World Nuclear Association

Nuclear Power in Japan

(updated 24 February 2011)

- **Japan needs to import some 80% of its energy requirements.**
- **Its first commercial nuclear power reactor began operating in mid 1966, and nuclear energy has been a national strategic priority since 1973.**
- **The country's 54 reactors provide some 30% of the country's electricity and this is expected to increase to at least 40% by 2017.**
- **Japan has a full fuel cycle set-up, including enrichment and reprocessing of used fuel for recycle.**

Despite being the only country to have suffered the devastating effects of nuclear weapons in wartime, Japan has embraced the peaceful use of nuclear technology to provide a substantial portion of its electricity. Today, nuclear energy accounts for almost 30% of the country's total electricity production (29% in 2009), from 47.5 GWe of capacity (net). There are plans to increase this to 41% by 2017, and 50% by 2030.

In 2008 Japan generated 1085 billion kWh gross, 30% from coal, 25% from gas, 24% from nuclear, 11% from oil, and 7.5% from hydro, though 8 GWe of nuclear capacity was shut down for checks following an earthquake in mid 2007. Per capita consumption is about 7900 kWh/yr. Demand for 2009 was expected to be 892 billion kWh, with peak 173.4 GWe, requiring capacity of 194 GWe.

As Japan has few natural resources of its own, it depends on imports for some 80% of its primary energy needs. Initially it was dependent on fossil fuel imports, particularly oil from the Middle East (oil fuelled 66% of the electricity in 1974). This geographical and commodity vulnerability became critical due to the oil shock in 1973. At this time, Japan already had a growing nuclear industry, with five operating reactors. Re-evaluation of domestic energy policy resulted in diversification and in particular, a major nuclear construction program. A high priority was given to reducing the country's dependence on oil imports. A closed fuel cycle was adopted to gain maximum benefit from imported uranium.

Nuclear power seems set to play an even bigger role in Japan's future. In the context of the Ministry of Economy, Trade and Industry (METI) Cool Earth 50 energy innovative technology plan in 2008, the Japan Atomic Energy Agency (JAEA) has modelled a 54% reduction in CO_2 emissions (from 2000 levels) by 2050 leading on to a 90% reduction by 2100. This would lead to nuclear energy contributing about 60% of primary energy in 2100 (compared with 10% now), 10% from renewables (now 5%) and 30% fossil fuels (now 85%). This would mean that nuclear contributed 51% of the emission reduction: 38% from power generation and 13% from hydrogen production and process heat.

In June 2010 METI resolved to increase energy self-sufficiency to 70% by 2030, for both energy security and CO_2 emission reduction. It envisages deepening strategic relationships with energy-producing countries. Nuclear power will play a big part in implementing the plan, and new reactors will be required as well as achieving 90% capacity factor across all plants.

History: Development of nuclear program & policy

Japan started its nuclear research program in 1954, with Y230 million being budgeted for nuclear energy. The Atomic Energy Basic Law, which strictly limits the use of nuclear technology to peaceful purposes, was introduced in 1955. The law aims to ensure that three principles - democratic methods, independent management, and transparency - are the basis of nuclear research activities, as well as promoting international co-operation. Inauguration of the Atomic Energy Commission in 1956 promoted nuclear power development and utilisation. Several other nuclear energy-related organisations were also established in 1956 under this law: the Science & Technology Agency; Japan Atomic Energy Research Institute (JAERI) and the Atomic Fuel Corporation (renamed PNC in 1967 - see below).

The first reactor to produce electricity in Japan was a prototype boiling water reactor: the Japan Power Demonstration Reactor (JPDR) which ran from 1963 to 1976 and provided a large amount of information for later commercial reactors. It also later provided the test bed for reactor decommissioning.

Japan imported its first commercial nuclear power reactor from the UK. Tokai-1 - a 160 MWe gas-cooled (Magnox) reactor built by GEC. It began operating in July 1966 and continued until March 1998.

After this unit was completed, only light water reactors (LWRs) utilising enriched uranium Ð either boiling water reactors (BWRs) or pressurised water reactors (PWRs) have been constructed. In 1970, the first three such reactors were completed and began commercial operation. There followed a period in which Japanese utilities purchased designs from US vendors and built them with the co-operation of Japanese companies, who would then receive a licence to build similar plants in Japan. Companies such as Hitachi Co Ltd, Toshiba Co Ltd and Mitsubishi Heavy Industry Co Ltd developed the capacity to design and construct LWRs by themselves. By the end of the 1970s the Japanese industry had largely established its own domestic nuclear power production capacity and today it exports to other east Asian countries and is involved in the development of new reactor designs likely to be used in Europe.

