# Study on Japan's Nuclear Materials

**China Arms Control and Disarmament Association**
**China Institute of Nuclear Information and Economics**

**September 2015**

# Foreword

The nuclear accident in March 2011 in Fukushima, Japan brought a disaster to the safety of local residents and to the environment of surrounding regions. However, the Japanese government failed to inform the international community of the accident in a timely, accurate, and comprehensive manner. The accident's consequential impacts still linger on today, and the international community is still highly concerned about the safety of Japan’s nuclear facilities.

In early 2014, media reports held that around 331 kilograms of weapon-grade plutonium had been stored by Japan for years. And in fact, Japan has stored a lot of sensitive nuclear materials for a long time, which far exceeds its actual need. The imbalance between supply and demand of nuclear materials in Japan has given rise to the concern of and questions raised by the international community.

Why does Japan store nuclear materials in such a large amount? How to ensure their safety? How to effectively prevent disasters similar to the Fukushima nuclear accident from happening again? How to ensure that these materials will be used exclusively for peaceful purposes? What measures should be taken to solve this serious imbalance of supply and demand of nuclear materials in Japan? These are questions that are often raised. Regretably, the Japanese government has yet to answer these questions.

In September 2015, the Japanese Diet ratified the new bills. In recent years, right-wings forces in Japan have kept denying the history of aggression of Japan and advocated the revision of Japan's "Peace Constitution", Which have aroused vigilance among all peace-loving people. The questions raised by the international community on the storage of weapon-grade nuclear materials and the imbalance of supply and demand of nuclear materials in Japan also reflect this kind of worries. Many experts and scholars have advised and encouraged us on different occasions to make a report on the issue of nuclear materials in Japan, so as to reveal the truth in a comprehensive and detailed way to the Chinese public and the international community, to sent a clear signal of Chinese scholars' concern about Japan's nuclear materials, nuclear safety and security, and the nuclear proliferation risks, and to express the strong aspiration of Chinese scholars for maintaining peace and opposing nuclearisation of Japan.

In view of the above, we drew up Study on Japan's Nuclear Materials. In addition to introducing the basic information on Japan's nuclear materials, the Report analysed the problems and risks in relation to Japan's large inventory of sensitive nuclear materials and also provided our views and suggestions on the solution of relevent issues. It is our hope that this Report can help governmental agencies, researh institutes and the general public to understand the situation and can constitute our modest contribution to the final settlement of relevant problems.

In future, we will continue to follow the issue of Japan's nuclear materials, update this Report when necessary and try to release it annually. All data and information in this Report are collected from publicly available resources. The Report despite our effort, cannot be free from error. So comments and suggestions by the readers are most welcome.

Finally, we'd like to express our appreciation for the support from the experts and scholars both at home and abroad, and to the foreign colleagues whose publicshed papers were taken as our reference.

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# Contents

# Summary

Japan has 47.8 tons of high sensitive separated plutonium., 10.8 tons of which are stored in Japan, enough to make 1350 nuclear warheads. In addition, Japan also has about 1.2 tons of highly-enriched uranium (HEU) for research reactors.

In the early 1990s, Japan declared a policy of “no excess plutonium”, aiming at maintaining a balance between supply and demand of plutonium. In over twenty years, however, the amount of separated plutonium in Japan was doubled rather than reduced. Once the Rokkasho reprocessing plant under construction starts its operation, Japan could obtain the ability of producing 8 tons of separated plutonium annually.

The large amount of nuclear materials stored by Japan and its imbalance between supply and demand constitute serious risks of nuclear proliferation, nuclear safety and nuclear terrorism. not a few international experts believe, based on Japan’s nuclear capability, once a political decision is made, Japan can produce nuclear weapons in a very short time. Taking into account the poor natural conditions, the frequent earthquakes and the ineffecient management of nuclear facilities in Japan, the more Japan stores sensitive nuclear materials, the higher the risk of safety accidents will be. This may bring serious impacts on itself and the surrounding countries. If Japan’s nuclear materials were seized by terrorists, it would result in serious threats of nuclear terrorism.

As a Non-Nuclear Weapon State prescribed by the Treaty on the Non-Proliferation of Nuclear Weapons, Japan is entitled to peaceful uses of nuclear energy. Meanwhile, Japan should take a responsible attitude toward the above-mentioned risks and the concerns of the international community, and take measures to properly solve the problem of the current nuclear materials inventory, such as reducing the growth of nuclear materials, and realizing the balance between supply and demand. Japan should also enhance the transparency of nuclear materials management, strengthen the safety and security of its nuclear facilities and voluntarily put them under stricter safeguards by the IAEA.

# 1. Japan's Plutonium Materials

According to IAEA <Guidelines for the Management of Plutonium> (INFCIRC/549) issued on 2014, the number of separated plutonium owned by Japan ranks fifth in the world (see the figure 1). The Japanese government released the latest data of its Plutonium in July 2015, and enclosed this with the Note verbale to IAEA in August. As of December 31, 2014, Japan owns 47.8 tons of unirradiated separated plutonium, with 10.8 tons stored domestically and 37 tons stored in France and UK. Moreover, Japan owns 161 tons of plutonium contained in spent fuel.[1]

In all, Japan has a total of 208.8 tons of plutonium, according to the definition by the IAEA as "Direct Use Material".[2] About 1350 nuclear warheads could be made from the 10.8 tons of separated plutonium stored domestically (8kg per warhead[3]).

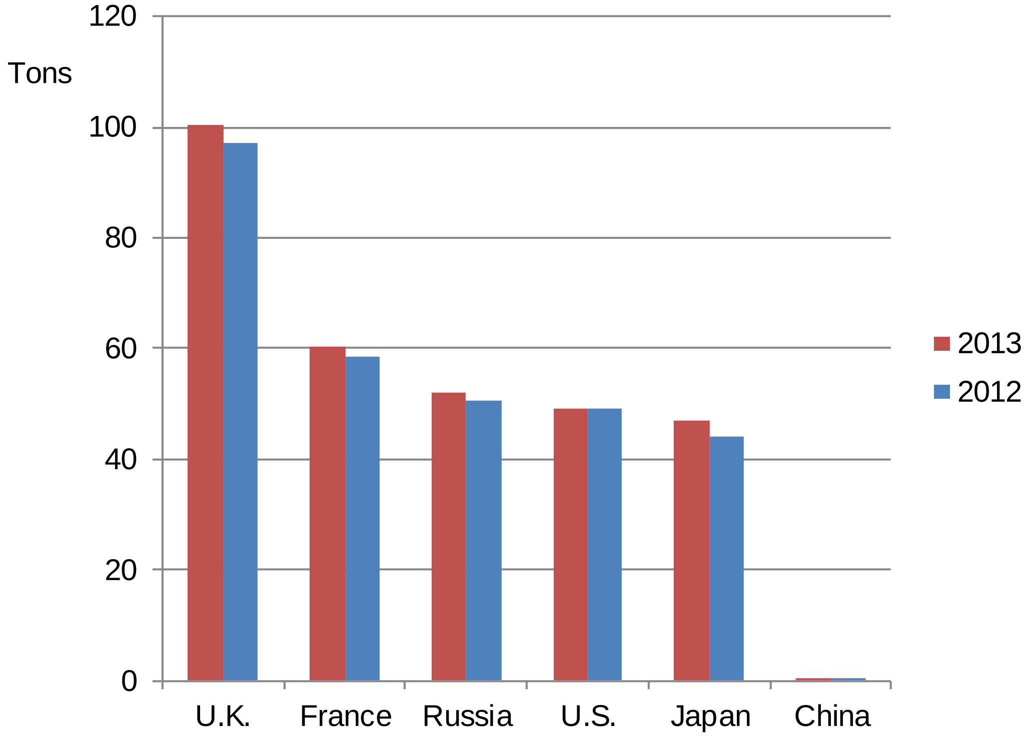


Figure 1: Separated plutonium declared to the IAEA by Japan and other countries[4, 5, 6, 7]

The Rokkasho reprocessing plant, affiliated to Japan Nuclear Fuel Ltd (JNFL), is scheduled to start operation in March 2016. After its full-scale operation in 2019[8], 8 tons of separated plutonium will be produced annually. In view of the large inventory of plutonium and such growth trend, the "no excess plutonium" policy declared by Japan is just empty talk.

## 1.1 Related Background

### 1.1.1 Definition of Plutonium

The chemical symbol of plutonium is Pu. Plutonium only exists with uranium mine, and its amount is less than $1/10^{11}$ of uranium in the same mine. It is very hard to obtain it by mining. Therefore, all plutonium is artificial. [9]

Plutonium contains 15 kinds of isotopes ( $^{232}Pu$ ~ $^{245}Pu$ ), among which $^{239}Pu$ and $^{238}Pu$ are the most important. $^{239}Pu$ is an important material for nuclear weapons, and can also be used as nuclear reactor fuel. $^{238}Pu$ is an important raw material for radioisotope battery.

