Nuclear energy and its fuel cycle in Japan: Closing the circle

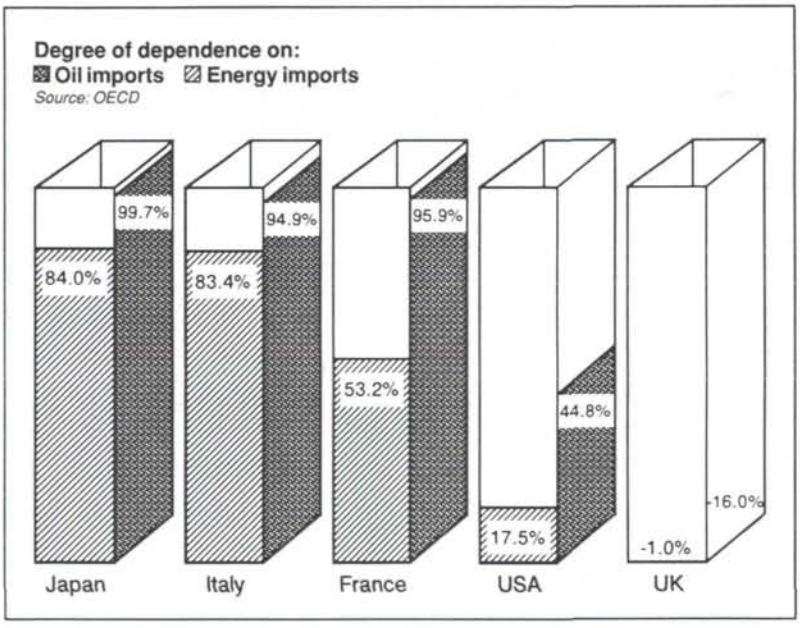
Recycling recovered plutonium as a renewable energy source is a central element of Japan's nuclear power strategy

With more than 80% of its energy resources imported from other countries, Japan is actively developing the commercial use of nuclear power. Over the past several years, nuclear power has become the core of Japan's strategy for further reducing its energy imports, and for building a more reliable and secure energy base for meeting projected demand.

Another important factor behind Japan's commitment to nuclear development is environmental protection. The generation of nuclear power, which does not emit pollutants associated with the "greenhouse effect" and global warming, is viewed with high expectations as playing a vital environmental role.

For the coming decade, the Japanese government has put into place programmes for establishing the country's own nuclear fuel cycle. New facilities that are being built include enrichment and reprocessing plants for producing the types of fuel required by the country's nuclear power plants. This article reviews Japan's nuclear policies and plans from the perspective of major activities related to the country's fuel-cycle research and development.*

Dependence on oil and energy imports of selected countries



Nuclear fuel recycling strategies

Nuclear electricity generation is firmly established in Japan, and at the end of 1992, there were 42 operating nuclear power plants, collectively supplying more than 33 000 megawatts of electricity. *(See map.)* Twelve plants were under construction. Of Japan's total electricity generation in 1991, nuclear power accounted for nearly 27%.

Light-water reactors (LWRs) are the major producers of nuclear-generated electricity and will be for some time to come. In the future, they will be used for recycling plutonium as fuel. In this way, recycling will be able to play an important role as an energy resource in Japan's nuclear power generation system. At the same time, the required technologies and infrastructures can be developed with the aim of commercializing fast-breeder reactors (FBRs), which utilize uranium resources highly efficiently. In Japan's approach, therefore, the FBR is being developed as the main reactor for future nuclear power generation and is considered to be the principal reactor for using plutonium fuel. Additionally, to enhance overall recycling programmes, advanced thermal reactors (ATRs) having a high degree of flexibility in fuel use will be used for recycling plutonium.

*This article is based on a number of documents, including the "White Paper on Nuclear Energy", published in October 1992 by the Atomic Energy Commission (AEC) of Japan; "Nuclear Fuel Recycling in Japan", a paper issued in August 1991 by the AEC's Advisory Committee on Nuclear Fuel Recycling; and "Plutonium: A Renewable Source of Energy", published in November 1992 by the Ministry of Foreign Affairs.