Due to reliability problems with the earliest reactors they required long maintenance outages, with the average capacity factor averaging 46% over 1975-77 (by 2001, the average capacity factor had reached 79%). In 1975, the LWR Improvement & Standardisation Program was launched by the Ministry of International Trade and Industry (MITI) and the nuclear power industry. This aimed, by 1985, to standardise LWR designs in three phases. In phases 1 and 2, the existing BWR and PWR designs were to be modified to improve their operation and maintenance. The third phase of the program involved increasing the reactor size to 1300-1400 MWe and making fundamental changes to the designs. These were to be the Advanced BWR (ABWR) and the Advanced PWR (APWR).

A major research and fuel cycle establishment through to the late 1990s was the Power Reactor and Nuclear Fuel Development Corporation, better known as PNC. Its activities ranged very widely, from uranium exploration in Australia to disposal of high-level wastes. After two accidents and PNC's unsatisfactory response to them the government in 1998 reconstituted PNC as the leaner Japan Nuclear Cycle Development Institute (JNC), whose brief was to focus on fast breeder reactor development, reprocessing high-burnup fuel, mixed-oxide (MOX) fuel fabrication and high-level waste disposal.

A merger of JNC and JAERI in 2005 created the Japan Atomic Energy Agency (JAEA) under the Ministry of Education, Culture, Sports, Science & Technology (MEXT). JAEA is now a major integrated nuclear R&D organization.

Recent energy policy: Focus on nuclear

Japan's energy policy has been driven by considerations of energy security and the need to minimise dependence on current imports. The main elements regarding nuclear power are:

- continue to have nuclear power as a major element of electricity production.
- recycle uranium and plutonium from used fuel, initially in LWRs, and have reprocessing domestically from 2005.
- steadily develop fast breeder reactors in order to improve uranium utilisation dramatically.
- promote nuclear energy to the public, emphasising safety and non-proliferation.

In March 2002 the Japanese government announced that it would rely heavily on nuclear energy to achieve greenhouse gas emission reduction goals set by the Kyoto Protocol. A 10-year energy plan, submitted in July 2001 to the Minister of Economy Trade & Industry (METI), was endorsed by cabinet. It called for an increase in nuclear power generation by about 30 percent (13,000 MWe), with the expectation that utilities would have 9 to 12 new nuclear plants operating by 2011.

At present Japan has 54 reactors totalling 46,102 MWe (net) on line, with two (2756 MWe) under construction and 12 (16,532 MWe) planned. In 2010 the first of those now operating reached their 40-year mark, at which stage some may close down. However, JAPC obtained approval for its small Tsuruga unit 1 to continue to 2016, due to 2 x 1538 MWe new capacity at that site being delayed. Then Kansai applied for a 10-year licence extension from November 2010 for its Mihama-1. NISA approved Kansai's long-term maintenance and management policy for the unit and granted a life extension accordingly, which was then agreed by local government.

In June 2002, a new Energy Policy Law set out the basic principles of energy security and stable supply, giving greater authority to the government in establishing the energy infrastructure for economic growth. It also promoted greater efficiency in consumption, a further move away from dependence on fossil fuels, and market liberalisation.

In November 2002, the Japanese government announced that it would introduce a tax on coal for the first time, alongside those on oil, gas and LPG in METI's special energy account, to give a total net tax increase of some JPY 10 billion from October 2003. At the same time METI would reduce its power-source development tax, including that applying to nuclear generation, by 15.7% - amounting to JPY 50 billion per year. While the taxes in the special energy account were originally designed to improve Japan's energy supply mix, the change is part of the first phase of addressing Kyoto goals by reducing carbon emissions. The second phase, planned for 2005-07, was to involve a more comprehensive environmental tax system, including a carbon tax.

These developments, despite some scandal in 2002 connected with records of equipment inspections at nuclear power plants, paved the way for an increased role for nuclear energy.

In 2004 Japan's Atomic Industrial Forum released a report on the future prospects for nuclear power in the country. It brought together a number of considerations including 60% reduction in carbon dioxide emissions and 20% population reduction but with constant GDP. Projected nuclear generating capacity in 2050 was 90 GWe. This means doubling both nuclear generating capacity and nuclear share to about 60% of total power produced. In addition, some 20 GW (thermal) of nuclear heat will be utilised for hydrogen production. Hydrogen is expected to supply 10% of consumed energy and 70% of this will come from nuclear plants.