Plutonium could be produced by reactor in large amount. A 1,000MWe thermal reactor could produce more than 200kg plutonium annually.[10] At present, a large amount of plutonium has been separated from spent fuel of production reactor or power reactor by some countries with nuclear industry. Along with the industrialization of fast reactor, the sources of plutonium will be more extensive.[11]

### 1.1.2 Definition of Direct Use Material

The term "Direct Use Material" [12] is defined by International Atomic Energy Agency as: nuclear material that can be used for the manufacture of nuclear explosive devices without transmutation or further enrichment. It includes plutonium in different purity[I], High Enriched Uranium(HEU) and $^{233}U$. Unirradiated plutonium (including plutonium contained in mixed oxide fuel, also named as MOX fuel) and plutonium in spent fuel fall into this category. Unirradiated plutonium is of greater risk, since it could be obtained through reprocessing and be easily used in nuclear explosive device.

### 1.1.3 Guidelines for the Management of Plutonium

IAEA formally published the <Guidelines for the Management of Plutonium> (INFCIRC/549) on March 16, 1998[13]. The Guidelines was aimed at ensuring the safe and effective management to plutonium and called for states to release information about plutonium inventory on a regular basis, including the submission of an annual report on the amount of unirradiated plutonium and the estimated amount of reactor spent fuels, and to balance the supply and demand of nuclear material. The Guideline apply to the management of all plutonium in all peaceful nuclear activities and to other plutonium after it has been designated by the Government concerned as no longer required for defence purposes.

In its note verbal dated December 1 1997 to the IAEA, the Japanese government declared its commitment to observing the Guidelines and ensuring that the plutonium and other nuclear materials possessed by Japan are safely and effectively managed. In

I Except the $^{238}Pu$ abundance over 80% of Plutonium materials the same note verbal, Japan proposed that similar guidelines should be established for the management of HEU. Since then, the Japanese government has made public an annual statement of its national holdings of civil unirradiated plutonium and of plutonium contained in spent civil reactor fuel every year[1].

### 1.1.4 Nuclear Security Summit

The Nuclear Security Summit is aimed at advocating nuclear security and preventing and combating nuclear terrorism. The first Summit was held in Washington, D.C., USA in April 2010. The second summit was held in Seoul, Republic of Korea, in March 2012.

The third summit was held in Hague, the Netherlands on 24th, March 2014. In the Communiqué of this summit, all Member States called upon each state to keep its separated plutonium stockpile at the lowest level according to its need.

## 1.2 Amount of Japan's Plutonium

From 1993 to 2014, Japan's separated plutonium had doubled. Figure 2 shows the growing trend of Japan's separated plutonium inventory during this period.

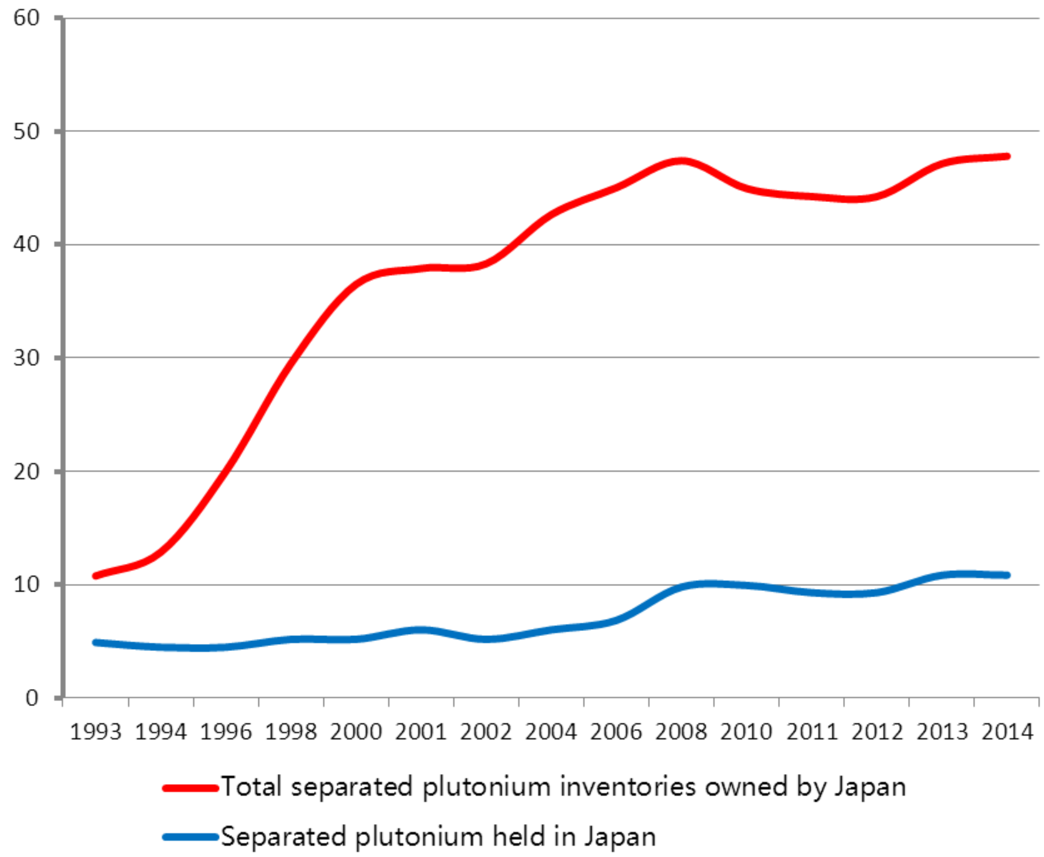


Figure 2: Japan's domestic separated plutonium inventory[1, 14]

According to the report sent to IAEA by The Japanese government in August 2015[1], as of December 31, 2014, Japan holds 47.8 tons of unirradiated separated plutonium (see Table 1), including 10.8 tons stored domestically and 37 tons stored overseas. Compared with 2013, the amount of plutonium has increased by 0.7 tons.

Table 1 Domestic plutonium as reported by Japan in 2015[1]

| Kinds of materials | The amount of plutonium(as of December 31, 2014, tons) | | | |
|---|---|---|---|---|
| Civil unirradiated separated plutonium | In product stores at reprocessing plants | In the course of manufacture or fabrication and plutonium contained in unirradiated semi-fabricated or unfinished products at fuel or other fabricating plant or elsewhere | Plutonium contained in unirradiated MOX fuel or other fabricated products at reactor sites or elsewhere | Unirradiated separated plutonium held elsewhere |
| | 4.3 | 3.0 | 3.1 | 0.4 |
| Estimated amount of plutonium contained in spent civil reactor fuel | In spent fuel at civil reactor sites | In spent fuel at reprocessing plants | In spent fuel held elsewhere | |
| | 134 | 27 | Less than 0.5 | |

According to the report released by Japan Atomic Energy Commission *the status of Plutonium Management in Japan* in July 2015[15], details of plutonium stored in each site as of December 31, 2014 is shown in figure 3.

As of December 31, 2014, the detailed inventory and usage of unirradiated separated plutonium are as follows:

## 1.2.1 Detailed Inventory of Separated Plutonium

Compared to 2013, the inventory of unirradiated separated plutonium possessed by Japan at the end of 2014 has increased by 0.662 tons. The increase was mainly contributed by the overseas reprocessing activities. By the end of 2014, the amount of separated plutonium stored in U.K. was 20.696 tons, with a 0.694 tons increase to 2013, and the amount in France was 16.278 tons, with a 32kg decrease to 2013. The number of separated plutonium stored in Japan has not charged.

The above descriptions are shown in Table 2, 3, 4.