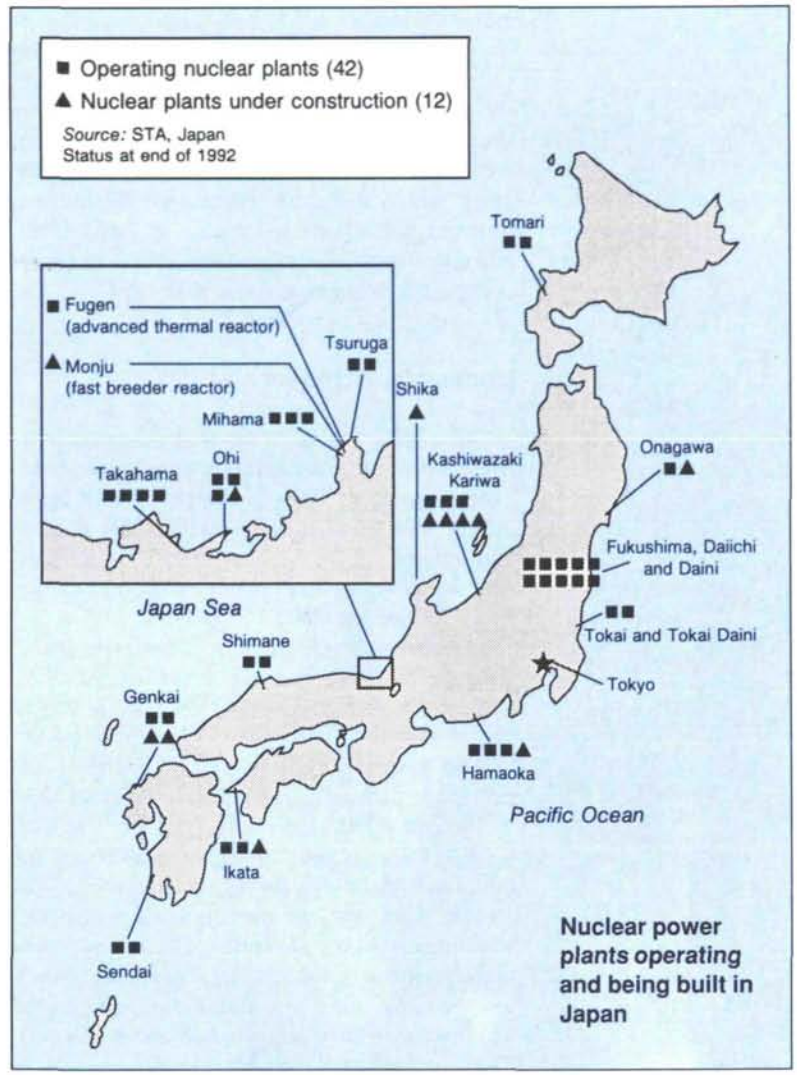
The plutonium needed to implement future recycling programmes will be supplied mainly by the Rokkasho reprocessing plant. The plant — scheduled for operation early in the next century — is indispensable for carrying out the FBR programmes, and is needed to provide plutonium for recycling in LWRs and ATRs. Plutonium recovered from Japan's existing Tokai reprocessing plant will be used basically for R&D of FBRs and ATRs. Reprocessing services that are now contracted to overseas nations are seen as a transitional measure.

Development of national capabilities

Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC) and the Japan Atomic Energy Research Institute (JAERI) have been playing major roles in R&D activities related to the country's nuclear fuel cycle. In the field of reconversion and fabrication of nuclear fuel, efforts are directed at stimulating and supporting industrialization in the private sector, which is accumulating considerable expertise.

At the Rokkashomura site, Japan Nuclear Fuel Limited (JNFL) has taken over industrialization efforts. The company resulted from the 1992 merger of two entities —the Japan Nuclear Fuel Industries (JNFI) and the Japan Nuclear Fuel Service (JNFS) — which had been working on the private industrialization of uranium enrichment, reprocessing of spent fuel of LWRs, and low-level radioactive waste disposal.

