CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES | Proliferation Prevention Program

JAPANESE NUCLEAR POLICY BACKGROUND PAPER

(updated November 20, 2014)

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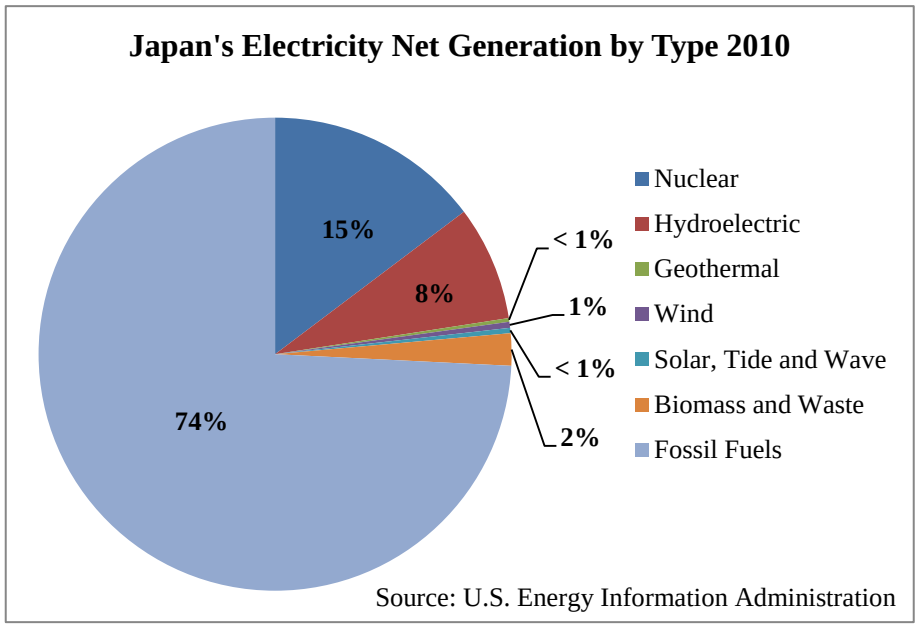
NUCLEAR ENERGY IN JAPAN POST-FUKUSHIMA

NUCLEAR ENERGY BEFORE FUKUSHIMA

Prior to the March 11, 2011 Great East Japan Earthquake and the resulting tsunami that led to the Fukushima-Daichii accident, nuclear power made up a significant percentage of Japan's overall electricity output. Between 1987 and 2011, nuclear energy accounted for roughly 30% of all power generation.[1] At the time of the accident, Japan had 54 nuclear reactors operating across 17 plants, with a total generating capacity of roughly 46 GW.



Energy Type	Net Generation (Billion kWh)
Nuclear	154.784
Hydroelectric	82.499
Geothermal	2.646
Wind	4.345
Solar, Tide and Wave	3.799
Biomass and Waste	23.146
Fossil Fuels	780.696
Total	**1,051.92**

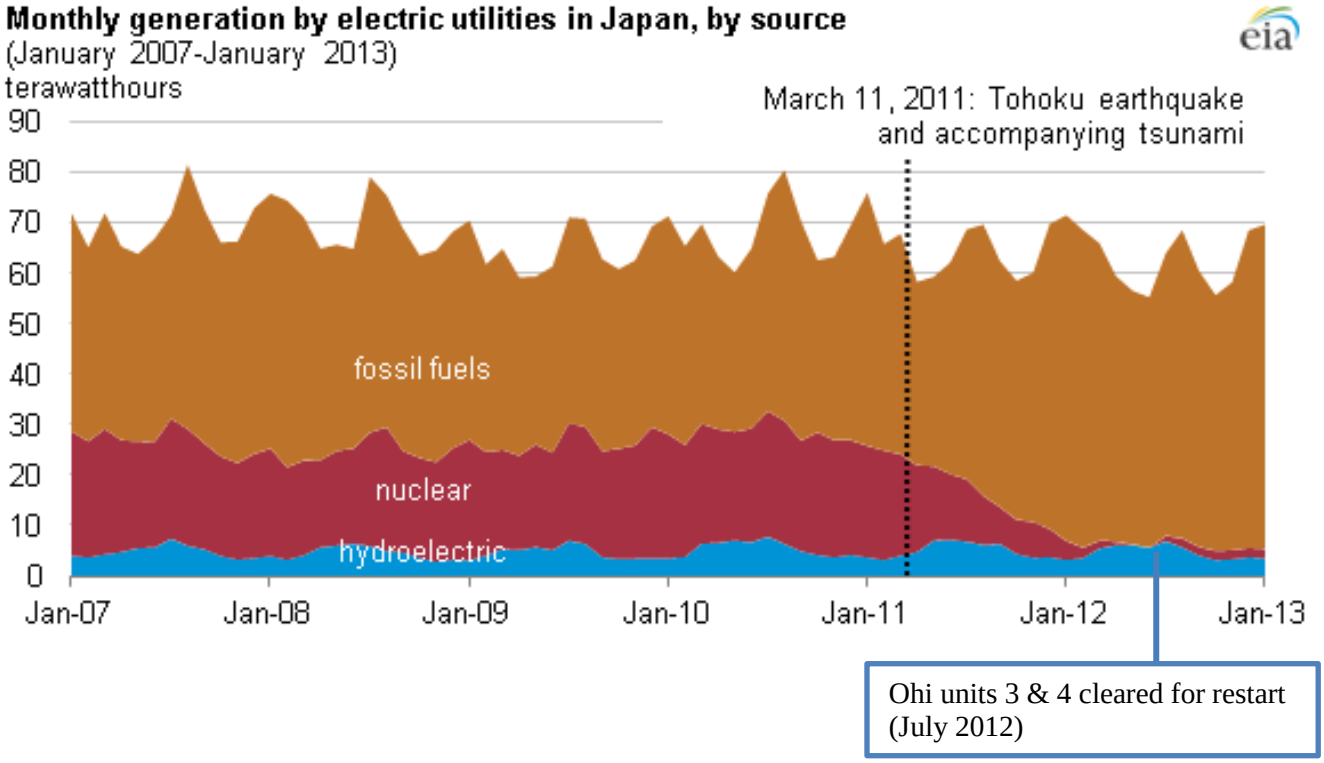
In 2010, Japan's Ministry of Economy, Trade and Industry outlined a long-term energy strategy meant to ensure maximum energy security by 2030. To achieve these goals, Japan hoped to build 9 new nuclear reactors by 2020 and a total of 14 additional plants by 2030.[2] This would have brought nuclear power to roughly 20% of overall electric capacity, with a total generating capacity across all reactors of roughly 68 GW.[3]

IMMEDIATE AFTERMATH OF THE FUKUSHIMA ACCIDENT

After the disaster at Fukushima, significant concerns arose regarding Japan's nuclear regulatory framework and the system's inability to ensure the safe operation of Japan's nuclear power plants. All 50 of Japan's remaining reactors (this number excluding reactor units 1-4 at Fukushima-Daichii that were quickly set on a track for decommissioning) were indefinitely shut down for maintenance and stress tests as the government reconsidered its long-term nuclear energy strategy.

On May 5, 2012, the last of Japan's nuclear power plants was shut down. After deliberation, the ruling Democratic Party of Japan (DPJ) government announced its intention to completely phase out the use nuclear power by the 2030s. All of Japan's reactors have remained shut down with the exception of units 3 and 4 at the Ohi nuclear power plant, which were cleared to restart in July 2012 in the face of blackouts and energy shortages. Then Prime Minister Yoshihiko Noda stressed that the restart of these reactors would not implicate the long-term plan to phase out nuclear power in favor of other energy sources.[4]

The following chart from the U.S. Energy Information Administration (EIA)[5] tracks Japanese electricity generation in the lead-up to and the aftermath of the Fukushima disaster.



JAPANESE NUCLEAR POLICY – LDP, DPJ, LOCAL POLITICS (2013-)

In December 2012, a coalition led by the Japanese Liberal Democratic Party (LDP) won a massive victory in the Lower House, leading to a new government headed by Prime Minister Shinzo Abe. The LDP government has treaded carefully with regard to nuclear power, but has progressively shied away from its predecessor's nuclear phase-out plan.

In the early months of the administration, the Abe government focused predominantly on implementing its economic policy, remaining rather quiet on domestic nuclear issues. Thus far, the cornerstone of Abe's economic policy (dubbed "Abenomics") has relied on massive quantitative easing measures aimed at bringing down the value of the yen in an attempt to boost exports. While this strategy has been somewhat successful, leading to large across-the-board increases in exports, this devaluation of the yen has made energy imports (especially the increased oil and gas imports that have filled in for nuclear energy) all the more expensive. For these reasons, many view nuclear energy as indispensable to the continued success of Abenomics, lest Japan's modest recovery be stunted by a progressively worsening energy crisis.[6]

On July 14, 2013, Shinzo Abe's Liberal Democratic Party (LDP) government released its annual white paper on energy. In this review (available in full only in Japanese), there was virtually no mention of the previous government's plan to phase out nuclear energy by 2030. There was also no indication of the fairly well-known widespread public opposition to restarting the country's nuclear reactors.[7]

On July 21, 2013, the LDP collation won a sizeable victory in the Upper House elections, solidifying a majority in both bodies of the Diet. Abe has claimed that the DPJ-controlled Upper House had prevented him from fully implementing his agenda. Many have cautioned against viewing the election as a mandate for Abe's entire agenda, especially with regard to nuclear power. A majority of Japanese continue to oppose a restart of nuclear power reactors. Abe himself campaigned mostly on economic issues, and the nuclear question remained mostly unaddressed. According to polls by the Mainichi Daily, only 25% of LDP winners in the Upper House election believe that Japan needs nuclear energy.[8] While it is likely that Abe will ramp up his push to restart the country's nuclear power plants, the election hardly clears the way entirely.

Two Former Prime Ministers, Junichiro Koizumi and Morio Hosokawa, establish the Japan Assembly for Nuclear Free Renewable Energy on May 7th, 2014.[9]
Yukiko Kada (Shiga governor), Yorihisa Matsuno (JRP), Takashi Shinohara (DPJ), and Shoichi Kondo (DPJ) attended the inaugural meeting. Hosokawa stated that government should learn lesson from Fukushima accident. Japan should change energy plan from nuclear to renewable energy.

Local Politics

Shiga Governor Election on July 13th, 2014[10]

Governor Name	**Pary**	**Status**
Taizo Mikazuki	DPJ (former HOR) and supported by current governor	No nuclear
Takashi Koyari	LDP and NKP (former METI)	Ambiguous. Decreasing dependence. Emphasizing Abenomics.
Ikuo Tsubota	JCP	No nuclear

The DPJ candidate, Taizo Mikazuki won in Shiga governor election. Mikazuki favors getting out of nuclear power, and promised to pursue development of renewable energy. But Chief Cabinet Secretary Yoshihide Suga said this result will not affect the administration's nuclear policy. Suga explained that source of defeat was self-defense and LDP member's sexual comments.[11]

Genkai Mayor Election[12]
Genkai NPP (Kyushu) is located in Genkai Town, Shiga Prefecture. One of the key issues of election was the restart of Genkai NPP. 70% of general account budget is from nuclear money (Kofu-kin and fixed asset etc).