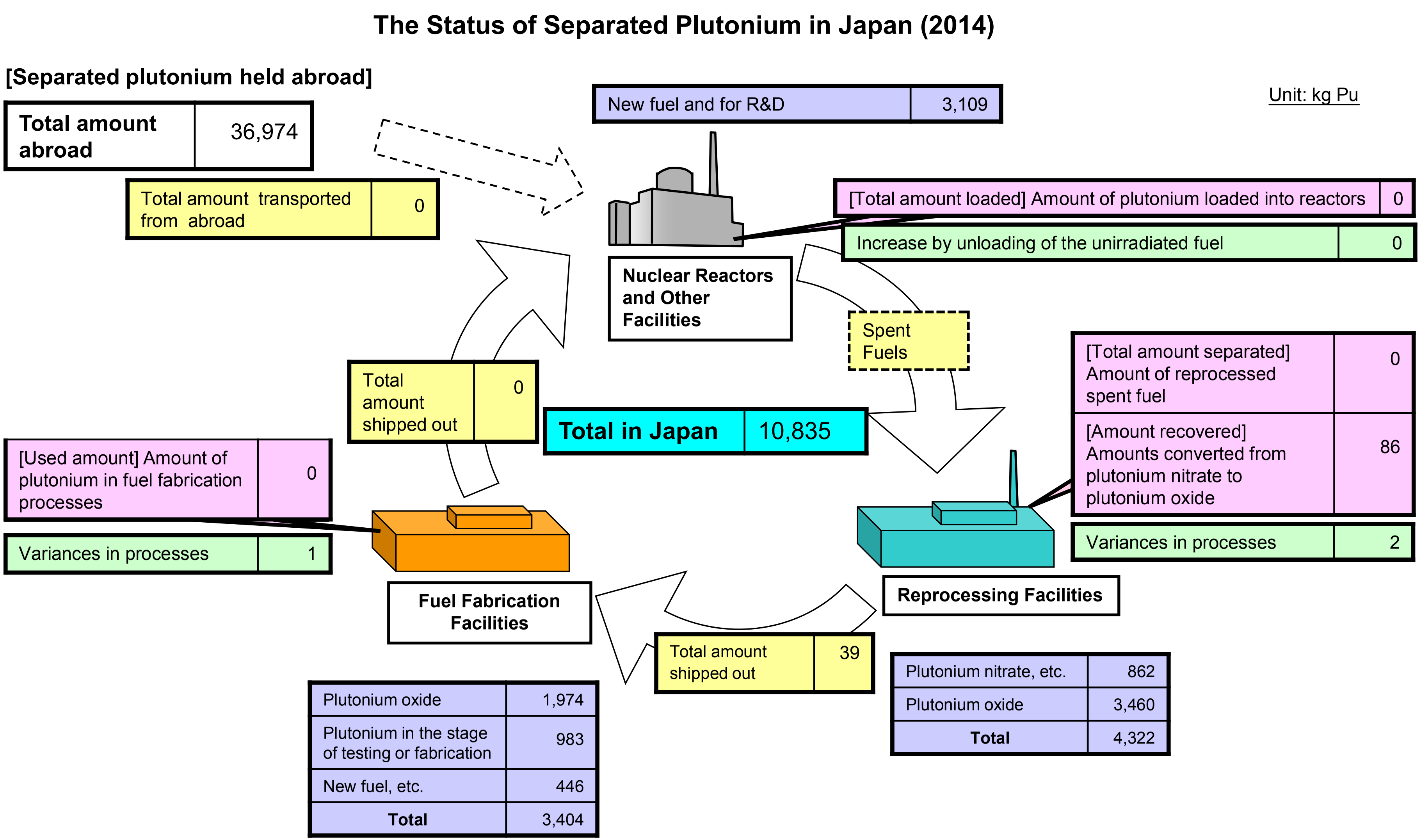


figure 3 The situation of management of separated plutonium in Japan

Table2 Domestic inventory of unirradiated separated plutonium *

(unit:kg)

| | | | | Japan Atomic Energy Agency Reprocessing Plant | Japan Nuclear Fuel Limited Reprocessing Plant | Total |
|---|---|---|---|---|---|---|
| Reprocessing Facilities | Facilities Name | | | | | |
| | Breakdown | Plutonium nitrate, etc. (After dissolution to the process before stored as mixed oxide in containers) | | 577(664) | 284(283) | 862(947) |
| | | Plutonium oxide (stored as mixed oxide in containers) | | 131(84) | 3329(3329) | 3460(3412) |
| | Total | | | 709(748) | 3613(3611) | 4322(4359) |
| | | Plutonium fissile in total | | 467(496) | 2348(2347) | 2815(2843) |

| | | | JAEA Plutonium Fabrication Plant |
|---|---|---|---|
| Fuel fabrication Facilities | Facility Name | | JAEA Plutonium Fabrication Plant |
| | Breakdown | Plutonium oxide (stored plutonium in plutonium oxide containers) | 1937(1939) |
| | | Plutonium in the stage of test or fabrication | 981(978) |
| | | New fuel, etc. (stored as finished fuel assemblies, etc.) | 446(446) |
| | Total | | 3364(3364) |
| | | Plutonium fissile in total | 2333(2333) |

| | | | Joyo | Monju | Commercial Reactors | R&D Facilities |
|---|---|---|---|---|---|---|
| Reactors and Other Facilities | Name of Nuclear Reactor, etc. | | Joyo | Monju | Commercial Reactors | R&D Facilities |
| | Unirradiated new fuel stored at nuclear reactor sites, etc. | | 134 (134) | 31(31) | 2501(2501) | 444(444) |
| | Total | | 3109(3109) | | | |
| | | Plutonium fissile in total | 2133(2133) | | | |
| Total | | | 10835(10833) | | | |
| | | Plutonium fissile in total | 7310(7309) | | | |

*The amount of plutonium in brackets for the end of 2013

Table 3 The amount of plutonium loaded and stored in nuclear reactors and other facilities in Japan

(unit:kg)

<table>
<tr><th colspan="2" rowspan="2">Facility name</th><th colspan="2">Stored plutonium</th></tr>
<tr><th>Separated Plutonium</th><th>Plutonium fissile in total (kgPuf)</th></tr>
<tr><td rowspan="2">JAEA</td><td>Joyo</td><td>134</td><td>98</td></tr>
<tr><td>Monju</td><td>31</td><td>21</td></tr>
<tr><td rowspan="2">The Tokyo Electric Power Company</td><td>Fukushima Daiichi Unit 3</td><td>—</td><td>—</td></tr>
<tr><td>Kashiwazaki Kariwa Unit 3</td><td>205</td><td>138</td></tr>
<tr><td colspan="2">Chubu Electric Power Company Hamaoka Unit 4</td><td>213</td><td>213</td></tr>
<tr><td rowspan="2">The Kansai Electric Power Company</td><td>Takahama Unit 3</td><td>901</td><td>585</td></tr>
<tr><td>Takahama Unit 4</td><td>184</td><td>110</td></tr>
<tr><td colspan="2">Shikoku Electric Power Company Ikata Unit 3</td><td>198</td><td>198</td></tr>
<tr><td colspan="2">Kyushu Electric Power Company Genkai Unit 3</td><td>801</td><td>801</td></tr>
<tr><td rowspan="4">Research and Development Facilities</td><td>JAEA, Fact Critical Assembly in Tokai R&D Center</td><td>331</td><td>293</td></tr>
<tr><td>JAEA<br>Deuterium Critical Assembly in Oarai R&D Center</td><td>87</td><td>72</td></tr>
<tr><td>JAEA<br>Static Experiment Critical Facility and Transient Experiment Critical Facility in Tokai R&D Center</td><td>15</td><td>11</td></tr>
<tr><td>Other facilities</td><td>11</td><td>9</td></tr>
</table>

Table 4 Separated plutonium stored overseas*

(unit:kg)

| Countries | Separated plutonium | Plutonium fissile in total |
|---|---|---|
| Recovered in the U.K. | 20696(20002) | 13939(11622) |
| Recovered in France | 16278(16310) | 10572(10604) |
| Total | 36974(36312) | 24511(24130) |

* The amount of plutonium in brackets for the end of 2013

## 1.2.2 Latest Changes

In Japan, the facilities in association with separated plutonium include Tokai Reprocessing Plant, Rokkasho reprocessing plant, MOX fabrication plant, the Fast Reactor-Joyo, Monju, nuclear power reactors, other Research and Development facilities. From January 1 to December 31 of 2014, Japan didn't use any unirradiated separated plutonium. The detailed changes of the amount of separated plutonium are as follows:

Table 5\6\7\8 show the detailed changes of plutonium inventory in these facilities.

(unit:kg)

| | |
|---|---|
| Total amount of plutonium newly separated at reprocessing facilities | 0 |
| Total amount of plutonium newly loaded in nuclear reactor | 0 |
| Variation in processes at facility | 2 |
| Total amount of plutonium returned from abroad | 0 |
| Increase by unloading from a reactor | 0 |
| Balance | 2 |

Table 5 JAEA Tokai Reprocessing Plant

(unit:kg)

<table>
<tr><th colspan="4">From separation and purification process to storage of raw material<br>at co-conversion process in the reprocessing plant</th></tr>
<tr><td colspan="3">Inventory as of Jan. 1, 2014 (the end of the year 2013)</td><td>748</td></tr>
<tr><td rowspan="8">Increase and decrease</td><td colspan="2">Increase by separation of plutonium (the amount for one year in 2014)</td><td>0</td></tr>
<tr><td colspan="2">Decrease by plutonium shipped out (the amount for one year in 2014)</td><td>-39</td></tr>
<tr><td colspan="2">Variation in processes at reprocessing facility</td><td>0</td></tr>
<tr><td rowspan="5">Breakdown</td><td>Transfer to retained waste</td><td>-0.1</td></tr>
<tr><td>Retransfer from retained waste</td><td>0</td></tr>
<tr><td>Nuclear loss</td><td>-1.1</td></tr>
<tr><td>Measured discard</td><td>0</td></tr>
<tr><td>Material unaccounted for (MUF)</td><td>1.2</td></tr>
<tr><td colspan="3">Inventory as of the end of Dec. 2014</td><td>709</td></tr>
</table>

## Table 6 JAEA MOX fuel Fabrication Plant

(unit:kg)

<table>
<tr><th colspan="4">From raw material of MOX to fuel assembly products</th></tr>
<tr><td colspan="3">Inventory as of Jan. 1, 2014 (the end of the year 2013)</td><td>3364</td></tr>
<tr><td rowspan="8">Increase and decrease</td><td colspan="2">Increase by plutonium received (the amount for one year in 2014)</td><td>39</td></tr>
<tr><td colspan="2">Decrease by plutonium shipped out (the amount for one year in 2014)</td><td>0</td></tr>
<tr><td colspan="2">Variation in processes at fuel fabrication facility</td><td>1</td></tr>
<tr><td rowspan="5">Breakdown</td><td>Shipper/receiver difference</td><td>0</td></tr>
<tr><td>Transfer to retained waste</td><td>0</td></tr>
<tr><td>Retransfer from retained waste</td><td>0</td></tr>
<tr><td>Nuclear loss</td><td>-0.6</td></tr>
<tr><td>Material unaccounted for (MUF)</td><td>1.4</td></tr>
<tr><td colspan="3">Inventory as of the end of Dec. 2014</td><td>3404</td></tr>
</table>