In July 2005 the Atomic Energy Commission reaffirmed policy directions for nuclear power in

Japan, while confirming that the immediate focus would be on LWRs. The main elements are that a "30-40% share or more" shall be the target for nuclear power in total generation after 2030, including replacement of current plants with advanced light water reactors. Fast breeder reactors will be introduced commercially, but not until about 2050. Used fuel will be reprocessed domestically to recover fissile material for use in MOX fuel. Disposal of high-level wastes will be addressed after 2010.

In April 2006 the Institute of Energy Economics Japan forecast for 2030 that while primary energy demand will decrease 10%, electricity use will increase and nuclear share will be 41%, from 63 GWe of capacity. Ten new units would come on line by 2030 and Tsuruga-1 would be retired.

In May 2006 the ruling Liberal Democratic Party urged the government to accelerate development of fast breeder reactors (FBRs), calling this "a basic national technology". It proposed increased budget, better coordination in moving from R&D to verification and implementation, plus international cooperation. Japan is already playing a leading role in the Generation IV initiative, with focus on sodium-cooled FBRs, though the 280 MWe (gross) Monju prototype FBR remained shut down until May 2010.

In April 2007 the government selected Mitsubishi Heavy Industries (MHI) as the core company to develop a new generation of FBRs. This was backed by government ministries, the Japan Atomic Energy Agency (JAEA) and the Federation of Electric Power Companies of Japan. These are concerned to accelerate the development of a world-leading FBR by Japan. MHI has been actively engaged in FBR development since the 1960s as a significant part of its nuclear power business.

METI's 2010 electricity supply plan shows nuclear capacity growing by 12.94 GWe by 2019, and the share of supply growing from 2007's depressed 262 TWh (25.4%) to about 455 TWh (41%) in 2019.

Power reactors operating in Japan

Reactor	Type	Net capacity	Utility	Commercial Operation
Fukushima I-1	BWR	439 MWe	TEPCO	March 1971
Fukushima I-2	BWR	760 MWe	TEPCO	July 1974
Fukushima I-3	BWR	760 MWe	TEPCO	March 1976
Fukushima I-4	BWR	760 MWe	TEPCO	October 1978
Fukushima I-5	BWR	760 MWe	TEPCO	April 1978
Fukushima I-6	BWR	1067 MWe	TEPCO	October 1979
Fukushima II-1	BWR	1067 MWe	TEPCO	April 1982
Fukushima II-2	BWR	1067 MWe	TEPCO	February 1984
Fukushima II-3	BWR	1067 MWe	TEPCO	June 1985
Fukushima II-4	BWR	1067 MWe	TEPCO	August 1987
Genkai-1	PWR	529 MWe	Kyushu	October 1975
Genkai-2	PWR	529 MWe	Kyushu	March 1981
Genkai-3	PWR	1127 MWe	Kyushu	March 1994
Genkai-4	PWR	1127 MWe	Kyushu	July 1997
Hamaoka-3	BWR	1056 MWe	Chubu	August 1987
Hamaoka-4	BWR	1092 MWe	Chubu	September 1993
Hamaoka-5	ABWR	1325 MWe	Chubu	January 2005
Higashidori-1 Tohoku	BWR	1067 MWe	Tohoku	December 2005
Ikata-1	PWR	538 MWe	Shikoku	September 1977
Ikata-2	PWR	538 MWe	Shikoku	March 1982
Ikata-3	PWR	846 MWe	Shikoku	December 1994
Kashiwazaki-Kariwa-1	BWR	1067 MWe	TEPCO	September 1985
Kashiwazaki-Kariwa-2	BWR	1067 MWe	TEPCO	September 1990
Kashiwazaki-Kariwa-3	BWR	1067 MWe	TEPCO	August 1993
Kashiwazaki-Kariwa-4	BWR	1067 MWe	TEPCO	August 1994
Kashiwazaki-Kariwa-5	BWR	1067 MWe	TEPCO	April 1990
Kashiwazaki-Kariwa-6	ABWR	1315 MWe	TEPCO	November 1996
Kashiwazaki-Kariwa-7	ABWR	1315 MWe	TEPCO	July 1997
Mihama-1	PWR	320 MWe	Kansai	November 1970
Mihama-2	PWR	470 MWe	Kansai	July 1972
Mihama-3	PWR	780 MWe	Kansai	December 1976
Ohi-1	PWR	1120 MWe	Kansai	March 1979
Ohi-2	PWR	1120 MWe	Kansai	December 1979
Ohi-3	PWR	1127 MWe	Kansai	December 1991
Ohi-4	PWR	1127 MWe	Kansai	February 1993
Onagawa-1	BWR	498 MWe	Tohoku	June 1984
Onagawa-2	BWR	796 MWe	Tohoku	July 1995
Onagawa-3	BWR	796 MWe	Tohoku	January 2002
Sendai-1	PWR	846 MWe	Kyushu	July 1984
Sendai-2	PWR	846 MWe	Kyushu	November 1985
Shika-1	BWR	505 MWe	Hokuriku	July 1993
Shika-2	BWR	1304 MWe	Hokuriku	March 2006
Shimane-1	BWR	439 MWe	Chugoku	March 1974
Shimane-2	BWR	791 MWe	Chugoku	February 1989
Takahama-1	PWR	780 MWe	Kansai	November 1974
Takahama-2	PWR	780 MWe	Kansai	November 1975
Takahama-3	PWR	830 MWe	Kansai	January 1985