On August 3rd, 2014, incumbent Hideo Kishimoto won Genkai Mayor Election.[13] He has a position in favor of restarting Genkai nuclear power plant under the NRA's standards. According to the Yomiuri Shimbun, Kishimoto mentioned that there was fewer oppose of restarting than he expected, and that he may think that public people in Genkai accepts nuclear power for local economy. He also mentioned that he wants to discuss the interim storage of Genkai NPP while in office.[14]

Tokyo Governor Election
Yoichi Masuzoe, supported by the LDP, has emerged as the winner of the Tokyo gubernatorial election. Masuzoe has stated that he supported a gradual phase-out of nuclear power. Some has cast the Tokyo election as a referendum on Abe's nuclear policy, although the governor holds little authority over those decisions.

STRUCTURAL CHANGES TO JAPAN'S NUCLEAR REGULATORY SYSTEM

Following the events at Fukushima, the DPJ government decided to completely overhaul its nuclear regulatory structure. Many believed that the Nuclear and Industrial Safety Agency (NISA) had done a woefully inadequate job ensuring the safety and security of Japan's nuclear facilities, believing that the agency lacked the necessary autonomy and authority to fulfill its duties.[15]

NISA's replacement, the Nuclear Regulation Authority (NRA), was officially established on September 19, 2012. The NRA was afforded significantly more autonomy than NISA, locating itself under the Ministry of Environment (MOE), a move meant to avoid the sorts of conflicts of interest that presumably occurred at NISA, given its location within the Ministry of Economy, Trade and Industry, a government department explicitly engaged in nuclear power promotion.[16]

The reforms also significantly consolidated all regulatory activities within the NRA, which had previously been divided across NISA (which was responsible for power reactor safety), the Ministry of Education, Culture, Sports, Science and Technology (which was responsible for test reactors and research facilities), and the Nuclear Safety Commission (which was responsible for "double-checking" the aforementioned bodies' actions). These changes are outlined graphically in Appendix A.

NEW REGULATIONS COME INTO EFFECT

On July 8, the new regulations under the NRA were officially put into effect. The most stark difference between the NRA regulations and those of its predecessor is that NRA regulations are legally binding and mandatory, whereas NISA regulations were intended to be adopted on a voluntary basis.[17] The most significant of those regulations, in brief:[18]

- Plant operators must strengthen tsunami defenses
- Any faults in close proximity to important reactor facilities must be proven to be relatively inactive
- Emergency command centers must be built that can be operated in the event of natural disasters or other external human-induced events
- New filtered venting system must be installed to guard against radioactive leakage and cool reactor parts in the event of meltdown

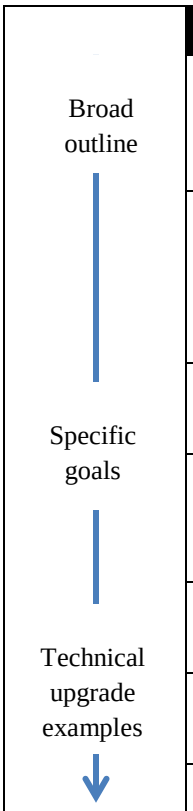
Faults are deemed to be active if seismic activity has occurred in the past 120,000-130,000 years. In the event that initial investigation is inconclusive, seismic activity in the past 400,000 years is to be inspected. Furthermore, the NRA abstractly states that investigators should err on the conservative side with regard to these investigations.[19] Much controversy has surrounded these standards in particular, especially the portions concerning how long a fault must be proven to have been inactive for it to be deemed presently inactive.

The general review process consists mainly of meetings between NRA officials and electricity utility representatives. These meetings are open to the public. Summaries of any smaller, follow-up meetings are to be publically released as well.[20]

Once reactors have been cleared by the NRA, the central government must approve the reactor for restart. While local government approval is not explicitly and legally required, most speculate that the central government will not approve a reactor for operation until relevant local authorities have given their blessing.[21]

Japan's basic regulatory system functions through multiple pieces of legislation that were intended to build upon one another. The starting point for all nuclear regulatory actions (covering more than just reactor safety) is the Atomic Energy Basic Law. The law establishes that regulatory guidelines be enacted through future, more

specific legislation; future legislation (the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors) establishes that regulatory requirements be enacted pursuant to future cabinet orders; cabinet orders establish that specific regulatory practices be laid out through NRA ordinance; and so on and so forth. The following chart expands upon this system in the context of NRA safety assessments.[22,23]



Regulatory Mechanism	Function
Atomic Energy Basic Law	- States broad objectives regarding nuclear endeavors - Establishes basic organization framework for subsequent laws to expand upon
Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors	- Lays out broad objectives and requirements regarding regulatory matters - Revised in 2013 (from 1957 version) to account for the creation of the NRA
Cabinet Order	- Establishes which organizations will be in charge of specific regulatory matters
NRA Ordinance	- Defines specific level of capacity, equipment and procedures that must be met to ensure safety (e.g. depressurization of a reactor's coolant system)
NRA Regulatory Guide	- Shows specific examples of how to reach the aforementioned requirements
Technical Documents by NRA, JNES, etc.	- Evaluates and critiques specific methods undertaken in particular reactors
Utility Operations	- Assess reactors' ability to meet requirements and submit reports to the above organizations

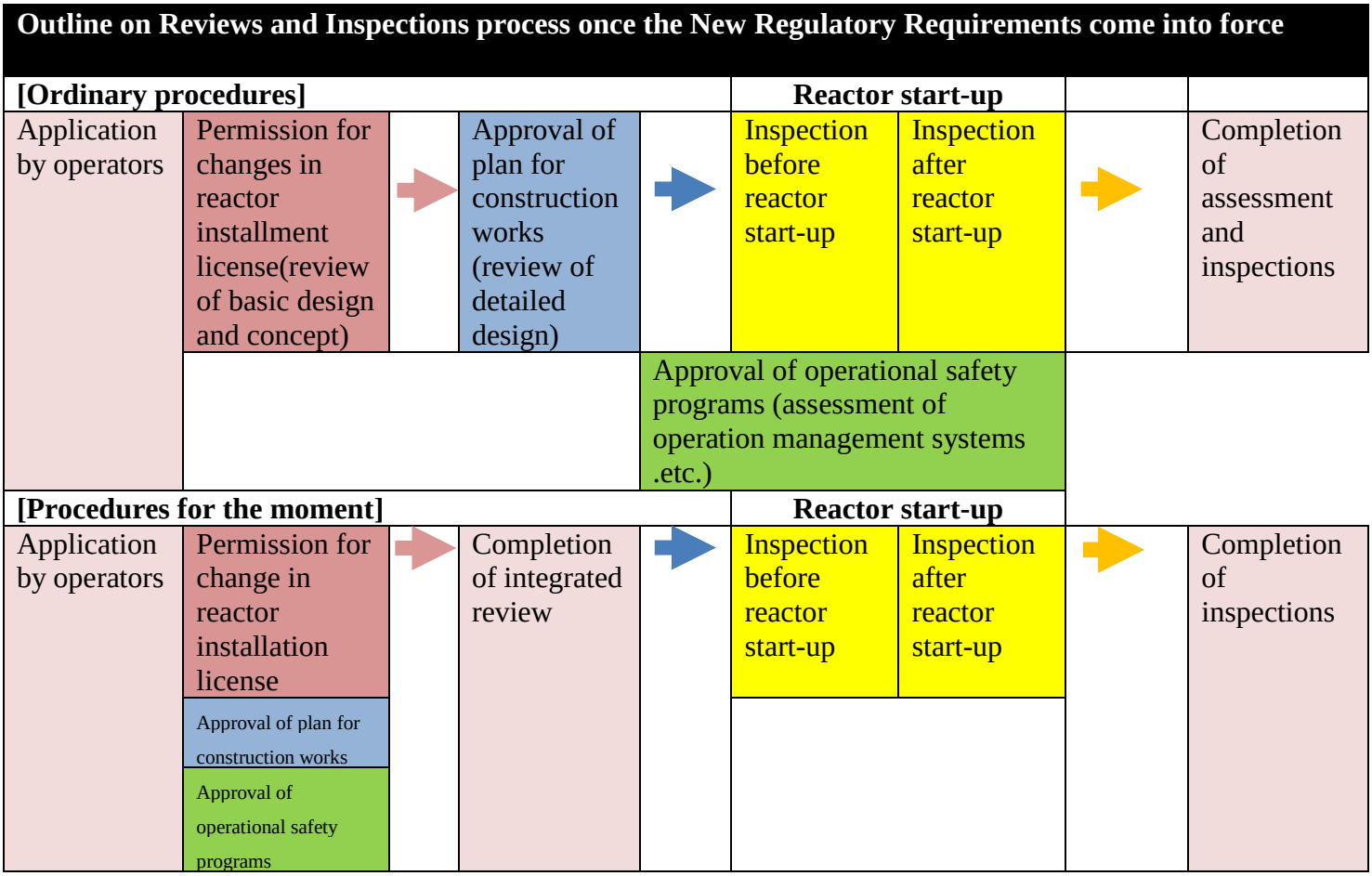


Figure 1 July 8, 2013 Nuclear Regulation Authority

NEW REGULATION IN MORE DETAIL

The most important implication of the structure outlined above is that the specifics of the new NRA regulations are not thoroughly outlined in legislation. The revised Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors contains only broad goals and objectives. Even subsequent releases by the NRA have been left vague, with the intent that specific procedures and processes will be expounded upon in more detail in future NRA documents.

Broad, all-encompassing requirements included a renewed focus on "defense-in-depth" measures, where equipment and procedures are designed in such a way that multiple, independent fail safe measures exist to check against malfunctions.[24] Completely new requirements include those relating to prevention of containment failure, as well as those intended to suppress the release of radioactive materials into the surrounding environment. Existing standards (such as those regarding earthquakes and tsunamis) were also enhanced.

Appendix B attempts to present a comprehensive list of the new safety measures, as gleaned from NRA presentations and press releases.[25,26]

The NRA has revised its protective action action guidelines to avoid exposure at plume passage, even outside of the UPZ (Urgent Protective Action Planning Zone). This revision of guideline would increase the number of municipalities that are required to prepare nuclear safety measures[27]

UTILITIES PUSH FOR SAFETY CLEARANCE RESTARTS

As of this writing, six utilities have applied for safety assessments on a total of sixteen reactors. Four utilities applied on the first date possible, when the safety guidelines were officially adopted on July 8, 2013. Shikoku Electric Power Co. submitted an application for the no. 3 unit at its Ikata plant; Kansai Electric Power Co. submitted official applications for units 3 & 4 at its Ohi plant, as well as units 3 & 4 at its Takahama plant; Kyushu Electric Power Co. submitted applications for reactors no. 1 & 2 at its Sendai plant; and Hokkaido Electric Power Co. submitted applications for units 1, 2 & 3 at its Tomari nuclear power plant.[28] Several days later, Kyushu also submitted applications for units no. 3 & 4 at its Genkai facility.[29] On September 27, Tokyo Electric Power Co. (TEPCO) submitted its first applications to restart units 6 & 7 at Kashiwazaki Kariwa, the world's largest nuclear plant.[30] Finally, Chugoku Electric Power Co. submitted an application for reactor 2 at Shimane and Tohoku Electric Power Co. applied for unit 2 at its Onagawa plant December 2013.[31]

Most of the aforementioned reactors have yet to fully upgrade their facilities in line with the NRA's new safety requirements. Shikoku's Ikata 3 reactor appears to be the furthest along with regard to safety upgrades. Because the Ikata plant is widely believed not to reside near an active fault line, installation of the required emergency facilities is expected to proceed relatively quickly.[32] Ikata 3 is expected to be one of the first reactors cleared to restart operations.