## Table 7 JNFL Rokkasho reprocessing plant

(unit:kg)

<table>
<tr><th colspan="4">From separation and purification process to storage of raw material<br>at mixed conversion process in the reprocessing plant</th></tr>
<tr><td colspan="3">Inventory as of Jan. 1, 2013 (the end of the year 2012)</td><td>3611</td></tr>
<tr><td rowspan="9">Increase and decrease</td><td colspan="2">Increase by separation of plutonium (the amount for one year in 2013)</td><td>0</td></tr>
<tr><td colspan="2">Decrease by plutonium shipped out (the amount for one year in 2013)</td><td>0</td></tr>
<tr><td colspan="2">Variation in processes at reprocessing facility</td><td>2</td></tr>
<tr><td rowspan="6">Breakdown</td><td>Transfer to retained waste</td><td>0</td></tr>
<tr><td>Retransfer from retained waste</td><td>0</td></tr>
<tr><td>Nuclear loss</td><td>-0.9</td></tr>
<tr><td>Measured discard</td><td>0</td></tr>
<tr><td>Plutonium sample received</td><td>0.1</td></tr>
<tr><td>Material unaccounted for (MUF)</td><td>2.5</td></tr>
<tr><td colspan="3">Inventory as of the end of Dec. 2013</td><td>3613</td></tr>
</table>

Table 8 Nuclear Reactors and Other Facilities

(unit:kg)

| “Joyo”“ “Monju”“ “Commercial Reactors”, and “R&D Facilities” | | |
|---|---|---|
| Inventory as of Jan. 1, 2014 (the end of the year 2013) | | 3109 |
| Increase and decrease | Increase by plutonium received (the amount for one year in 2014) | 0 |
| | Decrease by plutonium loading (the amount for one year in 2014) | 0 |
| | Decrease by plutonium shipped out (the amount for one year in 2014) | 0 |
| | Increase by unirradiated MOX fuel discharged | 0 |
| Inventory as of the end of Dec. 2014 | | 3109 |

# 1.3 Japan's Capability of Plutonium Production

Pure plutonium could be produced in reprocessing plant by separating the spent fuel, which has been irradiated in and then unloaded from reactors.

Among all Non-Nuclear Weapon States, Japan is the only one with complete nuclear fuel cycle industry. Through its nuclear power plants, two fast reactors, a centrifugal enrichment plant and two reprocessing plants, Japan has acquired great plutonium production capability.

## 1.3.1 Plutonium Production of Reactors

Nulcear power reactors and fast reactors are the main plutonium production facilities in Japan.

### 1.3.1.1 Nuclear Power Reactors

At present, there are 43 operational nuclear power reactors in Japan, including 18 BWR units, 4 ABWR units and 21 PWR units, with total intalled capacity of 40.48GWe. Furthermore, 2 reactors ( both ABWR) are under construction, with total installed capacity of 2.756GWe. [16]

The total installed capacity of BWRs in Japan is 22.523GWe, PWRs' is 17.967GWe. According to the report by the U.S. Department of Energy on calculating the amount of plutomium contained in spent fuel from LWR(Table 9), [17] and with the assumption that plutonium production is proportional to reactor capacity, it is estimated that plutonium produced by Japan's BWRs could be up to about 4.91 tons, and about 3.49 tons by PWRs, with a total of about 8.4 tons.

Table 9 Estimation of plutonium capacity of typical PWR and BWR[17]

| Reactor Type | Fraction of Commerical Reactor(%) | Core Power Electric (MWe) | Annual Pu Discharge (kg) | $^{239}$Pu Chontent (wt%) | Plutonium production per Unit power (kg/MWe) |
|---|---|---|---|---|---|
| PWR | 63.0 | 1000 | 218.2 | 51.1 | 0.2182 |
| BWR | 19.0 | 1000 | 194.1 | 46.9 | 0.1941 |

Due to the Fukushima nuclear accident, the majority of nuclear power reactors in Japan have been shut down. Units 3 & 4 of the Ohi nuclear power plant, whose installed capacity is 2.254 GWe, were restarted in July 2012. In 2013, these two reactors were closed again for safety reviews.

According to its Strategic Energy Plan[18] issued in April 2014, nuclear power was defined as the , key base-load power source, . The Japanese government made it clear that it would promote the restart of nuclear power. In April 2015, the Draft Plan of Power Production released by the Japanese government announced that it would restore the nuclear power proportion to 20-22% by the year of 2030. [19]

A first step to restart nuclear power reactors in Japan has been taken. On May 27th 2015, Japanese Nuclear Regulation Authority (NRA) approved the safety review of the unit 1 & 2 of the Sendai Nuclear Power Plant of the Kyushu Power Company. The unit 1, which began to load nuclear fuel in early July and entered into formal operation in Middle August, is the first nuclear power unit restarted under Japan's new nuclear safety regulation. [20]

### 1.3.1.2 Fast Reactors

In operation, fast breeder reactor could generate $^{239}$Pu in their breeding blanket, which is a kind of high-quality military plutonium (usually called as "super plutonium") [21]with a purity higher than weapons-grade plutonium and has a better performance for nuclear weapons.

Japan started early on the research and development of fast reactor technology, from 1961 to 1994. Since 1967, the development of fast reactor has been one of the main objectives of Japan’s nuclear program.

Japan has built two fast reactors: the Joyo Experimental Reactor and the Monju Prototype Reactor.

### *Joyo Experimental Fast Reactor*

Joyo(Figure 4), Japanese's first experimental fast reactor, was constructed in Oarai, Ibaraki since March 1970. Joyo is a sodium-cooled, MOX-fueled reactor. It was brought to critical in April 1977 and started operation since 1978. Its output thermal power was initially 50 MW, and then gradually lifted to 75 MW, 100 MW and 140 MW in 1979, 1983 and 2000 respectively.

Figure 4: Joyo Experimental Fast Reactor[22]

The initial design of Joyo reactor contains breeding blanket, which was removed in 1994 for the re-designing of reactor core. Whether the breeding blanket produced high quality military plutonium has raised international concern. After the breeding blanket being removed, Joyo lost the capability of producing super plutonium. In 2007, Joyo was shut down due to damage of some components in the reactor core.

### *Monju Prototype Fast Reactor*

The experiment and operation of Joyo Reactor provided valuable data to the development of Monju Prototype Fast Reactor. In 1985, Japan began to build the Monju Reactor in Tsuruga, Fukui Prefecture (Figure 5).

Monju is a sodium-cooled and MOX fueled fast reactor, with designing thermal power of 714 MW and electric power of 280 MW. [23]

Monju began its operation in 1994, and was shut down in 1995 due to an accident of sodium leaking from the heat transfer system. This accident was rated as a International Nuclear Events Scale (INES) “level 0” event by Japan’s Nuclear Safety Commission.

On December 8, 1995, Monju suffered a serious accident of leakage of liquid sodium coolant when being operated under rated power. Then, it was forced to operate with a lower power and was manually shut down. After emergent examination, the investigators found around 1 ton of solidified sodium, which was estimated as leakage from the connector of sodium temperature sensor and cooling duct. Although this accident did not caused radioactive contamination, the sodium coolant with strong causticity was very dangerous. This sodium leakage was a rather serious accident. Demonstrators called upon the Japanese government to shut down Monju, and the anti-nuclear campaigners further required to terminate this program. [24]

Figure 5: Monju Prototype Fast Reactor [25]

Koken Nosaka, then Chief Cabinet Secretary of Japan, announced at a press conference that Monju should not be operated again without ensuring its safety. [26]

The reconstruction project of Monju was started ten years later, in September 2005. However, the restart was postponed because the fake alarming problem of sodium leakage detector was not resovled. On May 6, 2010, 14 years after the shutdown of Monju, the Japanese government approved once again its restart. Unfortunately, in August, Monju was forced to shut down after a short resumption due to an accident in the refueling process. After the Fukushima accident, the Japanese Nuclear Regulatory Authority (NRA) suspended Monju’s restart plan and required JAEA to rebuild its maintenance and safety management system.[27] In September 2013, the Abe Administration renewed the Monju Research Plan, [28] which shows the intention of the Japanese government to restart Monju.

*Does Japan’s fast reactors produce military plutonium?*

In theory, if $^{238}U$ fuel assemblies are loaded on its reflecting layer, fast reactor could produce super plutonium with the abundance of $^{239}Pu$ over 97%.[21, 29] According to the information released by Japan Atomic Energy Agency (JAEA), Japan once reprocessed the spent fuel from Joyo Reactor and extracted plutonium in 1984.[30] Some experts have also questioned whether Japan has used its fast reactors for super plutonium production and how much has been produced. According to analisis made by US experts, [31] Japan may have accumulated 40 kg of super plutonium by Joyo Reactor before its core restructure in 1994, and another 10 kg of super plutonium by Monju reactor before the sodium coolant leakage accident in 1995. This amount to 50 kg of super plutonium. The international academia called upon Japan to make explicit answers to these questions.