Takahama-4	PWR	830 MWe	Kansai	June 1985
Tokai-2	BWR	1060 MWe	JAPC	November 1978
Tomari-1	PWR	550 MWe	Hokkaido	June 1989
Tomari-2	PWR	550 MWe	Hokkaido	April 1991
Tomari-3	PWR	866 MWe	Hokkaido	December 2009
Tsuruga-1	BWR	341 MWe	JAPC	March 1970
Tsuruga-2	PWR	1110 MWe	JAPC	February 1987
Monju	prototype FNR	246 MWe	JAEA	operated 1994-95, restarted May 2010
Total: 55 reactors		47,361 MWe (c 49,405 MWe gross)		

Fukushima I = Fukushima Daiichi, Fukushima II = Fukushima Daini

In 2006 NISA ordered Hamaoka 5 and Shika 2 to be shut down due to problems with steam turbine blades. They were then restarted at lower power levels - 1212 and 1108 MWe net respectively. When the turbines are repaired, they will revert to the above net power levels.

Japanese reactors under construction

Reactor	Type	Gross capacity	Utility	Construction start	Operation*
Shimane 3	ABWR	1373 MWe	Chugoku	December 2005	3/2012
Ohma 1	ABWR	1383 MWe	EPDC/ J-Power	May 2010	11/2014
total (2)		2756 MWe			

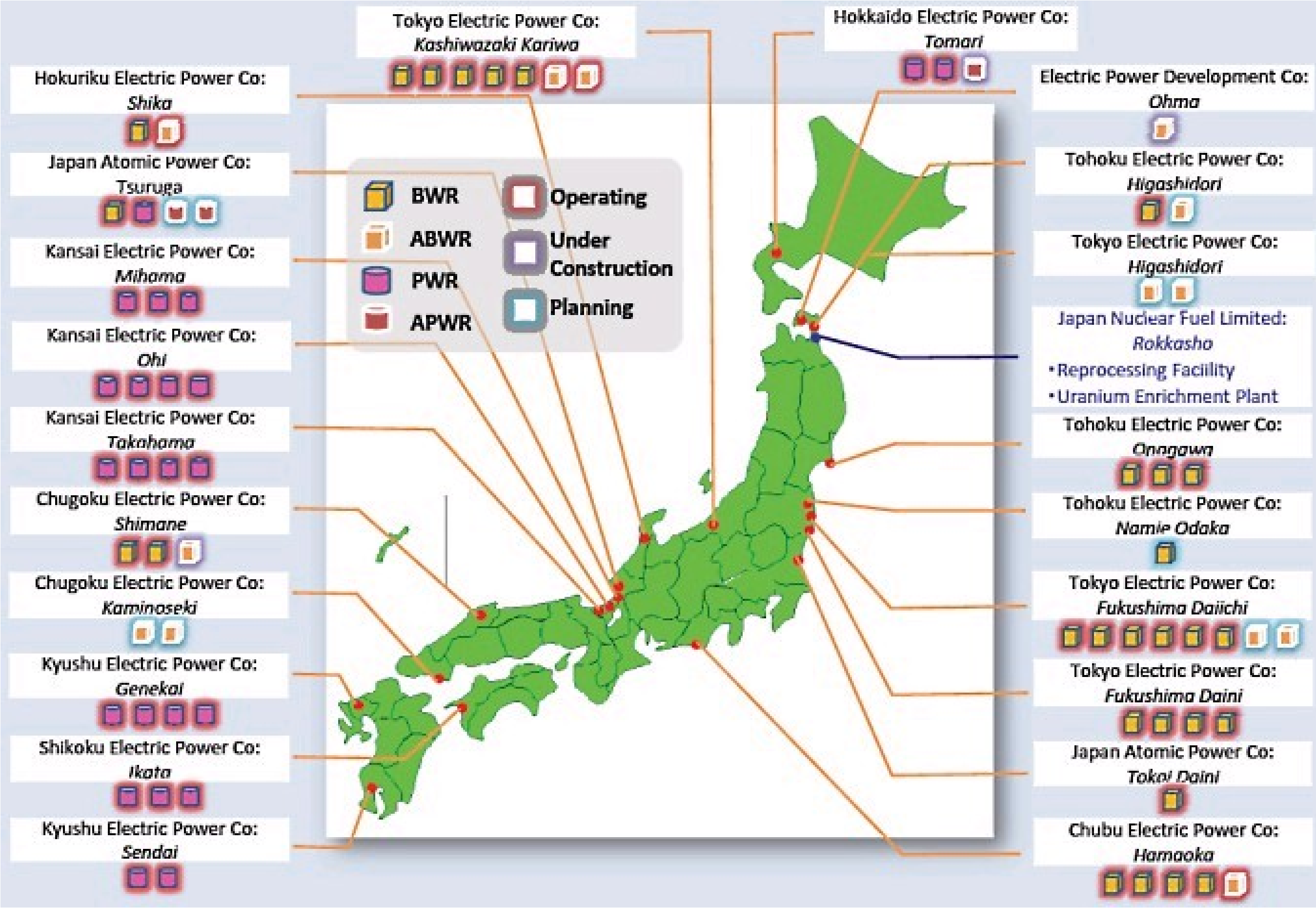
* Latest announced commercial operation.

