan's Gross National Product maintained a 3 to 6 percent growth rate during the same period. In manufacturing industry, for instance, energy consumption per real gross domestic production began to decline in 1975, and by 1981 was one-half of the level of 1973. A January 1984 study by Japan's Institute of Energy Economics documented three basic reasons for this decline: (1) energy conservation,including high-technology equipment investment, such as the introduction of continuous casting in steel making; (2) a shift to less energy-intensive industries, for example, to assembly industries from heavy industries; and (3) "achievement of high added value in manufactured goods," for example, making seamless pipes instead of steel plates.

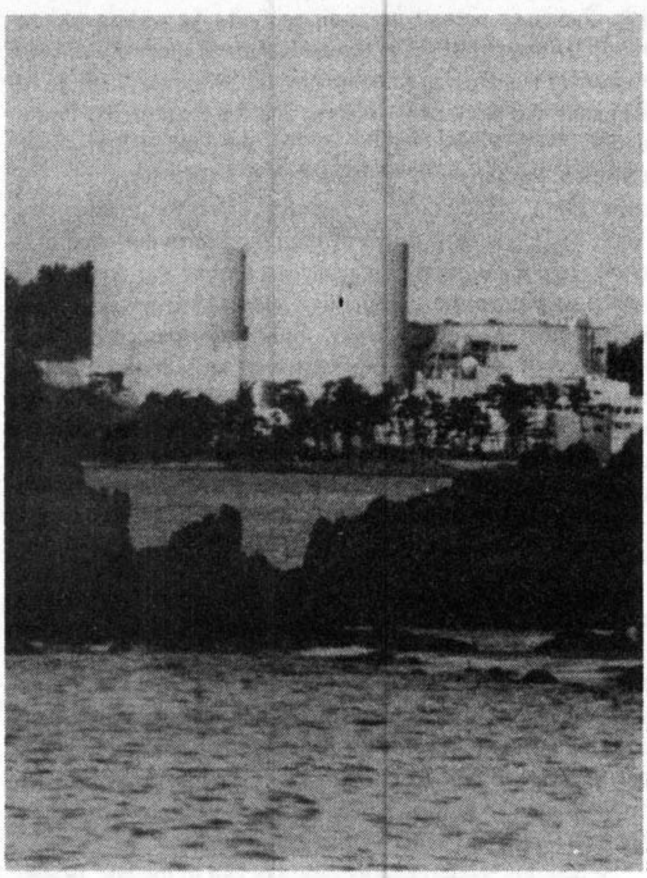
Another way to look at this decline is the per capita production of electricity. In 1970, it was 3.48 billion kilowatt/hours; in 1975, 4.25; in 1980, 4.94. In 1984, it had declined to 4.84 billion kilowatt/hours.

Japan's fight for nuclear power

It is no accident that the chairman of the MITI subcommittee for nuclear power, which prepared the 45-year plan for MITI, is a businessman—Mr. Isamu Yamashita, the chairman of Mitsui Shipping and Building Company and the vice chairman of Keidanren, Japan's business federation. Japan's business community has been in the leadership of nuclear energy from the beginning. In January 1954, it was the president of the Keidanren who helped launch Japan's nuclear program, after a visit to the U.S. Atomic Energy Commission's research facility in California, where he became convinced that Japan had to have an Atoms for Peace program. Within a year, Japan's parliament had established its own Atomic Energy Commission and had approved the first appropriations request for building an experimental nuclear reactor.

With the memory of Hiroshima and Nagasaki still vivid, the Atomic Energy Commission set up a joint government-business group called the Council for the Peaceful Uses of Atomic Energy and began to campaign for "Atoms for Peace." The first chairman of the AEC was Mr. Matsutaro Shoriki, the publisher of *Yomiuri Shimbun,* one of Japan's largest newspapers. In Shoriki's inaugural statement for the council, which had close to 100 business, scientific, and political leaders on it, he said:

> It has now become clear that nuclear energy, which was once used against us as a terrible weapon of destruction, can be used as a mighty power to banish wars from the Earth and liberate humanity from poverty and disease . . . to eliminate the causes of cold wars and achieve constructive peace. . . . The time has come for the whole nation to forge ahead without any hesitation whatever.


U.S. Atomic Energy Commission

A Westinghouse-built nuclear power plant operated by the Kansai Electric Power Company on Japan's Tsuruga Peninsula.

The council sponsored a vigorous educational campaign in 1955, including a six-week exhibit in a Tokyo park visited by 400,000 people. According to the polls at the time, 92% of those who saw the exhibit became convinced of the nation's need to go nuclear. This practice of public education has continued through the present, where education still commands a significant portion of the nuclear energy budget. It has been this vigorous education drive which has held back the anti-nuclear political opposition in Japan, coming mainly from the Japanese Socialist Party, preventing it from squashing the nuclear industry the way it has in the United States.