First reports from the proceedings show an NRA that knows it is under strict scrutiny and has carried out its assessments accordingly. Less than three weeks after submission, the NRA suspended the applications for Hokkaido Electric's Tomari 1 & 2 reactors, citing multiple issues with the applications. Regulatory officials claimed that Hokkaido's analysis on the reactors' cooling systems was based on a different cooling system, and that the analysis was thus far from applicable.[33] Hokkaido has stated that it intends to revise and resubmit the applications, but the incident may prove an important first step for the NRA towards proving its commitment to safety. The NRA has reported progress at ten of the sixteen reactors applying, but the process at several other units has been stalled because of inadequate safety measures.[34]

Sendai Nuclear Power Plant gets first OK. [35]
On July 16th, 2014, the NRA approved the safety measures of the Sendai Nuclear Power Plant in Kagoshima Prefecture. After this permission, Sendai NPP should be assessed plan for construction works and operational safety programs. It is anticipated that reviews will finish after October. The NRA is currently reviewing 17 Reactors.

Hokuriku submitted application for safety assessment of Shika 2 to the NRA on August 12, 2014.
Hokuriku wants to recover earnings from the ballooning fuel cost of thermal power since Fukushima accident. However, NRA has suspended the review of Shika 2 because active faults may lie under the Shika 2. NRA wants to wait the result of active faults which experts are debating the possibility of faults. NRA also suspends Higashidori because of possibility of active faults.[36]

CHALLENGES FOR PARTICULAR REACTOR TYPES

The first twelve units to submit applications are pressurized water reactors (PWRs), while the Kashiwazaki Kariwa, Shimane, and Onagawa reactors are boiling water reactors (BWRs). PWRs are expected to have an easier time achieving safety clearance than BWRs, which were the type in operation at Fukushima. The unique problems faced by BWR operators seeking restarts are two-fold.

The first set of problems is technical. PWRs will be given a five-year grace period to implement certain safety standards, namely installing new filtered ventilation systems.[37] PWRs have larger reactor vessels than BWRs, and are thus seen as less prone to kind of meltdown that occurred at Fukushima.[38]

The second set of problems is symbolic. Given that the reactors involved in the Fukushima disaster were BWRs, restarting other reactors of the same type will be extremely difficult from a political standpoint. As a case in point, when TEPCO initially announced its intention to apply for safety screenings on reactors 6 & 7 at the Kashiwazaki-Kariwa plant, local authorities came out staunchly against such plans, despite the fact that the reactors in question are the newest of the facility, technically classified as *advanced* boiling water reactors (ABWRs). TEPCO eventually submitted its applications for restart, but only after agreeing to install new filtered ventilation systems.[39]

Under new NRA regulations, reactors are initially restricted to a 40-year operating lifespan. Once that deadline has passed, reactors may apply for a one-time extension of (at maximum) 20 more years. This renewal process would include a strict reevaluation of the reactor's ability to meet previous safety requirements in light of whatever wear and tear may have occurred over the previous four decades.[40]

This system will replace the previous system under NISA where reactors could operate under their original licenses for 30 years before applying periodically for 10-year extensions. There was previously no limit to the number of extensions that could theoretically be granted.[41] This extension process was notoriously easily under NISA. Government agencies did not conduct direct inspections, instead relying on utilities to submit their own reports on reactor safety and maintenance. The infamous Fukushima Daiichi plant secured a 10-year extension roughly a month before its generators were knocked out by a tsunami. Reports have since surfaced that members of the expert panel commissioned by NISA to investigate the plant had indeed voiced concerns about Fukushima's ability to withstand weather-induced blackouts. Nothing was apparently done.[42,43]

Japan currently has three reactors that have been operating for longer than 40 years: unit no. 1 at the Tsuruga plant, and units no. 1 & 2 at the Mihama plant. These reactors will be given a three-year grace period before having to undergo inspection under the new regulations. Several other reactors will have been in operation for at least 37 years as of January 2014. These include units no. 1 & 2 at the Takahama nuclear plant, reactor no. 1 at the Shimane plant, and unit no. 1 at the Genkai plant.[44] None of these plants have as of yet applied for safety screenings with the NRA, and several (Tsuruga, Mihama and Shimane) are thought to reside on potentially-active faults.

LONG-TERM PROJECTIONS FOR NUCLEAR RESTARTS

Making long-term projections regarding Japan's nuclear industry is extremely difficult. Of Japan's 50 reactors, 24 are PWRs, while the remaining 26 are either BWRs or ABWRs. How the NRA goes about clearing (or not clearing) these different types of reactors over the next year will provide considerable insight regarding the future of nuclear energy in Japan.

Although a few more operators have recently applied for restarts, many utilities (especially those operating BWRs) have remained silent on whether they intend to apply. Many companies have expressed concerns over how much the various safety upgrades will cost, with some estimates that these could cost $12 billion across the entire industry.[45]

That said, most utilities, while having as of yet not put forth a concrete plan for restarting all of their reactors, have stated that they do not intend to decommission any reactors not already designated for permanent closure. As costly as safety upgrades may be, decommissioning costs may be comparably high.[46] It is unclear whether the government will take steps to make decommissioning less costly.

Political and public opposition further complicates calculations, as illustrated by TEPCO's first attempt to restart the Kashiwazaki-Kariwa units.

It is also unclear which reactors face the most serious difficulties regarding fault line proximity. Even before the new regulations took effect in July, the NRA accepted an expert report that the no. 2 unit at Japan Atomic Power Co.'s (JAPC) Tsuruga facility was located above an active fault line.[47] JAPC was quick to dispute these findings with their own reports, also petitioning that any NRA instruction and/or regulation dictated under the assumption that the fault is active is based upon untrue information and thus is illegal.[48,49] It is unclear how this ruling will affect Tsuruga's other reactor. JAPC has stated its intention to apply for safety screenings at all of its reactors: the two at Tsuruga (unit no. 1 a BWR, unit no. 2 a PWR), and also the no. 2 unit at the Tokai nuclear plant (a BWR).[50]

Other plants reportedly being investigated for active fault lines are two reactors at Hokuriku Electric Power Co.'s Shika plant, Kansai's four-reactor Ohi facility, and Tohoku Electric Power Co.'s one-reactor Higashidori plant.[51,52] The fact that a reactor is not currently being investigated for fault line risks does not mean that the reactor has been cleared. Further investigations may follow.

Appendix C contains a chart summarizing the status of individual Japanese reactors.

FUTURE CONSTRUCTION PLANS

Prior to the Fukushima disaster, Japan had planned to build 14 new reactors by 2030, a proposal that would have increased nuclear power's share of overall electricity generation to roughly 50%. After Fukushima, then Prime Minister Naoto Kan decided to abandon construction of new reactors.[53]

This moratorium on new construction lasted until October 2012, when the Japan Electric Power Development Corp (J-Power) resumed construction of its planned Ohma nuclear power plant.[54] Upon taking office at the end of 2012, Prime Minister Abe quickly announced his desire to construct new nuclear power plants.[55]

More information on under-construction reactors can be found in Appendix C.

Hakodate sues to halt Ohma reactor in Aomori. The city of Hakodate in Hokkaido sits 23 km from Ohma reactor in Aomori, which is within the 30 km accident safety zone around the plant. This is the first case in Japan that a municipality is suing to halt the construction of a nuclear plant.[56]

JAPAN'S NUCLEAR FUEL CYCLE

Since shortly after the first usage of nuclear power in Japan, successive Japanese governments have maintained plans to pursue a closed nuclear fuel cycle. Because Japan relies almost entirely on imported uranium, policymakers view recycling spent fuel as essential to maximizing Japanese energy security.

The current status of Japan's nuclear fuel cycle is summarized in Appendix D.

RECENT POLICY DEVELOPMENTS

In early 2013, Minister for Economy, Trade and Industry Toshimitsu Motegi announced that the Abe government intended to continue earlier efforts to recycle spent fuel, saying that the "significance of the policy" had not changed.[57] Abe has also expressed his intention to continue operation towards both reprocessing and developing fast-breeder reactor technology.[58]

The NRA implemented new safety regulations covering Japan's 247 noncommercial nuclear facilities (reprocessing plants, fuel fabrication facilities, experimental reactors, spent fuel storage sites) on December 18, 2013. These standards required such facilities to implement protections against criticality incidents, hydrogen explosions, earthquakes, and tsunamis, while also identifying any active fault lines near or under the sites.[59] The NRA has mandated that reprocessing plants as well as other fuel processing facilities remain offline until regulators can conduct safety inspections, a process which only began once the regulations legally entered into force.[60]

The Japanese government recently released its 4th Strategic Energy Plan, outlining several notable positions:[61]

- The government will continue development of Monju as an international research center for reduction of volume and mitigation of the harmfulness of radioactive waste.
- The Government will ensure "strategic flexibility" with regards to the future operating volume of nuclear power plants, the amount of nuclear fuel, and quantity of spent fuels produced.

The Recycle Equipment Test Facility (RETF) will be re-evaluated from a nuclear fuel cycle facility to another facility.[62]

New President of the Nuclear Waste management Organization of Japan (NUMO)
Shunsuke Kondo, professor emeritus of Tokyo University and former head of policymaking at the JAEC, will be the new president of NUMO in July. He expressed his intention to accelerate to the search for a final disposal site.[63] He stated that NUMO will develop the nuclear fuel disposal technology and reach out to the public for facility siting.[64]

Three economic associations urge Abe to restart nuclear power plant on June 12th, 2014.[65]
Three economic associations [Keidanren (Japan Business Federation), Japan Chamber of Commerce and Industry, and Keizai Doyukai (Japan Association of Corporate Executives)] all urged Prime Minister Abe to restart nuclear power plants as soon as possible.

METI may guarantee price for nuclear power plants
METI called a meeting of committee on August 21, 2014. In order to build new NPP or rebuild NPP easier under the electricity deregulation, METI suggested to adopt price guarantee for electricity generated by NPP.