Japanese reactors planned

Reactor	Type	MWe gross (each)	Utility	start * construction	start * operation
Tsuruga 3	APWR	1538	JAPC	3/2012	7/2017
Tsuruga 4	APWR	1538	JAPC	3/2012	7/2018
Higashidori 1 Tepco	ABWR	1385	Tepco	4/2011	3/2017
Fukushima I - 7	ABWR	1380	Tepco	4/2012	10/2016
Fukushima I - 8	ABWR	1380	Tepco	4/2012	10/2017
Kaminoseki 1	ABWR	1373	Chugoku	6/2012	3/2018
Sendai 3	APWR	1590	Kyushu	3/2014	12/2019
Higashidori 2 Tepco	ABWR	1385	Tepco	2014?	2019 or later
Hamaoka 6	ABWR	1380	Chubu	2015	2020 or later
Higashidori 2 Tohoku	ABWR	1385	Tohoku	2016	2021 or later
Namie-odaka	BWR?	825?	Tohoku	2017	3/2021
Kaminoseki 2	ABWR	1373	Chugoku	2018	2022
Total (12)		**16,532 MWe**			

* according to METI FY2010 plan, unless updated by company. Tsuruga 3-4 schedule has slipped by 16 months.

Tsuruga 3-4 and Tepco's Higashidori 1 are undergoing final safety assessment by regulatory authorities.


Tokyo Electric Power Co:
Kashiwazaki Kariwa
Hokkaido Electric Power Co:
Tomari
Hokuriku Electric Power Co:
Shika
Electric Power Development Co:
Ohma
Japan Atomic Power Co:
Tsuruga
BWR
ABWR
PWR
APWR
Operating
Under Construction
Planning
Tohoku Electric Power Co:
Higashidori
Kansai Electric Power Co:
Mihama
Tokyo Electric Power Co:
Higashidori
Kansai Electric Power Co:
Ohi
Japan Nuclear Fuel Limited:
Rokkasho
•Reprocessing Facility
•Uranium Enrichment Plant
Kansai Electric Power Co:
Takahama
Tohoku Electric Power Co:
Onagawa
Chugoku Electric Power Co:
Shimane
Tohoku Electric Power Co:
Namie Odaka
Chugoku Electric Power Co:
Kaminoseki
Tokyo Electric Power Co:
Fukushima Daiichi
Kyushu Electric Power Co:
Genekai
Tokyo Electric Power Co:
Fukushima Daini
Shikoku Electric Power Co:
Ikata
Japan Atomic Power Co:
Tokai Daini
Kyushu Electric Power Co:
Sendai
Chubu Electric Power Co:
Hamaoka

Fuel cycle - front end

Japan has been progressively developing a complete domestic nuclear fuel cycle industry, based on imported uranium.

JAEA operates a small uranium refining and conversion plant, as well as a small centrifuge enrichment demonstration plant, at Ningyo Toge, Okayama prefecture.