In March 1956, Japan and the United States signed a technology agreement for Japan's industrial development, which covered patent licensing. Just seven years later, in 1963, Japan became the world's fifth nation to generate electricity using nuclear power, in an experimental reactor operated by the new Science and Technology Agency. Commercial production began three years later, in 1966, in a

Magnox gas-cooled reactor design, purchased from the British, that uses natural uranium as fuel. According to one report (*Future U.S.-Japanese Nuclear Energy Relations: Report of the Working Group,* by the National Institute of Research Advancement, Tokyo, and the Rockefeller Foundation, New York, October 1979), the United States was miffed at the Japanese decision to buy a British reactor, but subsequently made more competitive offers to the Japanese: The U.S. government then offered long-term enriched uranium supply contracts on "attractive terms" and the private sector offered more competitive bids. As a result, Japan then decided to make the U.S. light water design its basic reactor, and it ordered reactors for its ambitious program, about equally divided between boiling water and pressurized water light water reactors. By 1968, the United States had committed delivery to Japan of enough enriched uranium to fuel 11 GWe of nuclear power.

Japan's policy, according to the above-mentioned report, was "to buy one unit of each successive model of the two major U.S. reactor manufacturers," an arrangement described as "important and mutually rewarding." Over the years, Japan gained the ability to manufacture complete reactor systems and to independently improve the design performance of the light water reactor. The Japanese also contributed to joint research projects. For example, Japan put $3 million per year for three years into joint breeder research and $1 million a year for three years into the U.S. Loss of Fluid Test (LOFT) facility in Idaho.

When this bilateral cooperation began in the late 1950s, the United States was treating Japan as a "developing sector" nation; within a short period, it was obvious that Japan was an industrial leader. For Japan, especially under the "nonproliferation" activities of President Carter, it became clear that nuclear independence was essential if its nuclear program was to proceed unimpeded by the vagaries of antinuclear politics in the United States. Today, of course, while the United States has its ambitious Atoms for Peace program only as a fond memory, the Japanese are in a position to supply America with nuclear plants, should the policy here change to one of reindustrializing the nation and industrializing the rest of the world.

Japan built up its indigenous nuclear industry using dirigist methods similar to those that built this country under the administration of President Lincoln—special low-interest loans to private industry and government-sponsored research to set up the proper infrastructure. Japan's nuclear industry today reflects the correctness of this approach. Schedules are met, and performance continues to improve. Reactors have a record of increasing reliability, for example, going from a 60.8% operation rate in 1980 to a 61.7% operation rate in 1981, to a 67.6% operation rate in 1982. In that year, Japan's 24 reactor units produced 103,000 gigawatt-hours of electrical power—about the same as the output from France's 32 reactors for the same time period. By 1983, Japan's reactors had a 71.3% operation rate, even though by regulation, there are 90 days of shutdown per year for reactor maintenance and refueling.

To further increase nuclear reliability, future reactors will be standardized and there is a plan for developing (by 1989) light water reactor robots—multi-joint, multi-finger robots that can perform diverse chores for reactor maintenance and repair.

Because of this reactor performance, a nuclear power plant that came on line in 1982 was able to produce power at 12.5 yen per kilowatt/hour, compared
fired power and 14 yen for coal-fired power, a cost relationship that has continued. For this reason, although nuclear is only 16% of Japan's present electric-power capacity (see **Table 1**), nuclear produces 26% of Japan's electricity: It is cheaper and more efficient and therefore is used proportionally more than the oil, coal, or gas electricity capacity for producing power.

The future

Right now, Japan's major nuclear reactor manufacturers, Hitachi, Toshiba, and Mitsubishi Heavy Industries Ltd. are working at perhaps 40% to 50% of their current capacity for producing 6-GWe nuclear capacity per year, and the depression worldwide has kept the Japanese from developing the further nuclear manufacturing capacity of which they are certainly capable. Under MITI's proposed 45-year nuclear plan, Japan will be adding about 2.5 GW per year to its nuclear capacity, toward a goal in 2030 of 137 GW.

Although this is undoubtedly the most ambitious nuclear growth rate in the Western world at this time, the truth is that in the year 1979, Japan added 5 gigawatts of nuclear capacity to its grid (see Figure 1) and MITI estimated at the time that Japan had the capability to add 6 to 10 gigawatts of nuclear power annually. The point is, that if we are to get the job

TABLE 1

Outlook of installed electric power capacity in Japan

(megawatts/% of total)

Power source	FY 1980	FY 1990	FY 1995
Nuclear	15,510/12.0	34,000/19.0	48,000/23.0
Coal	5,260/4.1	14,000/8.0	21,000/10.0
Natural gas	19,710/15.2	40,000/23.0	43,500/21.0
Hydro	28,670/22.2	38,500/22.0	42,000/21.0
Ordinary	17,860/13.8	20,500/12.0	22,500/11.0
Pumping-up	10,810/8.4	18,000/10.0	19,500/10.0
Geothermal	130/0.1	600/0.3	1,500/0.7
Oil	60,080/46.5	50,000/28.0	49,000/24.0
Total	129,360/100	177,100/100	205,000/100

Source: Japan Atomic Energy Commission

done of industrializing the developing sector, Japan will have to go well beyond the most optimistic predictions of 6 to 10 gigawatts production capacity per year.