This idea's model is Britain's "Contracts for Difference" scheme. However, this suggestion contradicts the government policy which states breaking with nuclear power generation and might bring backlash of public opinion.[66]

CONVERSION AND ENRICHMENT

Japan relies primarily on imported uranium. Japanese companies have been working towards expanding operations and contacts in uranium-supplying countries such as Kazakhstan and Uzbekistan, in addition to other overseas operations such as Australia and Canada.[67]

Importing Enrichment Services

Despite operating an enrichment facility in Rokkasho, Japan continues to import the majority of its enriched uranium supply. Historically, the majority of these services have been contracted to EURODIF, Urenco, and USEC Inc.[68] Japanese utilities have ensured enrichment services both through contracts and investment. For instance, Kansai Electric recently acquired shares (in conjunction with in Société d'Enrichissement du Tricastin (SET), the company that operates Eurodif's new Georges Besse II enrichment plant.[69] Japanese utilities have recently begun expanding their contracts beyond these three companies, as Russia's Tenex signed a contract with Japan's Chubu Electric Power Co. in May 2009, the first of any such agreement to follow Japan and Russia's nuclear cooperation agreement.[70]

Rokkasho Enrichment Facility

While Japan also relies mainly on imported uranium conversion and enrichment services, government and industry have taken steps to ramp up domestic enrichment capabilities. A Japan Nuclear Fuels Limited (JNFL) enrichment facility (RE2A) located in Rokkasho-Mura in the Aomori prefecture has been operating since 1992. The facility had an original capacity of 1,500 MTSWU/year. That has since been upgraded by 37.5 MTSWU/year. Centrifuges to increase capacity by an additional 37.5 MTSWU/year are planned for mid-2013 installation. An eventual goal of 1,500 MTSWU/year capacity has been recently reaffirmed by JNFL. The company was silent regarding the previous 2020 timeline.[71]

Future Japanese Enrichment Demand

The entirety of Japan's nuclear fleet (50 reactors), if brought back online, would consume roughly 6,000 MTSWU per year.

> **Aside:**
> This number (6,000 MTSWU) should be regarded as a rough approximation. Reactor-by-reactor SWU requirements are difficult to determine, given that Japan's reactors vary widely with regard to capacity. Estimates vary, but most accounts state that roughly 100-120 MTSWU are required to power a 1 GW light-water reactor for one year. Given that Japan has 50 reactors, this measurement would place yearly SWU requirements at between 5,000 and 6,000 MTSWU. I erred on the higher end of this estimate for three reasons: (1) on average, Japan's reactors operate at greater than 1 GW; (2) an older IAEA report stated that Japan used roughly 5,900 MTSWU in fiscal year 2002[72]; 6 reactors operating that year have since been shut down, while 4 newer reactors of greater capacities have been constructed; (3) various news sources[73] and other reports (including 2013 USEC documents[74]) estimate Japan's requirements to be 6 million SWU, or 6,000 MTSWU

Predicting is Japan's future SWU needs is difficult, given that the status of Japan's pluthermal program is still very much up in the air. Assuming business as usual, where the majority of Japan's light-water reactors continue to run on uranium, and annual demand sat at around 6,000 MTSWU, Japan would

have to continue to rely extensively on imported enrichment, given that the final projected capacity of JFNL's Rokkasho enrichment plant is only 1,500 MTSU per year.

Obviously, however, it does not appear that Japanese demand for enrichment services will reach that level in the near future. Were Japan to restart the 16 reactors currently up for review, annual demand for SWU would reach about 1,920 MTWSU. This estimate assumes that each reactor requires roughly 120 MTSWU per year.

Were the Rokkasho enrichment facility run at full capacity (currently 1,087.5 MTSWU/year, expected to soon reach 1,125 MTWSU when ongoing upgrading has been completed), it could theoretically supply a significant portion of Japan's low-enriched uranium needs under this short-term scenario. Uncertainty regarding further reactor restarts complicates any attempt at longer-term projection.

FUEL FABRICATION

Mitsubishi Nuclear Fuels also operates a reconversion to UO_2 in Tokai-Mura. The facility has been operating since 1972 as part of Mitsubishi's fuel fabrication operations, and has an operating capacity of 450 tonnes HM/year.[75] Four other facilities have supplied most of the fuel assemblies for Japan's fleet of BWRs and PWRs. Facility details and capacity specifications listed below:[76]

Company	Location	Intended Reactor	Capacity (tHM/year)	Start of Operation
Global Nuclear Fuel-Japan Co. (GNF-J)	Kurihama	BWR	750	1970
Mitsubishi Nuclear Fuel Ltd. (MNF)	Tokai-Mura	PWR	440	1972
Nuclear Fuel Industry Ltd. (NFI)	Kumatori	PWR	284	1972
	Tokai-Mura	BWR*	250	1980

*NFI's Tokai plant has also produced HTR and ATR fuel assemblies, though it mainly produces BWR fuel

REPROCESSING

Tokai Reprocessing Plant (TRP)
The Japan Atomic Energy Agency (JAEA) has operated a reprocessing plant in Tokai-Mura since 1977, when the facility first started testing its reprocessing capabilities. Commercial operation began in 1981. In March 1997, an explosion at the facility forced the plant to shut down. Operations did not resume until 2000.[77] The plant's reprocessing activities shut down in 2006 for maintenance. The plant has a capacity of 90 t HM/year, and reprocessed a total of 1,140 t U before shifting operations toward research and development towards MOX fuel processing.[78]

Rokkasho Reprocessing Plant (RRP)
JNFL's Rokkasho Reprocessing Plant began active testing in March 2006. The plant has reprocessed a total of 425 t HM of spent fuel, 220 t HM of which was recovered from boiling water reactors (BWRs) with the remaining 205 t HM coming from pressurized water reactors (PWRs). Recovered products included 364 t U (uranium oxide) and 6.7 t HM mixed oxide fuel (MOX). These operations yielded roughly 2.3 t Puf (fissile plutonium) as well as 119 canisters of vitrified high-level waste (HWL).[79]

After continual delays, RRP achieved a major milestone in May 2013 when the facility successfully tested both of its vitrification lines necessary to handle high-level waste (HLW).[80] JNFL originally planned for Rokkasho to begin reprocessing spent fuel by October 2013, however it postponed the date by approximately one year due to the upcoming release of the new Nuclear Regulatory Authority standards.[81] Following the December 2013 release of the new safety standards, JNFL filed for a regulatory safety screening on January 7, 2014. Reports put the planned reprocessing capacity at 800 tonnes per year.[82]

Recent NRA studies have hinted at the existence of an active fault off the coast of the Aomori province. Such an assessment would conflict with previous investigations submitted by JFNL and TEPCO. The Aomori province hosts JFNL's Rokkasho facilities, including the reprocessing plant and under-construction MOX fuel fabrication plant, as well as TEPCO's Higashidori nuclear power plant. Any

official ruling that declares the nearby fault to be active would undoubtedly affect nuclear operations in the province, though the extent of such effects is unclear.[83]

The new Nuclear Regulatory Authority (NRA) stated on June 19th, 2014 that the application to operate the plant was deficient and that a more sufficient explanation was needed. Shunichi Tanaka of the NRA mentioned that JNFL did not establish an appropriate risk management system in the application for the case of a severe accident. JNFL originally planned for RRP to begin reprocessing spent fuel by October 2014. However, this seems unlikely. The NRA stressed that JNFL needs a fundamental change of the plan and will need to resubmit the application to the NRA.[84]

MIXED OXIDE (MOX) FUEL PRODUCTION

Tokai Plutonium Fuel Production Facility

In 1987, operations began at the Japan Atomic Energy Agency's (JAEA) Plutonium Fuel Production Facility (PFPF) in Tokai-Mura. The plant was constructed to provide MOX fuel for Japan's Joyo experimental fast reactor and the Monju fast breeder reactor. The Tokai PFPF has a capacity of 5 t MOX (1 t Pu) per year.[85] The most recent Japan Atomic Energy Agency statement reports that Tokai PFPF and surrounding research facilities have produced approximately 1,700 MOX fuel assemblies.[86]

JNFL MOX Fuel Fabrication Plant

In 2010, JNFL began construction on a MOX nuclear fuel fabrication plant in Rokkasho. Initially, JFNL hoped to finish construction by early 2016. The company halted construction following the Fukushima incident, and did not resume activities until mid-2012. JFNL has yet to officially revise the 2016 expected completion date, though most expect significant delays, given that the facility was only about 3 percent complete come November 2012.[87] The plant is expected to have a capacity of 130 tHM per year.[88]

MOX Fuel from Abroad

Japan has made deals with both France and the United Kingdom regarding reprocessing fuel from Japanese reactors.

In 1975 and 1978, France's AREVA signed deals with ten Japanese power companies to reprocess 3,000 metric tons of spent fuel at AREVA's La Hague facility. The high-level waste (HLW) produced throughout this process was shipped back to Japan, with the final shipment arriving in 2007. AREVA has also signed agreements with eight Japanese utilities to supply MOX fuel fabricated at AREVA's MELOX plant from earlier Japanese spent fuel shipments. Five such MOX shipments have arrived from Britain and France to Japan (in 1999, 2001, 2009, 2010, and 2013).[89]

SPENT FUEL IN JAPAN

Japan will soon face serious problems concerning spent fuel storage. Some reports anticipate that 33 of the 50 reactors will have filled their on-site spent fuel pools to capacity within six years of full operation. Only three reactors are expected to have excess on-site spent fuel storage capacity after 12 years of operation. Assuming the NRA allows these reactors to restart, Genkai NPP (Saga Prefecture), Kashiwazakikariwa NPP (Niigata Prefecture), and Tokai No2 NPP (Ibaraki Prefecture) would be have no more capacity for spent fuel storage within 3 years. Only 4 NPPs have the spare capacity to store spent fuel for more than 10 years.

Off-site facilities do not provide a much better option. Spent fuel storage at the Rokkasho Reprocessing Plant is roughly 98 percent full.[90] Rokkasho has a capacity of 3,000 tons spent fuel.

Stockpile of nuclear spent fuel as of April in 2014				
Utility	**Plant**	**Refueled per cycle**	**Spent fuel stored (tU)**	**Percentage of Capacity Utilized (%)**
Hokkaido	Tomari	50	400	39
Tohoku	Onagawa Higashidori	60 30	420 100	53 23
TEPCO	Fukushima1 Fukushima2 Kashiwazaki-Kariwa	140 120 230	1,960 1,120 2,370	86 82 81
Chubu	Hamaoka	100	1,140	66
Hokuriku	Shika	50	150	22
Kansai	Mihama Takahama Ohi	50 100 110	390 1,160 1,420	58 67 70
Chugoku	Shimane	40	390	65
Shikoku	Ikata	50	610	65
Kyushu	Genkai Sendai	90 50	870 890	81 69
JAPC	Tsuruga Tokai	40 30	580 370	67 84
Total		1,340	14,330	69

Source: Nuclear Energy Subcommittee, http://www.meti.go.jp/committee/sougouenergy/denkijigyou/genshiryoku/pdf/001_s01_00.pdf

Mutsu Interim Storage Site

TEPCO and Japan Atomic Power Co. have established Recycable-Fuel Storage Co. to build and operate a dry storage facility in Mutsu city, roughly 40 km out from Rokkasho in the Aomori Prefecture. The facility will have a capacity of 5,000 tons, with the first storage site to hold 3,000 tons and the second site to hold the remaining 2,000 tons. The facility will hold spent fuel on a temporary basis until fuel can be moved to Rokkasho for reprocessing. [91]

Storage at Mutsu is not meant to exceed 50 years. Completion and operation of Mutsu will likely put additional pressure on the Japanese government and utilities to ensure long-term reprocessing operations at Rokkasho, given that TEPCO and its affiliates explicitly negotiated with the local population of Mutsu that spent fuel storage would only be temporary.[92]

TEPCO initially planned for Mutsu to begin operation in 2012, but construction was suspended for a year after Fukushima. The facility was completed in October 2013, but it has not started operations due to the release of the NRA's December 2013 safety standards on noncommercial nuclear facilities.[93] TEPCO and JAPC plan to begin operation on March in 2015.