While most enrichment services are still imported, Japan Nuclear Fuel Ltd (JNFL) operates a commercial enrichment plant at Rokkasho. This began operation in 1992 using indigenous technology and had seven cascades each of 150,000 SWU/yr, though only one has been operating. It has been testing a lead cascade of its new Shingata design, and is re-equiping the plant with this, to come on line in September 2011. The plant's eventual capacity is planned to be 1.5 million SWU/yr by about 2020. JNFL's shareholders are the power utilities.

A new enrichment plant in Japan using Russian centrifuge technology is planned under an agreement between Rosatom and Toshiba.

Japan has 6400 tonnes of uranium recovered from reprocessing and stored in France and the UK, where the reprocessing was carried out. In 2007 it was agreed that Russia's Atomenergoprom would enrich this for the Japanse utilities who own it.

At Tokai-mura, in Ibaraki prefecture north of Tokyo, Mitsubishi Nuclear Fuel Co Ltd operates a 440 tU/yr fuel fabrication facility, which started up in 1972 and has had majority shareholding by Mitsubishi Materials Corporation (MMC). In April 2009 this was restructured as a comprehensive nuclear fuel fabrication company to supply Japanese customers with uranium fuel assemblies for pressurized water reactors (PWR), boiling water reactors (BWR) and high-temperature gas-cooled reactors (HTR), as well as MOX fuel assemblies. It will also provide related services, including uranium reconversion from 2014. The new shareholdings are MHI 35%, MMC 30%, Areva 30% and Mitsubishi Corporation 5%, with capital of JPY 11.4 billion. In October it was announced that a new 600 t/yr plant using Areva's dry process technology would be built by the company. As part of the new partnership with Areva, MHI and Areva are preparing to build a dedicated nuclear fuel fabrication facility in the USA, with each having 50% equity.

At Kumatori and Tokai, Nuclear Fuel Industries (NFI) operates two fuel fabrication plants which have operated from 1976 and 1980 respectively. Kumatori (284 tU/yr) produces PWR and BWR fuel, Tokai (200 tU/yr capacity) is also set up to produce HTR and FNR fuel. NFI is also involved in a project to design MOX fuel for Areva to manufacture for Japanese power plants. In 2009 Westinghouse bought the 52% share of NFI owned by Furukawa and Sumitomo for $100 million.

JAEA has some experimental mixed oxide (MOX) fuel fabrication facilities at Tokai for both the Fugen ATR and the FBR program, with capacity about 10 t/yr for each.

Fuel cycle - back end

For energy security reasons, and notwithstanding the low price of uranium for many years, Japanese policy since 1956 has been to maximise the utilisation of imported uranium, extracting an extra 25-30% of energy from nuclear fuel by recycling the unburned uranium and plutonium as mixed-oxide fuel (MOX).

At Tokai, JNC (now JAEA) has operated a 90 t/yr pilot reprocessing plant using Purex technology which has treated 1116 tonnes of used fuel between 1977 and its final batch early in 2006. It processed over 1000 tonnes of used fuel, with a Pu-U mixed product. The plant will now focus on R&D, including reprocessing of MOX fuel. JAEA operates spent fuel storage facilities there and is proposing a further one. It has also operated a pilot high-level waste (HLW) vitrification plant at Tokai since 1995. Tokai is the main site of JAEA's R&D on HLW treatment and disposal.

Until a full-scale plant was ready in Japan, the reprocessing of used fuel has been largely undertaken in Europe by BNFL and AREVA (4200t and 2900t respectively), with vitrified high-level wastes being returned to Japan for disposal. Areva's reprocessing finished in 2005, and commercial operation of JNFL's reprocessing plant at Rokkasho-mura was scheduled to start in 2008. Used fuel has been accumulating there since 1999 in anticipation of its full-scale operation (shipments to Europe finished in 1998).

Reprocessing involves the conventional Purex process, but Toshiba is developing a hybrid technology using this as stage 1 to separate most uranium, followed by an electrometallurgical process to give two streams: actinides (plutonium and minor actinides) as fast reactor fuel, and fission products for disposal.

Rokkasho complex - reprocessing and wastes

In 1984, the Federation of Electric Power Companies (FEPC) applied to the Rokkasho-mura village and Aomori prefecture for permission to construct a major complex including uranium enrichment plant, low-level waste (LLW) storage centre, HLW (used fuel) storage centre, and a reprocessing plant. Currently JNFL operates both LLW and HLW storage facilities there, while its 800 t/yr reprocessing plant is under construction and is being commissioned. The used fuel storage capacity is 20,400 tonnes.