In March 1992, the uranium enrichment plant at Rokkashomura began partial operation,



The Monju prototype fast-breeder reactor. *(Credit: PNC)*

and in December 1992, the waste disposal facility opened. The Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC) have approved the application for the business of spent fuel reprocessing. In addition, a high-level radioactive waste management facility, which will store returned vitrified waste, received permission to operate in April 1992, and construction began in May 1992. Operation is expected to begin in fiscal year 1994.

Uranium enrichment

The PNC has been the major promoter of R&D in the domestic uranium enrichment field. From September 1979 to March 1990, it operated a pilot plant at Ningyo-toge. The PNC is currently operating a prototype enrichment plant (the successor to the pilot plant) having a capacity of 200 tonnes SWU.*

Regarding commercial uranium enrichment, the government licensed a plant in August 1988, and construction began in October 1988. Partial operation started in March 1992 with a capacity of 150 tonnes SWU per year. Capacity is expected to reach up to 1500 tonnes SWU per year by the year 2000.

R&D also is progressing on techniques for uranium enrichment. For example, the PNC, in co-operation with private companies, is constructing a test cascade facility employing a new high-performance centrifuge machine which uses new materials. In addition, laser and chemical processes have been studied and developed. They include the methods known as AVLIS (atomic vapor laser isotope separation) and MLSI (molecular laser isotope separation), both of which are in engineering test phases. Decisions on demonstration projects are expected to be taken in the late 1990s, according to a report issued in August 1992 by the AEC's Advisory Committee on Uranium Enrichment.

With respect to the gas centrifuge process, the report stated that advanced centrifuges will be needed at the Rokkashomura plant early in the next century. The extent and timing of the expansion of the Japanese uranium enrichment business beyond the Rokkashomura plant remains a matter for discussion, and will take into consideration relevant trends in Japan and abroad.

* Separative Work Unit, which is the unit of work required to enrich uranium-235 from natural uranium. For example, about 5.8 tonnes SWU are needed to produce one tonne of 4% enriched uranium (4% U-235) from natural uranium (0.7% U-235) when tail concentration is 0.25%.

Reprocessing of spent fuel

In the development of LWR spent fuel reprocessing technology, the PNC's Tokai reprocessing plant went into hot test operation using actual radioactive materials in September 1977 and after overcoming initial difficulties has been operating satisfactorily. More than 680 tonnes of spent fuel have been reprocessed there.

Spent fuels from Japan also are reprocessed under contract at plants in the United Kingdom and France. More than 4700 tonnes-uranium of LWR spent fuels have been sent to these plants; additionally, more than 1100 tonnes-uranium of spent fuels from a gas-cooled reactor have been sent for reprocessing to the United Kingdom.

To meet projected future domestic demand for reprocessing, Japan will rely on the Tokai plant and the reprocessing plant in Rokkashomura to be operated by the JNFL. The spent fuel that surpasses the domestic reprocessing capacity will be properly stored and managed until reprocessed. Construction of the Rokkashomura plant began in April 1993 and operation is planned to start by the year 2000; its annual capacity will be 800 tonnes-uranium.

Radioactive waste management

Of the low-level radioactive wastes generated in nuclear power stations, those in a gaseous state, and part of those in a liquid state, are being discharged through proper treatment. The treatment includes filtration and evaporation into the atmosphere or sea once their levels of radioactivity fall below release levels set by law. As for solid and other liquid wastes, measures are being taken to reduce their volume, properly treat them through solidification and incineration, and then store them under safe conditions at each nuclear facility site. As of the end of March 1991, waste equalling about 480 000 drums (200 liters each) was stored at nuclear power plants.

In December 1992, operations began at a low-level waste repository in Rokkashomura. The facility's disposal capacity is 200 000 drums and expansion will allow for a capacity up to about 3 million drums. Transport of the drums from sites at nuclear plants to the repository is by sea.