Hamaoka dry storage facility[94]

Chubu Electric Power Company will build dry storage facility in Hamaoka NPP with a capacity of 700 tons. Chubu states that dry storage facility will be established in their northern No. 4 reactor. At first, Chubu was aimed at starting to operate in 2004 but still they are in design stage. According to the Chubu, there are 6,575 spent fuel assemblies in Hamaoka NPP.[95] On July 31st, 2014, the Chubu Electric

Power Company concluded that it try to have the dry storage facility operating by FY 2018. Also they will reduce the capacity of dry storage facility from about 4000 assemblies to about 2000 assemblies because of earthquake protection.[96]

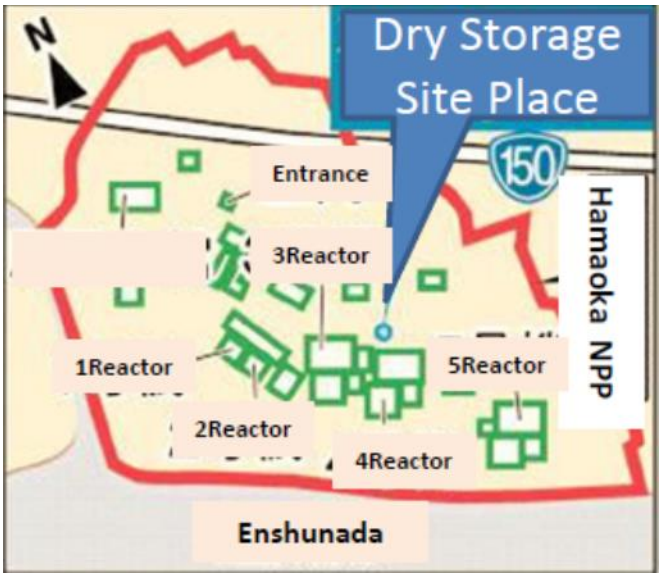


Figure 2 Hamaoka dey Storage Site Place http://www.at-s.com/news/detail/1124306969.html

Subcommittee meeting of Science Council of Japan (SCJ) on radioactive waste[97]
On July 2nd, the SCJ compiled a report which stated that spent fuel should be stored in interim storage for 30 years. They leave room the possibility of future solutions through new technology. For equity reasons, they suggested to establish interim storage site depending on power distribution area.

JAPAN'S PLUTHERMAL PROGRAM

In 2009, the Genkai nuclear facility's no. 3 reactor began operating on MOX fuel, becoming the first of Japan's light-water reactors to commercially utilize such fuel. Under the plutonium-thermal (or "pluthermal") program, MOX fuel that has been fabricated from reprocessed Japanese spent fuel is utilized in light-water reactors. After suffering from multiple delays and setbacks, Japanese officials hoped to see the program fully operation by 2010.

Due to setbacks to Japan's domestic reprocessing and MOX fuel production programs, foreign companies have been contracted to reprocess spent fuel and return finished MOX assemblies for use in Japan's pluthermal program (these shipments discussed above). Three of Japan's current reactors had begun to operate at least partially on MOX fuel before the Fukushima incident. These reactors included, in order of first MOX fuel operation: Genkai 3, Ikata 3, and Takahama unit 3. The Fukushima Daiichi 3 reactor had also been running partially on MOX fuel before the tsunami.

All three of the aforementioned reactors have applied for safety screenings under the new NRA regulations. In June 2013, Kansai Electric received its latest shipment of MOX fuel from France, the first of any such shipment since the Fukushima disaster. Kansai has stated that it intends to utilize MOX fuel again sometime between 2013 and 2015, tentatively establishing 2014 as a start date for MOX operations at Takahama units 3 & 4.[98]

It is unclear how the NRA will handle MOX fuel under the new regulations. Officials have stated that they will take MOX operations into account when assessing plants that have stated intentions to use the plutonium-

containing fuel, but have yet to release MOX-specific standards or expectations. Many have expressed concerns over the safety of MOX fuel, arguing that plutonium-thermal processes reduce the effectiveness of control rods that control the rate of fission within the reactor.[99]

In 2009, the Federation of Electric Power Companies of Japan (FEPC) laid out company-by-company plans for future pluthermal operations, revising previous goals. [100] A more comprehensive plan has yet to be released in the wake of the Fukushima disaster. The original 2009 plans, along with status updates on individual companies and reactors, are summarized in the following chart:

Company	Units for Pluthermal Program	Nuclear power plants	Status
Hokkaido	1	Tomari 3	Plans put on hold Nov. 2011 due to local public opposition[101]
Tohoku	1	Onagawa 3	National and local approval Planned for 2016 start-up[102] No plutonium on-site when shut down
TEPCO	3-4	3 or 4 units at TEPCO's plants (no specific units)	Fukushima-Daiichi 3 had been using MOX fuel before meltdown
Chubu	1	Hamaoka-4	Postponed Dec. 2010 due to safety concerns[103] Plutonium on-site
Hokuriku	1	Shika	No plutonium on-site when shut down
Kansai	3-4	Takahama 3 & 4 1 or 2 units at Ohi	Takahama 3 had been using MOX fuel before being shut down; Plutonium on-site for unit 4
Chugoku	1	Shimane 2	Contract signed with Areva for MOX fuel assemblies[104] No plutonium on-site when shut down
Shikoku	1	Ikata 3	MOX fuel in use when shut down Plutonium on-site
Kyushu	1	Genkai 3	MOX fuel in use when shut down Plutonium on-site
JAPC	2	Tsuruga 2	No plutonium on-site when shut down
EPDC	1	Ohma	Under-construction; no tentative start date
Total	16-18	-	-

All data regarding on-site plutonium storage comes from the 2013 JAEC plutonium management report for 2012 – additional detail regarding on-site summarized later along with other results of that report

FAST BREEDER REACTORS (FBRS)

For decades Japan has worked to create a commercial FBR that could utilize MOX fuel and help resolve the issue of the country's excess plutonium stores. Commercialization has been pushed back continually, however, and remains up in the air, heavily dependent on current demonstration projects (evidenced by how plans for a larger demonstration FBR fell through following problems at Monju) [105] as well as Japanese government decisions regarding fuel cycle policy.

Joyo Reactor

Japan's first experimental FBR, Joyo, first achieved criticality in 1977. Operators progressively upgraded Joyo's capacity, until 2007, when Joyo was shut down indefinitely for inspection after achieving a capacity of 140 MWt. Joyo was intended to primarily serve research interests, and has been the source of large amounts of data that Japan plans to use towards commercial development of FBRs.[106]

Monju Reactor
JAEA's demonstration Monju FBR first achieved criticality in 1994, but shut down in December 1995 after operators discovered a sodium leak in the reactor's cooling system. Subsequent problems prevented the reactor from restarting until May 2010. Problems resurfaced, however, and Monju was forced to shut down again in August of that year.

While JAEA hoped to restart Monju as soon as possible, the NRA in May 2013 ruled that Monju be shut down indefinitely. The NRA had found that JAEA employees failed to conduct safety inspections on over 10,000 devices at Monju, including those deemed essential to safety.[107] Crush zones beneath Monju are also being investigated for active fault lines, which, if confirmed, could shut down the reactor permanently.[108] The egregiousness of previous safety violations, as well as the aforementioned crush zone investigation, makes a restart of Monju extremely unlikely in the short- to medium-term. Government decisions regarding reprocessing and the long-term utilization of the nuclear fuel cycle will likely determine future operations at Monju (more on the fuel cycle policy decisions below).

In the meantime, the government has announced that (with the cooperation of various utilities) send a team of experts to the reactor in the hopes of upgrading equipment and alleviating safety concerns.[109] Monju has a gross generating capacity of 280 MW.

In the 4th Strategic Energy Plan, the Japanese government will repositioned Monju as a research center for technological development regarding waste reduction.

HIGH TEMPERATURE TEST REACTOR (HTTR)

The Nuclear Science and Engineering Commission created a working group for developing an HTTR (High Temperature engineering Test Reactor). The HTTR was included in The 4th Strategic energy plan of Japan. The HTTR was not originally included in the government energy plan, but the LDP voiced a strong desire to include HTTR in energy plan when the plan was summarized.[110] Shimomura Minister of Education, Culture, Sports, Science and Technology mentioned that Japan will promote to research HTTR on July 7, 2014.[111]

ADVANCED THERMAL REACTORS (ATRS)

Fugen Reactor
The Fugen Advanced Thermal Reactor (ATR) was the first reactor in the world to utilize a full MOX core. Fugen began operations in 1978, with a generating capacity of 148 MW. The reactor ran until 2003, when it was permanently shut down and put on a path for decommissioning.[112]

Ohma Reactor
Electric Power Development Co. (J-POWER) originally intended to build a larger ATR to replace the Fugen reactor. Specific designs have changed repeatedly. Presently, J-POWER intends to build a modified ABWR capable of running fully on MOX fuel, with a generating capacity of 1383 MW. Construction on Ohma began in 2009, but was postponed after the Fukushima incident and did not resume until October 2012.[113] J-POWER originally proposed a November 2014 start-up date, though operators have since abandoned that date. J-POWER has yet to determine a new commencement date.[114]

Many view Ohma's eventual operation as essential to the success of Japan's pluthermal program, given the high amount of MOX fuel Ohma can consume compared to other light-water reactors. This assessment will only intensify if Monju does not resume operations.

CURRENT STATUS OF PLUTONIUM IN JAPAN

As of 2013, the Japanese Atomic Energy Commission (JAEC) reported that Japan owned roughly 46 tons of plutonium, though only 10 tons of that amount is currently being stored in Japan. The United Kingdom and France oversee the remaining tons.[115]

The JAEC submits an annual report on the current status of Japanese plutonium stockpiles. The most recent report was released in September 2014, covering 2013. Results of that report in Appendix E.[116]

Utilities are also required under law to release annual reports detailing how they intend to use their plutonium stores. These reports have generally included an inventory of plutonium resources as well as a plan for when that plutonium will be reprocessed. No reports have been released since 2010, however, and the FEPC claims that subsequent reports cannot be released until utilities have a clearer idea what the status of their own reactors will be, along with what the status of Japan's overall reprocessing program will be.[117]

At the Nuclear Security Summit on March in 2014, Japan agreed to return Uranium and Plutonium to the US. According to the Japan Times, Japan returned to the U.S. more than 700 pounds (315 kg) of Plutonium and Uranium.[118]

The Japanese government underreported 640kg of unused plutonium in its annual report for the IAEA in 2012 and 2013.