In October 2004 the Atomic Energy Commission advisory group decided by a large majority (30 to 2) to proceed with the final commissioning and commercial operation of JNFL's 800 t/yr Rokkasho-mura reprocessing plant, costing some JPY 2.4 trillion (US$ 20 billion). The Commission rejected the alternative of moving to direct disposal of spent fuel, as in the USA. This was seen as a major confirmation of the joint industry-government formulation of nuclear policy for the next several decades.*

* A 2004 government study showed that projected over the next 60 years it would be significantly more expensive to reprocess - at 1.6 yen/kWh, compared with 0.9 - 1.1 yen for direct disposal. This translates to 5.2 yen/kWh overall generating cost compared with 4.5 - 4.7 yen, without considering the implications of sunk investment in the new plant, or apparently the increased price of uranium since 2004.

The Rokkasho-mura reprocessing plant was due to start commercial operation in November 2008, following a 28 month test phase plus some delay at the end of 13 years construction. The intended date is now October 2012, the ongoing delay being due to problems in the locally-designed vitrification plant for HLW at the end of the line (see below). The main plant is based on Areva's La Hague technology, and in late 2007 the twenty-year cooperation agreement with Areva was extended and related specifically to Global Nuclear Energy partnership (GNEP) goals. The modified PUREX process now employed leaves some uranium with the plutonium product - it is a 50:50 mix, so there is no separated plutonium at any time, alleviating concerns about potential misuse.

In FY 2007 (to end March 2008) some 210 tonnes of used fuel was reprocessed. In FY 2008 it was expected to reprocess 395 tonnes of used fuel, from which it will recover 1.9 tonnes of fissile plutonium (in reactor-grade material). In FY 2009 about 160 tonnes of fresh used fuel is expected to be reprocessed, yielding 0.9 t fissile plutonium (Puf), and apparently 425 tonnes of stored fuel, to recover an additional 2.3 t Puf.

Active testing at the new vitrification plant attached to the Rokkasho reprocessing plant commenced in November 2007, with separated high-level wastes being combined with borosilicate glass. The plant takes wastes after uranium and plutonium are recovered from used fuel for recycle, leaving 3% of the used fuel as high-level radioactive waste. However, the furnaces (developed at Tokai, rather than being part of the French technology) have proved unable to cope with impurities in the wastes, and commissioning is much delayed. Finally in 2010 JNFL decided to redesign the unit to better control temperature of the molten glass, resulting in a delay to October 2012 for commissioning.

The new Rokkasho plant will treat 14,000 tonnes of used fuel stockpiled there to end of 2005 plus 18,000 tonnes of used fuel arising from 2006, over some 40 years. It will produce about 4 tonnes of fissile plutonium per year, enough for about 80 tonnes of MOX fuel.

Mutsu storage

In 2010 Recyclable-Fuel Storage Co obtained approval to construct a facility at Mutsu in Aomori prefecture to store used fuel from Tepco and Japco nuclear plants for some 50 years before reprocessing at the Japan Nuclear Fuel plant. It is expected to take 3000 t/yr. Construction started in July 2010 and is due to be completed by 2012.

Regulation and safety

The Nuclear & Industrial Safety Agency (NISA) within the Ministry of Economy Trade & Industry (METI, the successor of MITI) is responsible for nuclear power regulation, licensing and safety. It conducts regular inspections of safety-related aspects of all power plants.

The Nuclear Safety Commission (NSC) is a more senior government body set up in 1978 under the Atomic Energy Basic Law and is responsible for formulating policy, alongside the Atomic Energy Commission. Both are part of the Cabinet Office.

The Science & Technology Agency was responsible for safety of test and research reactors, nuclear fuel facilities and radioactive waste management, as well as R&D, but its functions were taken over by NISA in 2001.

Public support for nuclear power in Japan has been eroded in the last few years due to a series of accidents and scandals. The accidents were the 1996 sodium leak at the Monju FBR, a fire at the JNC waste bituminisation facility connected with its reprocessing plant at Tokai, and the

1999 criticality accident at a small fuel fabrication plant at Tokai. The criticality accident, which claimed two lives, happened as a result of workers following an unauthorised procedures manual. None of these accidents were in mainstream civil nuclear fuel cycle facilities.

Following the 1999 Tokai criticality accident, electric power companies, along with enterprises involved with the nuclear industry established the Nuclear Safety Network (NSnet). The network's main activities were to enhance the safety culture of the nuclear industry, conduct peer reviews, and disseminate information about nuclear safety. In 2005 this was incorporated into the Japan Nuclear Technology Institute, based on the US Institute of Nuclear Power Operations. The NSnet division cooperates with INPO and WANO and arranges peer review activities.