## 1.3.2 Plutonium Production of Reprocessing Facilities

Japan has built up two reprocessing plants: Tokai Reprocessing Plant and Rokkasho reprocessing plant. In November 2014, JAEA announced that Tokai Reprocessing Plant would be closed.[32] According to Japan's latest plan, the Rokkasho reprocessing plant, which has been under construction since 1993 and whose operation was postponed 21 times, will start operation at the beginning of 2016 and achieve full-scale operation in 2019[8], with an output capacity of 8 tons of plutonium each year.[33]

### 1.3.2.1 Tokai Reprocessing Plant

Tokai Reprocessing Plant, Japan's first reprocessing plant (Figure 6), has made significant contributions to the development of Japan’s reprocessing technologies.

Tokai Plant was designed by SGN subordinated to Cogema (later incorporated into AREVA), and began operation since 1977. It's actual processing ability is 90 tons per year[33], with the output of $UO_3$ and plutonium nitrate under the PUREX process. Tokai began reprocessing spent fuel from commercial nuclear power reactors in 1981, and was reconstructed in 2006 as research and assessment facility for reprocessing technology, including the reprocessing of fast reactor's MOX fuel. JAEA continue to utilize this Plant to conduct “test” reprocessing of high burn up fuel, MOX fuel and fuel for the closed Fugen Advanced Thermal Reactor (ATR).

From 1977 to 2006, the Tokai Plant reprocessed about a total of 1140 tons of spent fuel, including 82 tons uranium fuel and 29 tons MOX fuel from the Fugen ATR, 644 tons boiling water reactor fuel, 376 tons pressurized water reactor fuel, and 9 tons fuel from the Japan Power Demonstration Reactor (JPDR). Each year, 42 tons of spent fuel was reprocessed by Tokai Plant. Figure 7 shows the historical data of reprocessing by Tokai Plant.[34]

Figure 6: Tokai Reprocessing Plant[35]

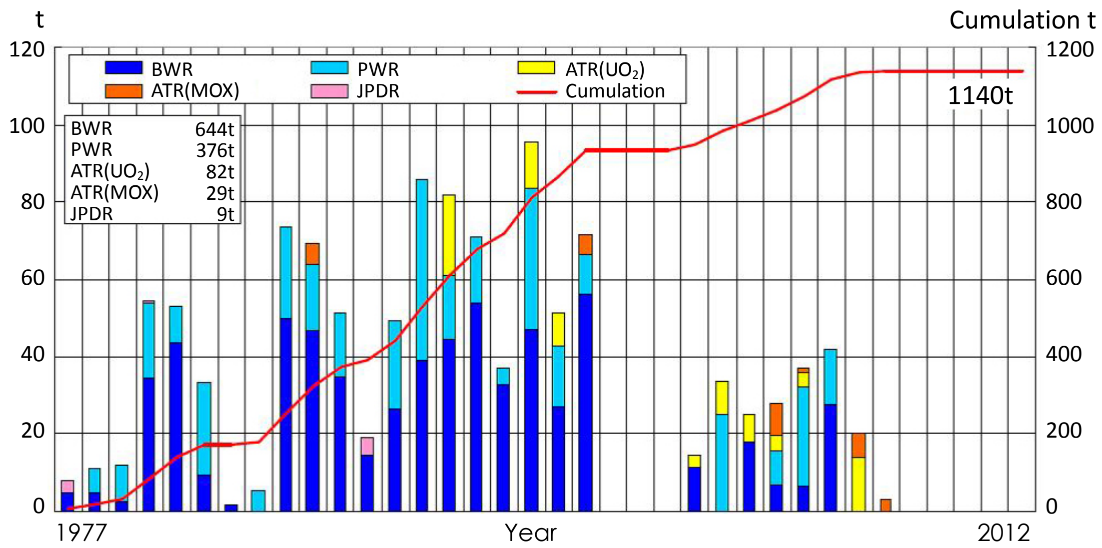


Figure 7: History of spent fuel reprocessing in Tokai Plant

After Fukushima nuclear accident, due to the high cost of 100 billion Japanese yuan ($ 915 million) for safety facility reconstruction in accordance with the new regulatory standards, JAEA declared to close the Plant.[32] On 29 September 2014, JAEA announced the permanent shut-down of the head-end of the Tokai Plant. And the entire decommissioning plan would be developed in 2015.

It is noteworthy that a criticality accident occurred at the JCO fuel fabrication facility in Tokai Plant site in 1999. The accident led to two deaths and radiation exposure to over 600 workers and local residents, causing catastrohpic hurts to the public. The announcement of closing the Tokai Plant was made just one day earlier to the 15th anniversary of the 1999 accident.

According to the decision made by JAEA on September 29th 2014, an additional 120 tons of spent fuel, including MOX fuel from Fugen, currently stored at the Tokai site, are likely to be shipped overseas for reprocessing. The first choice for the reprocessing would be the AREVA plant at La Hague.[32]

#### 1.3.2.2 Rokkasho reprocessing plant

Japan's Rokkasho reprocessing plant(RRP)is the only large-scale commercial spent fuel reprocessing plant in Non-Nuclear Weapon States. RRP's designing capacity is 800 tons of heavy metal per year, with an annual output of 8 tons of plutonium. Figure 8 shows the aerial view of RRP.

Figure 8: Bird's eye view of RRP[36]

The construction and launch time of RRP have been delayed for many years. Particularly, due to the serious safety risks, the safety accidents occured already, and the absence of a practical using plan for the plutonium use, the start of RRP has been strongly opposed both internationally and domesticly.

RRP adopted the PUREX process of UP3 plant of France, with two forms of product: MOX and uranium dioxide. Its designed life extention was 40 years (25 years for THORP reprocess plant in England and UP3 plant in France).

Besides the main process which utilizing Areva's technology, RRP also introduced technologies from BNFL and KEWA (DWK). In particular, its vitrification technology was developed based on Tokai Reprocessing Plant. Figure 9 gives information on RRP's key process and technology sources.

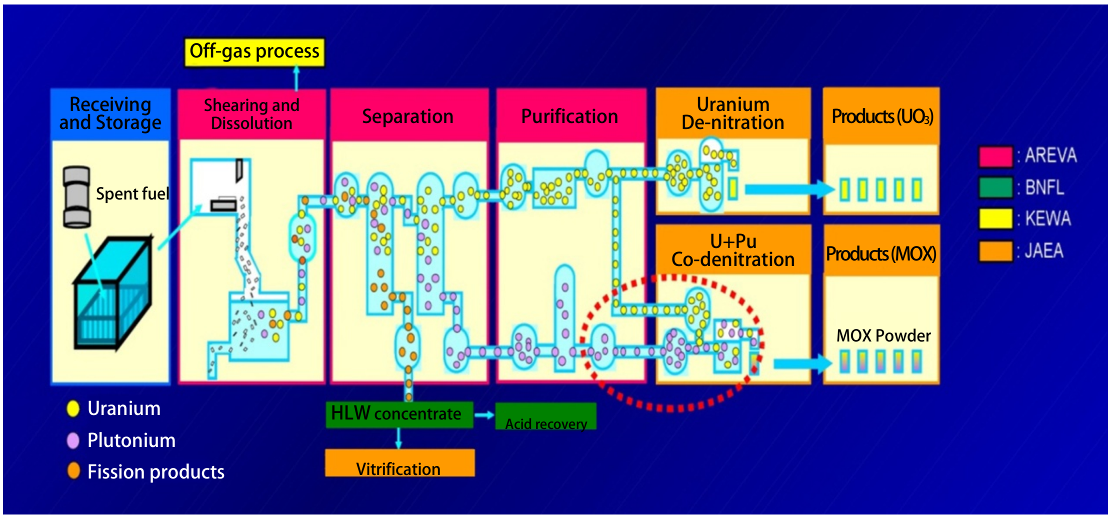


Figure 9: The Reprocessing Process of RRP[37]

RRP's construction was started in 1993 by Japan Nuclear Fuel co. LTD (JNFL). The infrastructure and facility construction was finished in 2002 and then started debugging. The hot pilot testing was commissioned in 2006. The grand total investment was about $20 billion.

Japan plans to reprocess all spent fuel domesticly after the launching of RRP (currently its spent fuel reprocessing is entrusted to France and UK).