HIGH-LEVEL WASTE (HLW) DISPOSAL

High-level waste that has been produced from reprocessing Japanese spent fuel abroad has been sent back to Japan for storage and disposal. From 1995 to 2007, France returned 12 shipments of HLW to Japan, comprised of over 1,300 canisters containing a sum total of roughly 700 tons of vitrified HLW. Shipments from the U.K. are expected to total 900 canisters and take 8-10 years to complete.[119]

HLW returned to Japan from France

Year	1995	1997	1998	1999	2000	2001	2003	2004	2005	2006	2007	Total
HLW canisters shipped	28	40	60	144*	192	152	144	132	124	164	130	1,310

*Two shipments were sent in 1999 (comprising 40, then 104 canisters)

HLW returned to Japan from the U.K.

Year	2010	2011	2012	2013	Total	Total (France and U.K.)
HLW canisters shipped	28	76	0	28	132	1,442

Japan has stored these HLW shipments at the Rokkasho High-Level Radioactive Waste Storage Facility. That facility has a storage capacity of 2,880 canisters.[120]

LOW-LEVEL WASTE (LLW) DISPOSAL

Japan has been working towards final disposal of LLW since 1992. LLW is stored on an interim basis at power plant facilities before being sent to a JNFL facility in Rokkasho. The Rokkasho LLW disposal site has two main facilities, each with a capacity of 200,000 200-liter drums. The first facility has been completed while the second disposal facility is on track to be finished by the end of 2013. As of December 2013, JNFL reports that the disposal center has placed 260,619 drums of waste underground .[121]

2012 JAEC REPORT ON FUTURE NUCLEAR FUEL CYCLE OPTIONS

In 2012, under the DPJ government, the Japan Atomic Energy Commission presented recommendations for Japanese nuclear fuel cycle policy for three different nuclear energy scenarios (phase-out by 2030, 15% of overall electricity usage by 2030, and 25% electricity usage by 2030). If the government were to follow JAEC's recommendations, some amount of reprocessing would be necessary for anything other than a full phase-out of nuclear energy. Monju's status (and the status of future FBR programs) is more uncertain, with the JAEC deeming Monju necessary only under a "full reprocessing" scenario, a scenario the commission only recommends in the event of a modest resumption of nuclear power (around 25%). Full recommendations of the report summarized in more detail on the following page:[122]

Nuclear Power Choice	Fuel Cycle Recommendation	Policy Recommendation	Recommendations for Fast Reactor Program
Zero nuclear power by 2030	"Full direct disposal"	- Decommission Rokkasho Reprocessing Plant - Long-term storage of spent fuel - Immediately work towards direct disposal	- Suspend Monju operations - Promote only basis research and development
Reduce nuclear power to roughly 15% by 2030	"Coexistence of reprocessing and direct disposal"	- Proceed with Rokkasho reprocessing plans - Spent fuel exceeding reprocessing should be stored	- Conduct studies to determine feasibility of further expansion - Conduct performance and feasibility tests for Monju
Lower than before but aim for 25% in 2030	"Coexistence of reprocessing and direct disposal" (allowing flexibility w/r/t increasing reprocessing)	- Proceed with Rokkasho reprocessing plans - Spent fuel exceeding reprocessing should be stored	- Conduct studies to determine feasibility of further expansion - Conduct performance and feasibility tests for Monju
	"Full reprocessing"	- Proceed with Rokkasho reprocessing plans - Spent fuel exceeding reprocessing should be stored on an interim basis until more reprocessing plants can be constructed	- Achieve intended goals for Monju within a decade - Continue research for further commercialization, including demonstration phase

2012 INNOVATIVE STRATEGY FOR ENERGY AND THE ENVIRONMENT

In September 2012, the Japanese DPJ cabinet released its "Innovative Strategy for Energy and the Environment," a plan crafted by the Energy and Environment Council that was meant to incorporate the

aforementioned recommendations of the JAEC. The proposal reaffirmed a nuclear phase-out, to be achieved sometime in the 2030s, arguing for gradual temporary restarts only if needed to address energy crises.

Despite the decision to completely phase out nuclear energy, the strategy suggested the continuation of reprocessing operations at Rokkasho, citing earlier commitments with the local community. The government stated that they would uphold an earlier commitment to the residents of the Aomori Prefecture to not to make the locality a site for final disposal of nuclear material.[123] Considering that the Mutsu dry storage facility and Rokkasho reprocessing facility are both located in Aomori, and both hold (and will continue to hold) large amounts of spent fuel and HLW, it is unclear how the government would uphold these commitments while continuing reprocessing if nuclear power was eventually phase out.

JAPAN'S NUCLEAR EXPORTS

JAPANESE NUCLEAR COOPERATION AGREEMENTS[124,125]

Japan currently has 12 nuclear cooperation agreements in force, with two others recently signed. One of the 12 agreements is between Japan and Euratom, opening the door to cooperation with most European countries. Note that for many of these countries (notably the United States, United Kingdom, and Australia) prior nuclear cooperation agreements existed that preceded the most recent one listed below. Agreements with Canada and France have been revised somewhat since entering into force, but have not been replaced by new agreements.

Country/Organization	Year Signed (Entry into Force)	Termination
United States	1987 (1988)	Indefinite duration
United Kingdom	1998 (1998)	Indefinite duration
Canada	1959 (1960)	Indefinite duration
Australia	1982 (1982)	Indefinite duration
France	1972 (1972)	September 21, 2017
China	1985 (1986)	Indefinite duration
Euratom	2006 (2006)	Indefinite duration
Russia	2009 (2012)	Unspecified
Kazakhstan	2010 (2011)	Unspecified
Jordan	2010 (2012)	Unspecified
Republic of Korea	2010 (2012)	Unspecified
Vietnam	2011 (2012)	Unspecified
United Arab Emirates	2013	-/-
Turkey	2013	-/-

Older agreements that were signed/negotiated but never followed up (e.g. a vague agreement with Belarus signed in 1994) are omitted from the above table.

RECENT DEVELOPMENTS

Nuclear Cooperation between Japan and Turkey

France's Areva and Japan's Mitsubishi Heavy Industries Ltd. are undertaking a joint venture to supply the reactors for Turkey's Sinop nuclear power plant. The consortium will build four Atmea1 pressurized water reactors, operated by Itochu and Gdf Suez.[126] Mitsubishi and Areva expect to begin construction in 2017, and are hopeful that the first reactor will start operations by 2023. [127]

Nuclear Cooperation between Japan and the United Arab Emirates
After representatives from Japan and the United Arab Emirates signed the necessary agreements in May 2013 to facilitate nuclear cooperation, officials announced that Japan would likely contribute (in some way) to the construction of Barakah 1 & 2 which is currently being led by South Korea's Korean Electric Power Co. (KEPCO). [128] Others have speculated that Japan is likely in the running to build the third and fourth units at Barakah. [129]

Nuclear Cooperation between Japan and France
In addition to aforementioned cooperation between Areva and Mitsubishi to develop nuclear energy in Turkey, the two companies have undertaken various other cooperative initiatives. The two had been working together to develop a new reactor, with the Generation III Atmea1 reactor being the result. This reactor will first be used at the aforementioned Sinop plant.[130]

In June 2013, JFNL and Areva issued a joint statement declaring their intentions to cooperation on issues relating to Japanese nuclear fuel cycle efforts.[131] Stated goals included:

- Ensuring commercial operation of the Rokkasho Reprocessing Plant
- Construction and commissioning of JFNL's MOX fuel fabrication plant (JMOX)
- Cooperation regarding safety standards

Potential Nuclear Cooperation between Japan and India
Shinzo Abe and Indian Prime Minister Manmohan Singh released a very broad statement in May 2013, stating their intentions to cooperate on civilian nuclear energy issues. Talks officially restarted in September 2013 for the first time since the disaster at Fukushima and the two sides are reportedly close to an agreement.[132] Much controversy has surrounded these negotiations, with some critics arguing that Japanese-Indian cooperation over nuclear energy would result in a "hollowing out" of the nonproliferation regime.[133]

Potential Nuclear Cooperation between Brazil and Japan
Many expected Brazil and Japan to advance talks on nuclear cooperation in June 2013.[134] However, Brazilian representatives postponed discussions due to unrelated protests in Brazil.[135]

Potential Nuclear Cooperation with Other Countries
In June 2013, Prime Minister Abe had several highly-publicized meetings with the leaders of the Visegrad Group, a European coalition consisting of the Czech Republic, Hungary, Poland and Slovakia. Poland in particular expressed interest in nuclear energy cooperation.[136]

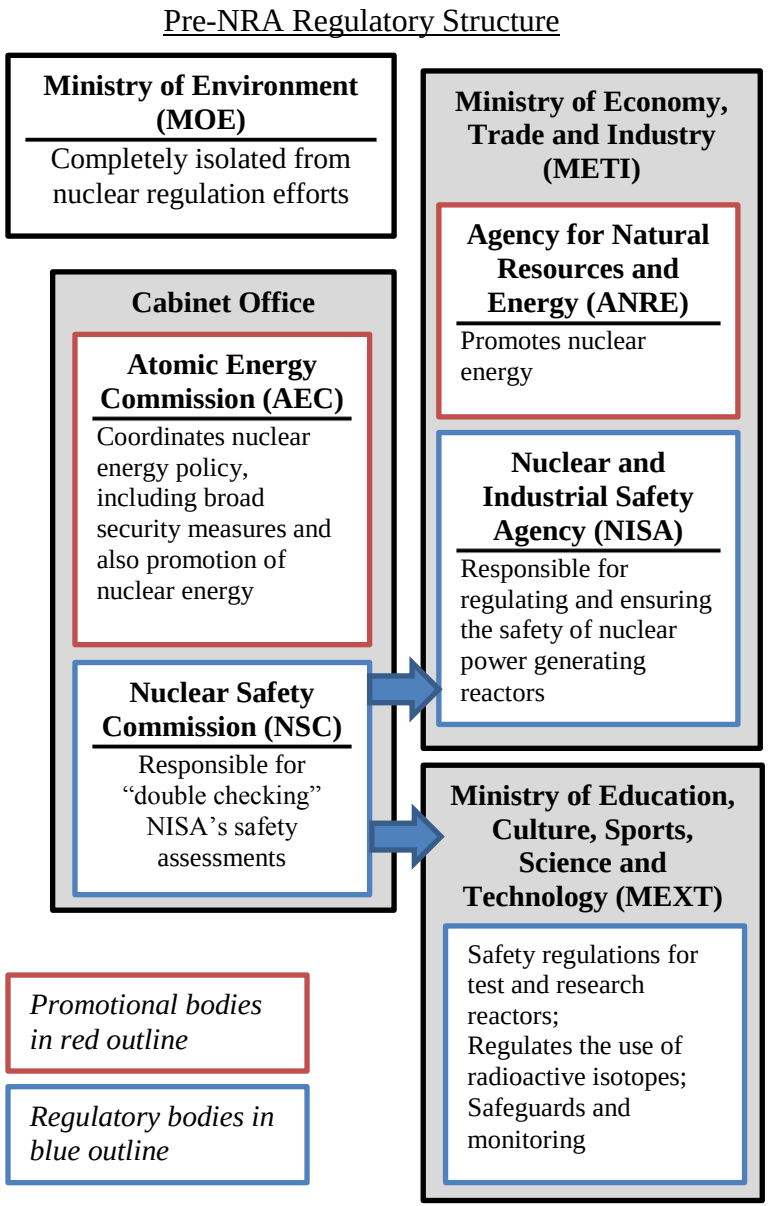
Nuclear Exports under the Abe Administration
Prime Minister Abe has pushed heavily to expand nuclear cooperation and exports as part of his economic agenda, hopeful that the weakened yen will help boost exports. Substantial controversy has arisen over Abe's push to export Japanese technology in the aftermath of the Fukushima incident. Polls from the Japan Times have reported that the majority of the Japanese public opposes ramping up exports.[137]