Japan's Nuclear Safety Commission confirmed in April 2002 that using mixed oxide (MOX) fuel is safe, and that its use at up to 18 reactors by 2010 was supported. Senior members of the government have reaffirmed that the country's use of MOX "must happen", and that the government will initiate educational and information programs to win wider acceptance for it. A local referendum last year has delayed plans for its introduction.

In 2002 a scandal erupted over the documentation of equipment inspections at Tepco's reactors, and extended to other plants. While the issues were not safety-related, the industry's reputation was sullied. Inspection of the shrouds and pumps around the core is the responsibility of the company, which in this case had contracted it out. In May 2002 questions emerged about data falsification and the significance of cracks in reactor shrouds (used to direct water flow in BWRs) and whether faults were reported to senior management. By May 2003 Tepco had shut down all its 17 reactors for inspections, and by the end of 2003 only seven had been restarted. Replacement power cost on average over 50% more than the 5.9 yen/kWh (5.5 cents US) nuclear generation cost. Tepco now has all its reactors back on line, with the whole fiasco costing it about JPY 200 billion (US$ 1.9 billion).

In 2007 NISA ordered reactor owners to check their records for incidents which should have been reported at the time but were not. This revealed a brief (15 minute) criticality incident during refuelling at Hokuriku's Shika-1 BWR in 1999. A series of deficiencies and errors contributed to the incident, and clearly more should have been learned from it to benefit other operators of boiling water reactors such as Chubu and Tohoku, which have also had control rod anomalies over the last 20 years. Tepco said that its Fukishima I-3 BWR may have experienced criticality over seven hours during an outage in 1978, when control rods slipped out of position. NISA ordered the Shika-1 reactor to be shut down for detailed checks.

Because of the frequency and magnitude of earthquakes in Japan, particular attention is paid to seismic issues in the siting, design and construction of nuclear power plants. In May 2007 revised seismic criteria were announced which increased the design basis criteria by a factor of about 1.5 and required utilities to undertake some reinforcement of older plants. See also paper on Nuclear Power Plants & Earthquakes.

In July 2007 the Niigata Chuetsu-Oki earthquake occurred on a fault very close to the Kashiwazaki-Kariwa nuclear power plant, and the ground acceleration exceeded the design parameters for the plant, ie it was more severe than the plant was required to be designed for. The operating reactors shut down safely and there was no damage to the main parts of the plant. The government (METI) then set up a 20-member Chuetsu Investigation and Countermeasures Committee to investigate the specific impact of this earthquake on the power station, and in the light of this to identify what government and utilities must address to ensure nuclear plant safety. It acknowledged that the government was responsible for approving construction of the first units in the 1970s very close to what is now perceived to be a geological fault line. It was also agreed that the International Atomic Energy Agency (IAEA) would join Japan's Nuclear Safety Commission in a review of the situation. The second IAEA team confirmed after inspecting key internal components that there was apparently "no significant damage to the integrity of the plant". Ground subsidence damaged much equipment around the seven reactors, but the main part of each plant is built on bedrock, which had entailed excavation in some places to 45 metres.

In October 2008 NISA presented to the NSC its evaluation of Tepco's report on Kashiwazaki Kariwa, assessing it as "appropriate". It contained the results of Tepco's inspections and assessments of equipment, buildings and other structures at the plant following the July 2007 earthquake. In 2009 the NSC endorsed NISA's recommendation that units 6 & 7 be restarted.

A new inspection system of nuclear facilities came into effect in 2009, following deliberations on the matter since November 2005. Under the new system, the number of nuclear power plants approved for operation over 40 years can be expected to increase, starting with Tsuruga-1.

References:

OECD/NEA 1995, *Japan*
Nuclear Fuel Cycle, TEPCO, March 2002.
Nuclear Power Stations in Japan, CRIEPI, January 2000.
Paper by H Kurihara, WNA Symposium, 2002.
Masuda, S. 2003, HLW Disposal Program in Japan, KAIF/KNS Conference, Seoul.
Ichimiya, M. 2003, Design Study on Advanced Fast Reactor Cycle System in Japan, KAIF/KNS Conference.
Pickett S.E. 2002, Japan's nuclear energy policy, *Energy Policy* 30, 1337-55, Dec 2002.
Nuclear Engineering International, Oct 1998 & Nov 2004.
JAIF Atoms in Japan , various.
Tanaka, H 2006, Japan's nuclear power program, WNA Symposium 2006