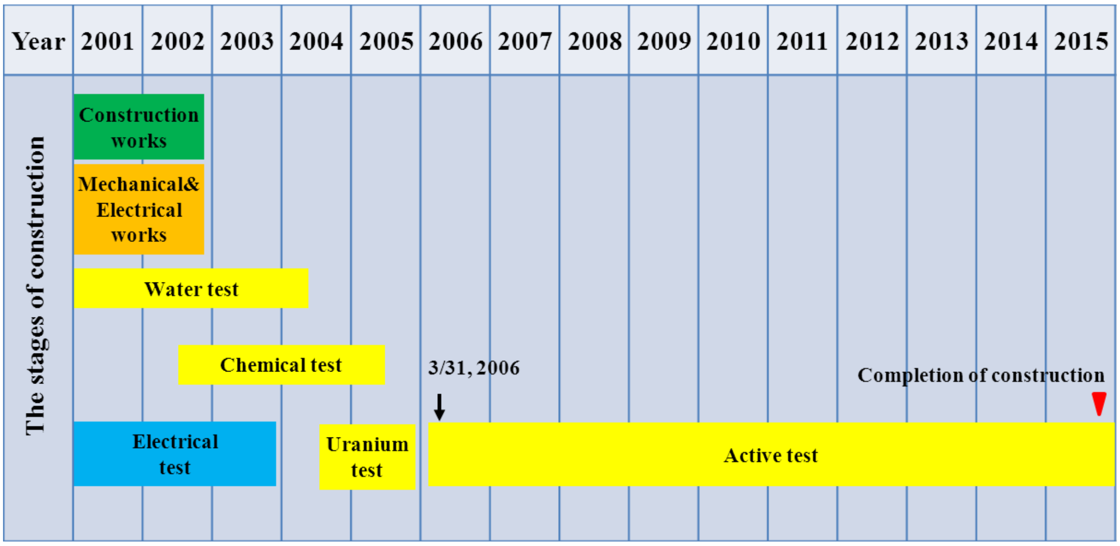


Figure 10: The stages of RRP’s construction

Figure 11 shows that RRP has received 3384 tons of spent fuel.[38]

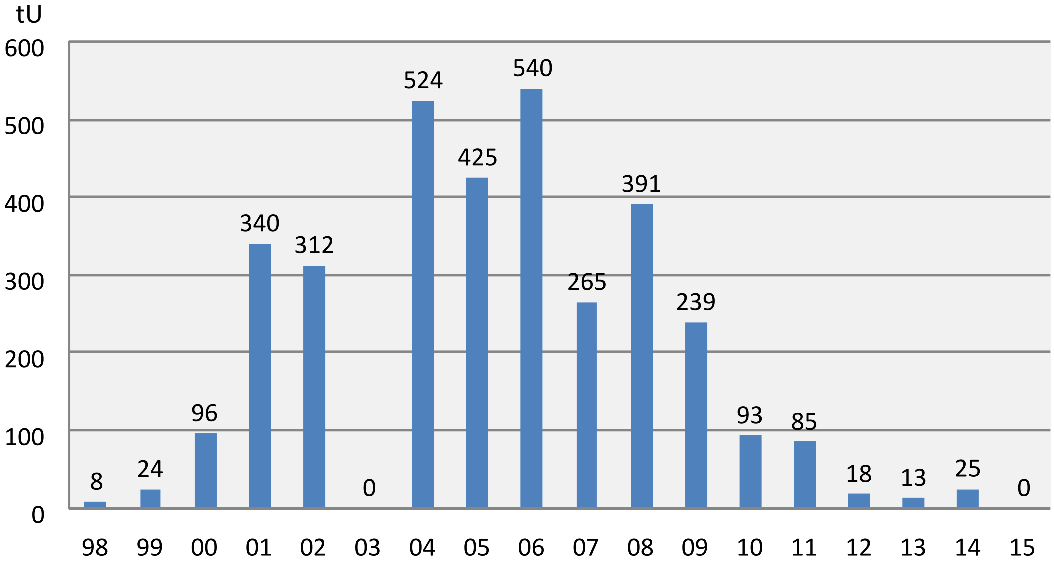


Figure 11: the amount of spent fuel received by RRP[39]

Hot commissioning of RRP has encountered lots of difficulties, the main one of which is the design imperfection of vitrification facility. This led to the suspension of the hot commissioning several times.

RRP produced the first batch of MOX powder in November 2006, and the debugging work of vitrification facility was started in November 2007. However, several accidents occured during the debugging work. Among these accidents, the leakage of 134 liters of high radioactive wastes lasted 12 days before being found, [40] which fully exposed the insufficiency of the Plant's safety.

After the 2011 Fukushima nuclear accident, RRP was subject to more rigorous safety examination. Despite JNFL asserted that the the problem in relation to vitrification facility has been sovled initially and that due to the on-going safety examination, the planned launching of RRP in October 2014 would be postponed to early 2016. RRP will achieve full capacity operation in 2019.

Table 10 shows JNFL's latest plan on RRP. [41]

Table 10 JNFL's Latest Plan on RRP Published in October 2014

| Plant or Office | | Name | | Reprocessing Office | | | | Reprocessing Plant | | | | Reprocessing Facility | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Location | | Rokkasho, Kamikita District, Aomori Prefecture | | | | Maximum Throughput per Year | | | | 800 t·Upr | | | | |
| Program | | SNF Receipts | | Reprocessing Capacity | | Ending Inventory | | Plutonium Product | | Uranium Product | | Other Useful Materials | | Ending Inventory | | |
| | | Amount of Fuel Assemblies | Uranium(tons) | Amount of Fuel Assemblies | Uranium(tons) | Amount of Fuel Assemblies | Uranium(tons) | Output (kg) | Deliveries(kg) | Output(kg) | Deliveries(kg) | Output(kg) | Deliveries(kg) | Uranium(kg) | Plutonium(kg) | Other useful materials(kg) |
| Year 2014 | 1st half | BWR 0 | BWR 0 | BWR 0 | BWR 0 | BWR 8550 | BWR 1478 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 14 | PWR 6 | PWR 0 | PWR 0 | PWR 3472 | PWR 1479 | | | | | | | | | |
| | 2nd half | BWR 11 | BWR 2 | BWR 0 | BWR 0 | BWR 8561 | BWR 1480 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 0 | PWR 0 | PWR 0 | PWR 0 | PWR 3472 | PWR 1479 | | | | | | | | | |
| | Total | BWR 11 | BWR 2 | BWR 0 | BWR 0 | BWR 8561 | BWR 1480 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 14 | PWR 6 | PWR 0 | PWR 0 | PWR 3472 | PWR 1479 | | | | | | | | | |
| Year 2015 | 1st half | BWR 12 | BWR 2 | BWR 0 | BWR 0 | BWR 8573 | BWR 1482 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 7 | PWR 3 | PWR 0 | PWR 0 | PWR 3479 | PWR 1482 | | | | | | | | | |
| | 2nd half | BWR 12 | BWR 2 | BWR 0 | BWR 0 | BWR 8585 | BWR 1484 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 7 | PWR 3 | PWR 0 | PWR 0 | PWR 3486 | PWR 1485 | | | | | | | | | |
| | Total | BWR 24 | BWR 4 | BWR 0 | BWR 0 | BWR 8585 | BWR 1484 | 0 | 0 | 0 | 0 | — | — | 6656 | 364022 | — |
| | | PWR 14 | PWR 6 | PWR 0 | PWR 0 | PWR 3486 | PWR 1485 | | | | | | | | | |
| Year 2016 | 1st half | BWR 12 | BWR 2 | BWR 471 | BWR 80 | BWR 8126 | BWR 1406 | 1989 | 0 | 111 | 0 | — | — | 8645 | 474624 | — |
| | | PWR 7 | PWR 3 | PWR 0 | PWR 0 | PWR 3492 | PWR 1488 | | | | | | | | | |
| | 2nd half | BWR 12 | BWR 2 | BWR 376 | BWR 64 | BWR 7761 | BWR 1344 | 2858 | 0 | 146 | 0 | — | — | 11502 | 620991 | — |
| | | PWR 7 | PWR 3 | PWR 218 | PWR 96 | PWR 3281 | PWR 1395 | | | | | | | | | |
| | Total | BWR 24 | BWR 4 | BWR 847 | BWR 144 | BWR 7761 | BWR 1344 | 4846 | 0 | 257 | 0 | — | — | 11502 | 620991 | — |
| | | PWR 14 | PWR 6 | PWR 218 | PWR 96 | PWR 3281 | PWR 1395 | | | | | | | | | |
| Total | | BWR 58 | BWR 10 | BWR 847 | BWR 144 | BWR 7761 | BWR 1344 | 4846 | 0 | 257 | 0 | — | — | 11502 | 620991 | — |
| | | PWR 41 | PWR 18 | PWR 218 | PWR 96 | PWR 3281 | PWR 1395 | | | | | | | | | |

# 2. Japan's Uranium Materials

Japan is poor in uranium mine resources, only 6600 tons of low-cost uranium have been detected and 84 tons have been exploited. Japan operates a commercial enrichment plant, equipped with two cascades of new type centrifuge for LEU production, with a total separation work capacity of 1050 tons SWU/yr. It is expected that its total separation work capacity would reach to 1500 tons SWU/yr by 2022. However, the LEU used in Japan's nuclear power reactors is mainly imported.

The 2500kg HEU(part of them is weapon grade)provided by the United States and the United Kingdom have been used in Japan's research reactors and critical assemblies. Some of these materials has been returned to the providers, while the rest about 1, 200 to 1, 400 kg of HEU are stilled possessed by Japan.

## 2.1 Definition of Uranium

Uranium is a chemical element with symbol U and atomic number 92. Uranium is radioactive. Among uranium isotopes, the most common two are $^{238}U$(accounting for almost 99.27% of the uranium found in nature) and $^{235}U$ (accounting for almost 0.72% of uranium found in nature). $^{235}U$ can sustain an explosive fission chain reaction in a certain critical mass. Therefore, $^{235}U$ can be used to make nuclear fission weapons and to fuel nuclear power plants. $^{238}U$ is fissionable by absorbing fast neutrons, and can be converted to $^{239}Pu$ by absorbing neutrons in a nuclear reactor. [42]

According to the definition by IAEA, uranium with the abundance of $^{235}U$ reaching to or excess of 20% could be defined as highly-enriched uranium (HEU), which could also be directly used as nuclear weapon loading material (direct use material).