Hitachi and Lithuania signed an MOU to establish a project company that will manage the construction of the Visaginas nuclear power plant on July 30th. Capacity is about 1400MW and total cost of construction is about 400 - 500 billion yen. The aim of operation is 2020.[138]

Westinghouse has announced that it has contracted with a Bulgarian utility for building the Kozloduy NPP, with a 30% stake. Aimed operation is by 2023. However, Since the PM resigned in July 2014, and another election will take place in October, Westinghouse will have to gain acceptance from the new cabinet for construction of NPP.[139]

APPENDIX A: CHANGES TO JAPAN'S NUCLEAR REGULATORY STRUCTURE

Descriptions of regulatory bodies is meant to describe their stated mission, and does not reflect how effective said bodies were at these goals



Changes

- Consolidation of nuclear regulatory duties into one agency (via the abolishment of NISA and the NSC)
- Separation of those agencies responsible for promotion (METI, AEC) from those responsible for regulation (then NISA, NSC; now NRA)

This diagram a adapted from similar ones found in the following documents - sources:

Nuclear Regulation Authority website, "Organization of the Nuclear Regulation Authority" http://www.nsr.go.jp/english/e_nra/outline/

Report presented to the IAEA by Tomoho Yamada, Secretariat of the NRA, on the June 29, 2013 Technical Meeting on Technology Assessment of Embarking Countries, "Regulatory Changes for Nuclear Power Plants in Japan." http://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-06-24-06-28-TM-NPTD/21-nra-regulatorychanges.pdf

Fukasawa, Jun, and Momoko Okusaki. "Reform of the Nuclear Safety Regulatory Bodies in Japan." International Nuclear Law Association, 2012 Congress. http://www.burges-salmon.com/INLA_2012/10147.pdf

Nuclear Regulation Authority's "Nuclear Regulation for People and the Environment" pamphlet. http://www.nsr.go.jp/english/e_nra/leaflet/data/nsr_leaflet_English.pdf

APPENDIX B: NRA REGULATIONS (IN DETAIL)

Top-Level Changes (broad objectives the NRA has laid out to holistically base safety assessments on)	
"Defense-in-Depth" Concept	- Prepare multiple layers of protection, isolating assessment of layer in question from assessments of other layers - Assume breach of preceding layer when evaluating efficacy

New "Beyond Design Basis Accidents (DBA)" Requirements	
Suppression of release of Radioactive Materials	- E.g. outdoor water spraying
Measures against Terrorism such as Intentional Aircraft Crash	- Creation of a "Specialized Safety Facility" to reduce release of radioactive materials ("emergency room")
Prevention of Containment Failure	- Cooling and depressurization of CV (containment vessel), measures to reduce release of radioactive materials (e.g. CV spray) - Heat removal from CV and depressurization (via filtered venting) - Cooling of molten core at the base of CV, inside RPV (reactor pressure vessel) (via water injection) - Prevention of direct containment heating (via depressurization of RPV) - Prevention of hydrogen explosion inside CV
Prevention of Core Damage (Multiple Failures)	Assuming situations more severe than DBAs – these accidents include: - ATWS (anticipated transient without scram) - Loss of reactor cooling function (at high pressure) - Loss of reactor depressurization function - Loss of reactor cooling function (at low pressure) - Loss of UHS (ultimate heat sink) system – via alternative UHS systems: o PWRs: through main steam relief valves to the exterior; sea water injection to RHR-S (residual heat removal system) o BWRs: filtered venting system; mobile RHR - Loss of support function (makeup water, power supply) o Re: Blackout – e.g. batteries (8 hours without load shedding; 16 additional hours with load shedding); alterantvie onsite AC power for 7 days; external support by the 6th day - Others identified by IPE (individual plant examinations) and IPEEE (individual plant examinations of external events)

Other Changes (expansions to existing regulations/requirements)	
Natural Phenomenon	- Consideration of other natural hazards such as volcanoes, tornados and forest fires in addition to tsunamis, earthquakes, etc.
Fire	- Reinforce fire protection measures
Reliability (General)	- Increased redundancy of passive components (such as piping) that have been relied on for long periods of time
Reliability of Power Supply	- Connect to different substations by multiple transmission lines
Ultimate Heat Sink	- Physical protection (e.g. walls) for seawater pumps, etc.
Seismic/Tsunami Resistance	- Stricter standards – explicitly define "Design Basis Tsunami" as one that exceeds the previous largest known tsunami - Elevate rankings for some SSCs for tsunami protection to that of RPV (Class S, having important safety functions) - Ex. of tsunami protective measures – breakwater wall around entire site; tsunami gate at building - More stringent criteria for active faults (definite 120,000-130,000 years ago; 400,000 years ago if necessary)

APPENDIX C: JAPANESE NUCLEAR REACTORS [140]

Information current as of July 31st, 2014

Plant	Capacity, net	Type	Utility	Status (all currently idle unless otherwise noted)
Fukushima I – 5	760 MW	BWR	TEPCO	No stated plans; Prime Minister Shinzo Abe has admitted that restarts are unlikely given local opposition, regardless of conformity to new NRA safety standards Fukushima I-1, 2, 3, 4 are permanent shutdown which resulted on April 19, 2012. Fukushima I-5 and 6 are permanent shutdown which resulted on January 31, 2014.
Fukushima I – 6	1067 MW	BWR		
Fukushima II – 1	1067 MW	BWR		
Fukushima II – 2	1067 MW	BWR		
Fukushima II – 3	1067 MW	BWR		
Fukushima II – 4	1067 MW	BWR		
Genkai 1	529 MW	PWR	Kyushu	No stated plans (contingent on Genkai 3 & 4 applications)
Genkai 2	529 MW	PWR		
Genkai 3	1127 MW	PWR		Application for safety assessment submitted to the NRA on July 12, 2013
Genkai 4	1127 MW	PWR		
Hamaoka 3	1056 MW	BWR	Chubu	Accident countermeasures expected to be complete by the end of 2014, with application for safety assessment to follow
Hamaoka 4	1092 MW	BWR		Application of safety assessment submitted to the NRA on February 14, 2014
Hamaoka 5	1325 MW	ABWR		Accident countermeasures expected to be complete by the end of 2014, with application for safety assessment to follow
Higashidori 1	1067 MW	BWR	Tohoku	Application of safety assessment submitted to the NRA on June 10, 2014
Ikata 1	538 MW	PWR	Shikoku	No stated plans (contingent on Ikata 3 application)
Ikata 2	538 MW	PWR		
Ikata 3	846 MW	PWR		Application for safety assessment submitted to the NRA on July 8, 2013
Kashiwazaki-Kariwa 1	1067 MW	BWR	TEPCO	No stated plans
Kashiwazaki-Kariwa 2	1067 MW	BWR		
Kashiwazaki-Kariwa 3	1067 MW	BWR		
Kashiwazaki-Kariwa 4	1067 MW	BWR		
Kashiwazaki-Kariwa 5	1067 MW	BWR		
Kashiwazaki-Kariwa 6	1315 MW	ABWR		Application for safety assessment submitted to the NRA on September 27, 2013

Kashiwazaki-Kariwa 7	1315 MW	ABWR		
Mihama 1	320 MW	PWR	Kansai	No stated plans; the NRA has been investigating the facility for active fault lines
Mihama 2	470 MW	PWR		
Mihama 3	780 MW	PWR		

(Chart continues on next page)

(Chart continued from previous page)

Plant	Capacity	Type	Utility	Status (all currently idle unless otherwise noted)
Ohi 1	1120 MW	PWR	Kansai	No stated plans (contingent on Ohi 3 & 4 applications)
Ohi 2	1120MW	PWR		
Ohi 3	1127 MW	PWR		**S**hut down for safety checks; application for safety assessment submitted to the NRA on July 8, 2013
Ohi 4	1127 MW	PWR		
Onagawa 1	498 MW	BWR	Tohoku	No stated plans
Onagawa 2	796 MW	BWR		Application for safety assessment submitted to the NRA on December 27, 2013
Onagawa 3	796 MW	BWR		No stated plans
Sendai 1	846 MW	PWR	Kyushu	Application for safety assessment submitted to the NRA on July 8, 2013
Sendai 2	846 MW	PWR		
Shika 1	505 MW	BWR	Hokuriku	Application for safety assessment submitted to the NRA on August 12, 2014
Shika 2	1304 MW	ABWR		
Shimane 1	439 MW	BWR	Chugoku	No stated plans
Shimane 2	789 MW	BWR		Application for safety assessment submitted to the NRA on December 25, 2013
Takahama 1	780 MW	PWR	Kansai	No stated plans (contingent on Takahama 3 & 4 applications)
Takahama 2	780 MW	PWR		
Takahama 3	830 MW	PWR		Application for safety assessment submitted to the NRA on July 8, 2013
Takahama 4	830 MW	PWR		
Tokai 2	1056 MW	BWR	JAPC	Application for safety assessment submitted to the NRA on May 20, 2014
Tomari 1	550 MW	PWR	Hokkaido	Application for safety assessment submitted to the NRA on July 8, 2013; the NRA then suspended the screening process pending numerous revisions and amendments they deemed necessary to the reactors' applications
Tomari 2	550 MW	PWR		

Tomari 3	866 MW	PWR		Application for safety assessment submitted to the NRA on July 8, 2013
Tsuruga 1	341 MW	BWR	JAPC	NRA originally reported the existence of active fault lines beneath the facility; JPAC quickly released reports disputing this; resolution pending; JPAC likely to apply for safety screenings to force issue with NRA
Tsuruga 2	1115 MW	PWR		

Total Capacity: 44,415 MW[141] (including Fukushima I-5 and I-6)[142]

- PWRs: 19,291 MW
- BWRs/ABWRs: 25,124MW (including Fukushima I-5 and I-6)[143]

Reactor Totals: 50 reactors (including Fukushima I-5 and I-6)[144] across 17 plants (24 PWRs, 22 BWRs, 4 ABWRs)
Long-Term Shutdown: 1
Permanent Shutdown: 11