Note on sources: *The author is grateful to Mr. Toru Namiki of the Japan Electric Power Information Center in Washington, D.C. for his help in summarizing in English the MITI 45-year plan.*

For the history of the Japanese fusion and nuclear program, see articles in the August 1981 issue of Fusion *magazine and the July 1984 issue of* Fusion Asia *magazine.*

Fusion: 'If the U.S. won't do it, we will'

The Japanese expect to reach fusion breakeven next year—getting more energy out than that required to start the reaction—in the big JT-60 tokamak reactor. And they expect to commercialize fusion energy beginning in about 2010.

A Fusion Experimental Reactor (FER) is now under discussion with a demonstration reactor expected in about 2000. Other magnetic confinement devices are proceeding in experimentation,

versity and the tandem mirror Gamma 10 machine at Tsukuba University.

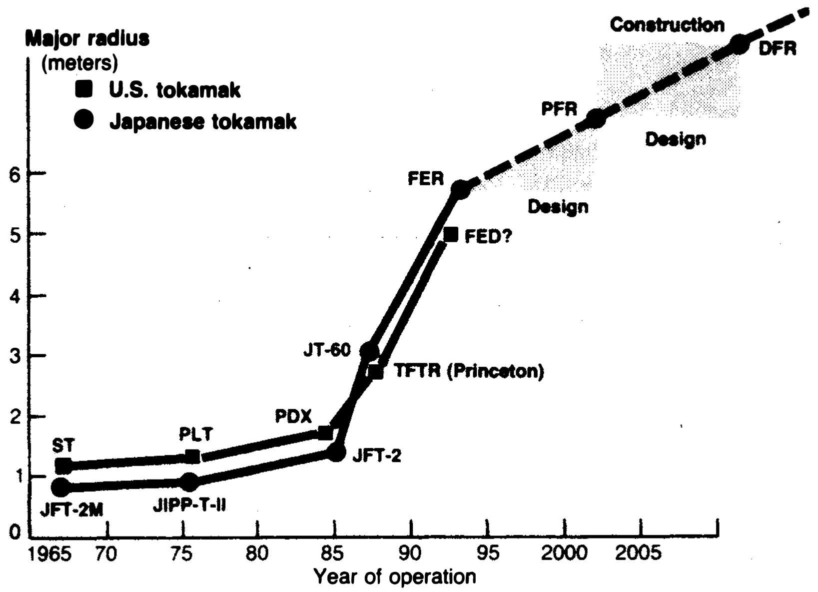
There is also a full range of inertial confinement experiments centered at the Institute of Laser Engineering at Osaka University that are making notable progress both theoretically and experimentally using a variety of drivers from glass lasers to ion beams to particle beams. A variety of innovative and promising experiments are under way, from new target designs to a combination of magnetic and inertial fusion.

In May 1978, Japan's Prime Minister Takeo Fukuda surprised President Carter with the announcement at a New York City foreign policy forum that Japan was prepared to spend $1 billion in a joint research program. The Japanese had decided in 1975 that fusion was "the energy resource of the 21st century," and as with nuclear energy, they embarked on a research and development program to commercialize the technology. When the United States declined Japan's offer (under the direction of Energy Secretary James Schlesinger), Japan continued full speed ahead on its own.

Japan's total fusion budget was a high of 44 billion yen in 1981 and is slightly lower in 1986, 36.6 billion yen, comprising 13% of Japan's total energy R&D budget. (A direct dollar comparison with the U.S. budget is difficult, because these Japanese figures do not include salaries and administration.) This kind of funding commitment to a broad-based research program has left the United States, once the world leader in fusion, behind in the dust, with U.S. fusion scientists reduced to pushing back their schedules because of funding cuts and "choosing" which alternative program should be chopped out of the budget first.

FIGURE 5

Comparison of U.S. and Japanese tokamak devices



SOURCE: Fusion magazine and the Japanese Atomic Energy Research Institute

Japan expects to reach breakeven with the JT-60 tokamak in 1987, putting it ahead of the budget-strapped U.S. program's Tokamak Fusion Test Reactor (TFTR) at the Princeton P sma Physics Laboratory. Japan plans to put the Fusion Experimental Reactor (FER) on line in the 1990s, followed by a Prototype Fusion Reactor (PFR) and then a Demonstration Fusion Reactor (DFR) in the early 21st century. The future of the U.S. magnetic fusion program beyond the TFTR is clouded by funding cuts and lack of a firm commitment from the administration.