## 2.2 Supply and Demand of Natural Uranium in Japan

Before the Fukushima nuclear accident, nuclear power contributed almost 30% of the country's total electricity production. However, after the Fukushima accident, nuclear power reactors were shut down in succession. Its nuclear power electricity took up 2.1% and 1.7% of the gross electricity generation respectively in 2012 and in 2013, while in the whole year of 2014 no nuclear electricity. [43] From the second half of 2015, Japan has began to restart the nuclear power reactor.

Japan's nuclear electricity production was 263.1TWh in 2009, 280.3TWh in 2010, 156.2TWh in 2011, 17.2TWh in 2012 and 14TWh in 2013. Before the Fukushima nuclear accident, the World Nuclear Association predicted that Japan's demand to nuclear fuel in 2011 would reach the peak with the amount of 8195 tU (1 tU is equal to 1.18 $tU_3O_8$). [44]But actually, from March 2011 to August 2015, Japan has basically no uranium demand.

the uranium resouces needed in Japan’s nuclear power were mainly imported from countries such as Australia, Canada, Kazakhstan, etc. At the same time, Japanese companies have also expanded investment into overseas uranium resource projects. Japanese companies had held certain stocks of the uranium companies in Kazakhstan, Uzbekistan, Australia and Namibia. [45]

## 2.3 Production of Low Enriched Uranium

Though Japan's most uranium enrichment products rely on import, it does operate a commercial enrichment plant at Rokkasho(Figure 12), which is affiliated to Japan Nuclear Fuel Ltd(JNFL).

The Rokkasho Enrichment Plant was initially built 7 cascades, which used by the martensitic steel centrifuge. By 1998, 7 cascades were eventually built up with the whole capacity of 1, 050 tons SWU/yr(150 tons SWU/yr per cascade). From 2000, because of quality problems, these cascades were shut down successively, with the last one closed in December 2010.

Figure 12: Rokkasho Enrichment Plant (2010, JNFL)

In order to replace the old model centrifuge, JNFL developed a new type of machine using carbon fiber, which is called Shingata. In November 2007, the pilot scale cascade test of the new type was conducted. In March 2008, JNFL began to construct a plant for fabricating and assembling the new type centrifuge(Figure 13). JNFL applied to Ministry of Economy, Trade and Industry of Japan for the license of using the new type machine in December 2008, and got the operating license in January 2010. In 2014, JNFL began to fabricate the new type of centrifuge in the plant.

Figure 13: Japan's centrifuge assembling plant

According to the data released by the World Nuclear Association in July 2015, as of June 2015, the Rokkasho enrichment plant has gotted a total capacity of 1050 tons SWU/yr. The capacity of 1500 tons SWU/yr is expected to be reached about 2022. A total amount of 1698 tons of low enriched uranium have been produced in the plant since 1995(Figure 14). [46]

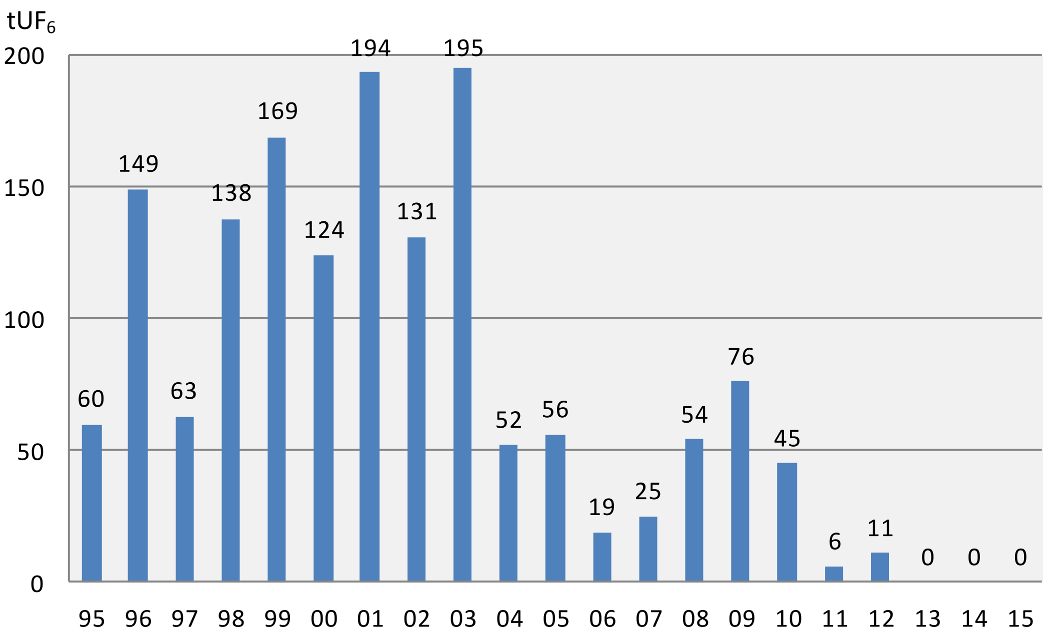


Figure 14: The low enriched uranium output of the Rokkasho enrichment plant since 1995[46]

Japan’s other enrichment facilities have been shut down, i.e. JNC(Japan Nuclear Cycle Development Institute) Ningyo-Toge Enrichment Demonstration Plant and Ningyo-Toge Uranium Pilot Plant(both are pilot centrifuge plants, shut down in 2004); the Asahi Uranium Enrichment Laboratory, Hyuga, Miyazaki prefecture(a pilot chemical exchange plant, shut down in 1991); and two laser enrichment labs in Tokai(shut down in 2003 and 2005).

In addition, Japan got 6400 tons of uranium extracted through the spent fuel reprocessing entrusted to France and UK. In 2007, it concluded contract with Russian company, for intrusting the latter to enrich these materials and return the products to Japan. [45]

## 2.4 Highly Enriched Uranium for Research Reactors

2.4.1 According to the progress report of 2012 Nuclear Security Summit, Japan still possesses 1, 200~1, 400 kg highly-enriched uranium (HEU). [47]

The HEU in Japan’s research facilities was provided by US and UK. According to US Department of Energy report *Highly Enriched Uranium: Striking a Balance 2011 edition*, US exported HEU to Japan for research purpose. From 1957 to 1994, US transferred 2, 054kg uranium, containing 1, 000kg U-235, to Japan. These materials are composed of 1, 523 kg less than 90% uranium containing 507 kg of U-235, and 531 kg more than 90% uranium, containing 493 kg of U-235.

Japan built up in 1967 Fast Critical Assembly (FCA), which received about 500 kg HEU from UK. The total amount of HEU provided by US and UK was about 2, 500 kg.

Repatriation of spent fuel stored in these facilities' sites back to the US began from 1997, and till now this work continues under the auspices of the Global Threat Reduction Initiative (GTRI). From May 1996 to May 2010, Japan sent back spent fuel elements of approximately 656 kg HEU (originally containing 354 kg U-235). [48]

2.4.2 Under the international pressure and repeated requirements by US, leaders of Japan and US , in a joint statement in March 2014 during the Hague Nuclear Security Summit, reaffirmed the engagement to minimize the global stockpile of HEU and separated plutonium to the largest extent, pledged to remove and dispose all weapon-grade plutonium and HEU form FCA, returning back to US. [49]

The announcement is an inspiring signal. However, after the Hague Nuclear Security Summit, no information on progress is released. We also noticed that, in the above-mentioned Japan-US joint statement, other states were encouraged to minimize the stockpile of HEU and separated plutonium. We are looking forward to seeing Japan’s commitment to its own promise at first.

# 3. Status of Supply and demand of Plutonium in Japan

## 3.1 Official Policy and Realities

JAEC put forward the policy “no excess plutonium” in 1991, for the sale of easing international concerns over Japan’s large plutonium inventory. The core of this policy was that Japan would not hold plutonium exceeded its real need. In the policy, one of the measures was to use MOX fuel in light water reactors so as to consume the plutonium stocks. JAEC brought “no surplus plutonium policy” into its long term plan in 1994. However, JAEC removed the expression of “no excess plutonium” in its white paper of 2004, while at same time retained the principles of not holding plutonium exceeded its real need. In 2014, during the Hague Nuclear Security Summit, Japanese Prime Minister Abe claimed that Japan would maintain the policy that it should possess no plutonium reserves without specified purposes.

As a step of implementing the “no excess plutonium” policy, JAEC and Federation of Electric Power Companies (FEPC) pushed forward an official MOX plan in 1997, with an initial aim of using MOX fuel in 16 to 18 light-water reactors in Japan by 2010. Plutonium recovered in UK and France was planned to be used at first. However, due to the objection by local authorities and some other reasons, this plan didn't work well. In June 2009, FEPC posponed the schedule to 2015. The fact is that, although MOX plan has been raised for 18 years till now, only 4 reactors in Japan used MOX fuel, MOX fuel has been used in only four reactors and only 2.5 tons of plutonium has been consumed.

The function of the MOX fuel fabrication plant, neighboured to the Rokkasho reprocessing plant, is using uranium and plutonium recovered by Rokkasho Plant to make MOX fuel. According to the plan released by JNFL in 2010, the operation of MOX fuel fabrication plant would start in March 2016. However, up to April 2013, only 3.5% of the plant’s construction was finished[14]. Now, the plant is under construction, and plan to complete in October 2017[50].

## 3.2 Growth Trend

Japanese Prime Minister Abe claimed during the Hague Nuclear Security Summit that Japan would continue to pursue the “no excess plutonium" policy, and take fully into account the balance between plutonium recycle and utilization.