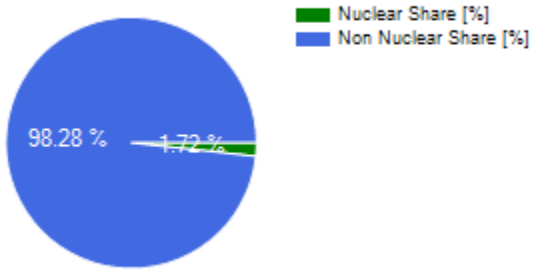
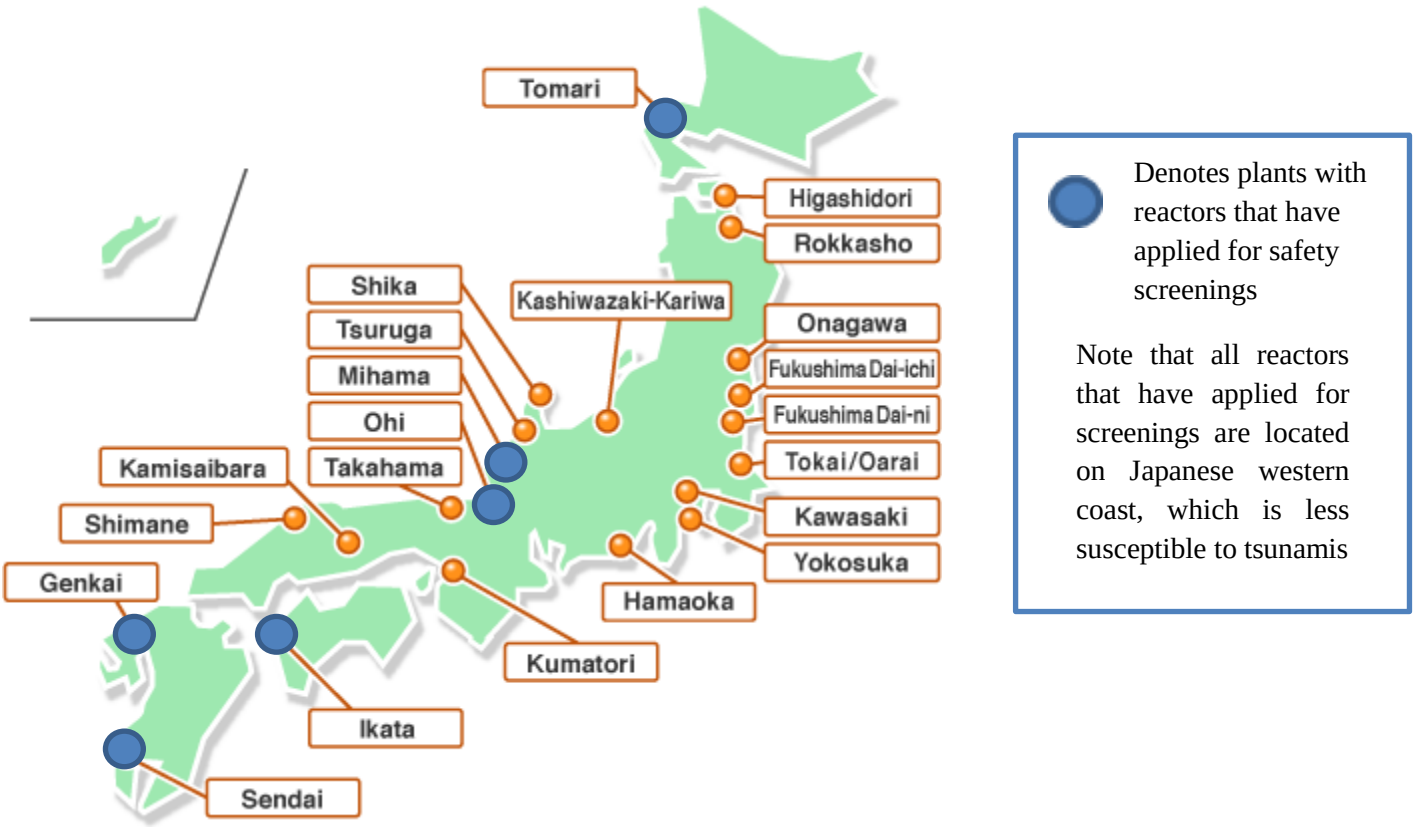


Figure 3: Electricity Production Share in 2013
Source: IAEA/PRIS http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=JP



Source: Japan's Nuclear Regulation Authority, 2013

Japanese Nuclear Power Reactors Currently Under Construction[145]

Plant	Capacity, gross	Type	Utility	Status
Under Construction				
Monju	280 MW	FNR	JAEA	Indefinitely shut down (see "Monju Reactor" subsection)
Shimane 3	1373 MW	ABWR	Chugoku	Resumption of construction approved September 2012[146] - Chugoku has begun installing safety upgrades
Ohma 1	1383 MW	ABWR (MOX)	J-Power	Construction resumed October 2012 Operation date not yet announced

Planned Japanese Nuclear Power Reactors [147]

Plant	Capacity, gross	Type	Utility	Status
Planned				
Tsuruga 3	1538 MW	APWR	JAPC	Several utilities had applied for licenses to continue planning/pre-construction operations on these reactors; under the previous DPJ government, these applications had been summarily rejected
Tsuruga 4	1538 MW	APWR	JAPC	
Higashidori 1	1385 MW	ABWR	TEPCO	
Kaminoseki 1	1373 MW	ABWR	Chugoku	
Sendai 3	1590 MW	APWR	Kyushu	
Higashidori 2	1385 MW	ABWR	TEPCO	
Hamaoka 6	1380 MW	ABWR	Chubu	
Higashidori 2	1385 MW	ABWR	Tohoku	
Kaminoseki 2	1373 MW	ABWR	Chugoku	

APPENDIX D: JAPAN'S NUCLEAR FUEL CYCLE

Type	Operator	Location	Capacity, Other Details	Current Status
Mining, milling and conversion services imported from abroad				
Enrichment	Japan Nuclear Fuels Ltd. (JFNL)	Rokkasho, Aomori	1,087.5 MTSWU/year (current) 1,500 MTSWU/year (planned)	Resumed limited commercial operation in March 2012; temporarily shut down awaiting NRA regulations (out Dec. 2013)
Fuel Fabrication	Global Nuclear Fuel-Japan Co. (GNF-J)	Kurihama, Yokosuka	750 tHM/year BWR	Temporarily shut down awaiting NRA regulations (out Dec. 2013)
	Mitsubishi Nuclear Fuel Ltd. (MNF)	Tokai, Ibaraki	440 tHM/year PWR	
	Nuclear Fuel Industry Ltd. (NFI)	Kumatori, Osaka	284 tHM/year PWR	
		Tokai, Ibaraki	250 tHM/year BWR (previously ATR as well)	
*MOX Fuel Fabrication**	Japan Nuclear Fuels Ltd. (JFNL)	Rokkasho, Aomori	130 tHM/year MOX	Resumed construction mid-2012 after being shut down in the wake of Fukushima 2016 start-up date very unlikely
Reactors	(See Appendix C)	(See Appendix C)	44,414 MWe total capacity (See Appendix C for breakdown)	(See Appendix C)
Reprocessing	Japan Atomic Energy Agency (JAEA)	Tokai, Ibaraki	90 t HM/year	Commercial shutdown in 2006; operations have shifted to R&D for Rokkasho
	Japan Nuclear Fuels Ltd. (JNFL)	Rokkasho, Aomori	800 t HM/year (8 t Pu/year) Storage capacity of roughly 3,000 t HM	Final tests completed; filed for regulatory screening Jan. 2014 with commercial operation slated to begin around Oct. 2014
Disposal	Recyclable-Fuel Storage Co. (established by TEPCO and Japan Atomic Power Co.)	Mutsu, Aomori	Interim dry storage prior to reprocessing 3,000 t HM (first phase) 5,000 t HM (planned total)	Facility completed Oct. 2013; startup delayed due to Dec. 2013 NRA regulations
	Japan Nuclear Fuels Ltd. (JNFL)	Rokkasho, Aomori	HLW storage and disposal 2,880 canisters (total)	Has stored HLW from France, U.K.
	Japan Nuclear Fuels Ltd. (JFNL)	Rokkasho, Aomori	LLW storage; 2 facilities, total 400,000 200-liter drum capacity	Facility no. 1: 147,000/200,000 Facility no. 2: 104,000/200,000

*Excludes JAEA's Tokai PFPF (see earlier in report) given its mostly experimental/historical usage

APPENDIX E: CURRENT STATUS OF PLUTONIUM IN JAPAN

Japan Atomic Energy Commission Plutonium Management Report for 2013 (released Sep. 2014):

Plutonium (in kg) currently in reprocessing facilities			
	Tokai Reprocessing Plant (JAEA)	Rokkasho Reprocessing Plant (JFNL)	Total
Plutonium nitrate	664	283	947
Plutonium oxide	84	3,329	3,412
Total (fissile)	748 (741)	3,611 (3612)	4359 (4363)

Plutonium (in kg) currently in fuel fabrication plants		
	Tokai Plutonium Fabrication Plant (JAEA)	
Plutonium oxide	1,937	
Test/fabrication	981	
New fuel	446	
Total (fissile)		3,364 (3364)

Plutonium (in kg) currently in other facilities				
	Joyo	Monju	Commercial Reactors	R&D Facilities
Un-irradiated new fuel	134	31	2501	444

Total domestic plutonium (fissile)	**10833 (7309)**

Plutonium (in kg) abroad			
	Recovered in France	Recovered in the United Kingdom	Total (fissile)
Separated plutonium	20,002 (13,526)	16,310 (10,604)	**36,312 (24,130)**

Breakdown of separated plutonium (in kg) use	
Loaded into nuclear reactors	0

Breakdown of plutonium (in kg) stored and loaded in nuclear reactors and other facilities			
Facility	Stored Pu (fissile)	Loaded Pu (fissile)	Pu in core (fissile)*
Joyo (JAEA)	134 (98)	-	261 (184)
Monju (JAEA)	31 (21)	-	1,533 (1,069)
Fukushima Daichii Unit 3 (TEPCO)	-	-	210 (143)
Kashiwazaki-Kariwa Unit 3 (TEPCO)	205 (138)	-	-
Hamaoka Unit 4 (Chubu)	213 (145)	-	-
Takahama Unit 3 (Kansai)	901 (585)	-	368 (221)
Takahama Unit 4 (Kansai)	184 (110)	-	-
Ikata Unit 3 (Shikoku)	198 (136)	-	633 (436)
Genkai Unit 3 (Kyushu)	801 (516)	-	677 (468)
Fact Critical Assembly, Tokai R&D Center (JAEA)	331 (293)	N/A	N/A
Deuterium Critical Assembly, Oarai R&D Center (JAEA)	87 (72)	N/A	N/A
Static Experiment Critical Facility and Transient Experiment Critical Facility, Tokai R&D Center (JAEA)	15 (11)	N/A	N/A
Other R&D Facilities	11 (9)	N/A	N/A

***** "Pu in core" is un-irradiated plutonium in the core equivalent to the difference between the total loaded plutonium (un-irradiated) and the total unloaded plutonium (irradiated) for 2012. Available in Japanese at www.aec.go.jp/jicst/NC/jinkai/teirei/siryo2014/siryo31/siryo3.pdf

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