Utilization of plutonium

Japan's programme for utilizing plutonium in nuclear power reactors encompasses a number of projects:

Use of plutonium in LWRs and ATRs. Utilities are promoting the utilization of plutonium in LWRs and are carrying out small-scale demonstration programmes. The first project on a practical scale is targetted for the mid-1990s. It assumes that mixed-oxide (MOX) fuel will be loaded to an amount corresponding to 25% of the reactor core in pressurized-water reactors and boiling-water reactors (above 800-MWe). Utilities progressively will proceed with projects that assume the MOX loading of one-third of the reactor core for about four 1000-MWe LWRs at the end of the 1990s and then for up to about 12 reactors shortly after 2000.

With respect to ATRs, the PNC has been carrying out development work and has been successfully operating the Fugen prototype reactor (electric output of 165 MWe) since 1977. Japan's Electric Power Development Company is preparing to construct an ATR with an electric output of 606 MWe in Oma-cho, with a scheduled start-up in 2002.

Fast breeder reactor. The PNC has been successfully operating the Joyo experimental reactor (thermal power 100 MW) and accumulating the technological data and operating experiences for the development of a prototype reactor. With the co-operation of the private sector, it has built the Monju prototype reactor (electric power 280 MW) in Tsuruga-shi, which is scheduled to reach criticality in the spring of 1994.

Development of a demonstration FBR is being headed by the Japan Atomic Power Co. (JAPC), which has finished preliminary conceptual design studies. Collaborative activities are continuing with the PNC and Japanese utilities.

FBR spent-fuel reprocessing. With respect to the reprocessing technology of FBR spent fuel, the PNC is performing full-scale mock-up tests and compiling basic data in the Tokai's chemical processing facility. The PNC intends to build a facility for conducting engineering-scale hot tests. Results of the work will be used in the construction plan of a pilot plant, whose start-up is envisaged in the beginning of the next century.

MOX fuel fabrication. Since technical development of MOX fuel production was initiated in Japan in 1966, more than 123 tonnes of MOX have been produced for fuels at the Fugen, Joyo, and Monju plants. The PNC is planning the construction of a fuel-production facility for the demonstration ATR.

Taking into account requirements for the LWR fuel recycling programme and the Rokkashomura reprocessing plant, it is foreseen that commercial MOX fuel fabrication of about 100 tonnes per year will be required in Japan.

Transparency of nuclear development

As demonstrated over the past 30 years, Japan is firmly committed to the peaceful uses of nuclear energy, and to contributing to global efforts for preventing the further spread of nuclear weapons in close co-ordination with other countries. The government's stated intention is to provide as much transparency as possible about the country's nuclear energy programmes so as not to incur international concerns.

In order to ensure transparency in Japan's nuclear fuel recycling plan, the AEC's Advisory Committee on Nuclear Fuel Recycling issued a report in August 1991 on the projected supply and demand of plutonium. It stated that the cumulative demand for plutonium up to around the year 2010 will be between 80 and 90 tonnes. At approximately 85 tonnes, projected cumulative supply, including plutonium reshipped to Japan after reprocessing overseas, is adequate to meet the demand. Eventually it is projected that the total supply and demand will be balanced for the medium to long term. Furthermore, Japan scrupulously maintains the national policy of not possessing plutonium stocks beyond the amount required to implement its nuclear recycling programmes.

The country further has underscored strict adherence to its three non-nuclear principles of not possessing, producing, or allowing nuclear weapons within its territory. Its Atomic Energy Basic Law explicitly states that all R&D and utilization of nuclear energy must be limited to peaceful purposes. In accordance with this basic policy, Japan is a signatory of the Treaty on the Non-Proliferation of Nuclear Weapons and has concluded full-scope safeguards agreements with the IAEA. The government, moreover, actively supports efforts to improve and strengthen the Agency's safeguards system.

Regarding the international, long-distance transportation of plutonium, Japan has reaffirmed its commitment to fulfilling the obligations and responsibilities provided in bilateral and multilateral agreements. It will continue to work closely with countries concerned so as to foster greater understanding and co-operation, fully recognizing that it is Japan's international responsibility to apply stringent safety and physical protection measures to the transportation. ❐