The growth of Japan’s separated plutonium stocks in the 1990s and early 2000s was primarily due to reprocessing of Japan’s spent fuel in France and the UK. However, 3.6 tons of plutonium were separated during the pilot testing operations of RRP, in 2006 to 2008.

In the report Ending reprocessing in Japan: An alternative approach to managing Japan's spent fuel and separated plutonium[14] published by the International Panel on Fissile Materials, with the assumption that RRP starts operation in 2014, it is estimated that Japan's separated plutonium stocks would increase to 100 tons in the following 10 years (Figure 15). Although JNFL announced in October 2014 that RRP would start operation in March 2016, the above conclusion would not be influnced.

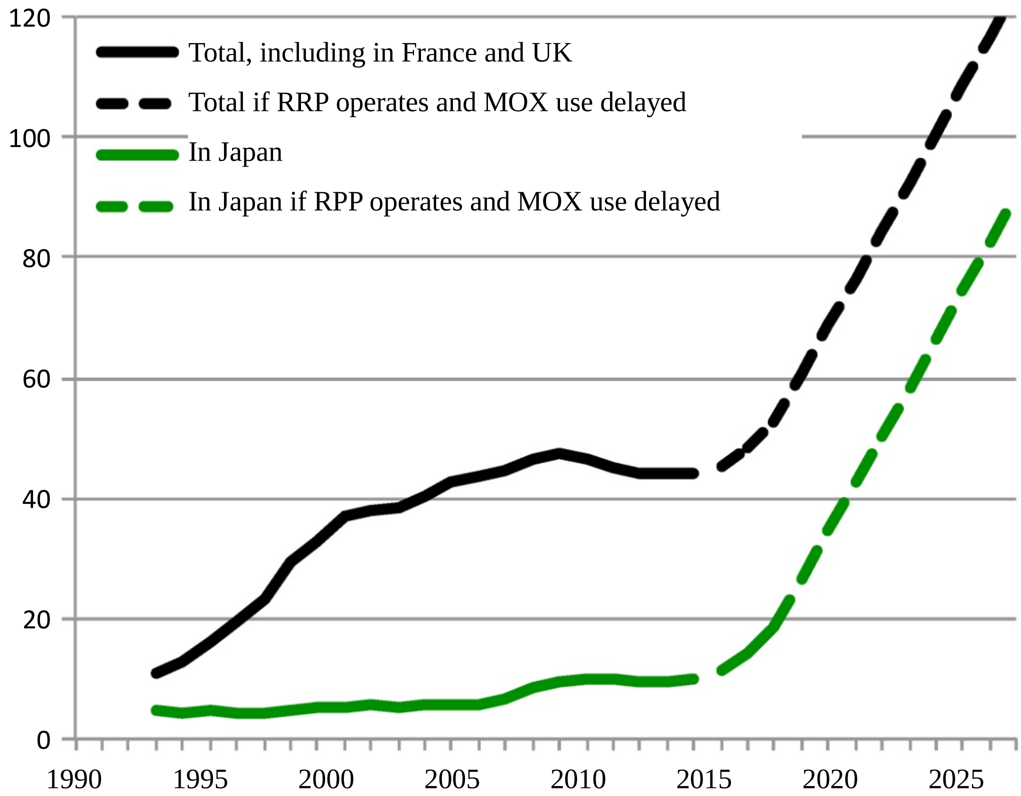


Figure 15: Evolution of Japan's plutonium stockpile until 2025[14]

(*Assuming the RRP in operation and the MOX fuel plan delayed)

# 4. Response of International Community

## 4.1 Positions of Governments

International community has reached consensus on dealing with nuclear materials for civilian purposes. Besides the IAEA Plutonium Management Guidelines, in the Communiqué of the Hague Nuclear Security Summit, all countries were encouraged to reduce the stockpile of highly-enriched uranium (HEU) and keep the amount of separated plutonium at the lowest level according to their respective needs, and to reduce the use of HEU by converting HEU for nuclear fuel to LEU if technical and economic conditions permits.

Japan, as a member state of IAEA and Nuclear Security Summit, has actively advocated these initiatives and proposals. However, there has been a serious imbalance between the supply and demand of its nuclear materials. It has become a major concern of the international community. On the government level, conerns have been raised mainly by China, South Korea , Russia and the United States. These countries have viewed this issue from political perspective, and payed close attention to the political intention of Japan in developing nuclear fuel cycle and reserving large amount of sensitive nuclear materials.

### 4.1.1 China

Since early 2014, spokespersons of the Chinese Foreign Ministry have answered relevant questions 13 times, elaborating Chinese government's concerns and worries of the proliferation risk and nuclear safety and security in Japan. China has urged the Japanese government to return weapon-grade nuclear materials to the providers, give explaination to the imbalance between supply and demand of its sensitive nuclear materials, and take concrete steps to solve these problems as soon as possible.

In March 2014, Chinese Vice Foreign Minister Li Baodong, when taking the interview, expressd that the international community has raised doubts and concerns about Japan's storage of weapon-grade nuclear materials; as to this issue, Japan is obliged to give an explanation to the international community; only by taking substantive actions to truly follow a peaceful path while making clear explanation, can Japan dispel concerns in the international community.

Also in that month, Ambassador Cheng Jingye, Permanent Representative of China to the U.N. and other international organizations in Vienna, made a statement at the Board of Governer Meeting of IAEA expressing gravely concern on the imbalance of supply and demand of Japan's nuclear materials, asking the Japanese government to make explanations and to eliminate through concrete actions the hidden nuclear security threats and proliferation risks.

In year 2015, the Chinese government called upon relevant countries to strengthen the control of sensitive nuclear materials and keep balance between supply and demand in several international conferences, including the Nineth NPT Review Conference and meetings of Board of Governors of IAEA.

### 4.1.2 Republic of Korea(ROK)

On March 12, 2014, ROK's foreign minister Yun Byung-se delivered a speech on the nuclear security summit held in Seoul, saying that if a country possesses or produces much more nuclear materials than needed, its intention is questionable. These nuclear materials could be stolen illegally, which will poses threat to this country and its neighboring countries. Thus, this issue must be addressed through the cooperation between IAEA and relevant countries, in order to reduce the concerns of neighbouring countries.

### 4.1.3 Russia

In March 2014, in the statement made by Amb. Berdennikov, Russia's Permanent Representative in Vienna, at the IAEA Board of Governor Meeting, he expressed Russia's concern about the presence in Japan of large amounts of weapon-grade plutonium of foreign origin, asked Japan to make explanation without delay to the imbalance between those large amounts and its actual requirements. He also emphasized that IAEA should pay close attention to this issue and focus its maximum safeguards efforts on relevant countries.

### 4.1.4 USA

The comments of the U.S. government on Japanese nuclear materials is quite cautious, and the U.S. government deliberately shows its tolerance and trust to Japan. This attitude is not surprising because U.S. is Japan's main ally and supporter of its nuclear cooperation. However, we also noticed that U.S. officials have expressed their concerns in different occasions.

In April 2013, Assistant Secretary of State Countryman and Deputy Secretary of Energy Kahneman met deputy president of Japan Atomic Energy Commission **Tatsujiro Suzuki**, expressing deep concern over the plutonium reprocessing program in Japan. [51]

On March 13, 2014, Secretary of State Kerry said on a hearing of Senate Appropriations Committee that U.S. is working with Japan and other countries in order to make sure they don't feel so threatened by nuclear North Korea that they move towards nuclearization in self-help.[52]

Except for expressing concerns, U.S. government also took some remedial measures. For example, at the repeated requirements of U.S. Government, Japan and U.S. leaders launched a joint statement in Hague Nuclear Security Summit, in which Japan pledged to remove and dispose all HEU and separated plutonium from the Fast Critical Assembly in Japan and transport them to the US.

The attitude and actions above fully indicate that U.S. has realized the serious risk posed by Japan's nuclear materials.

## 4.2 Views of International Academia

The international academic community has long been focusing on the issue of Japan’s nuclear materials. Many experts and scholars have raised questions about the Japan’s practice and offered lots of technologically reasonable and feasible recommendations. Taking into account the length of this report, now we just introduce several examples.

In year 2005, many scholars including senior officials of the current U.S. administration and Nobel Prize Winners published an article named Call for Japanese government enhance NPT by permanent delaying the operation of Rokkasho spent fuel reprocessing plant. They said in the article that it was very wise for Japan to have no intention to join the nuclear club. They urged Japan show its leaderships in implementing the no-surplus-plutonium policy and stop increasing the stockpile of separated plutonium. They call upon Japan to permanently postpone the operation of Rokkasho spent fuel reprocessing plant. [53]

On November 2013, IPFM published a report named Ending reprocessing in Japan: An alternative approach to managing Japan’s spent fuel and separated plutonium. The report believed that it was unnecessary, even harmful of implementing reprocessing process for the nuclear industry. Operating Rokkasho reprocessing plant whose design life was 40 years would cost more than 8 trillion Japanese yen than simply stocking the spent fuel. Rokkasho reprocessing plant would output additional 8 tons of separated plutonium when operating in full scale, but Japan does not have a clear plan to deal with the existing about 48 tons of separated plutonium until now. Although the plutonium from reprocessing could be used to fuel sodium-cooled breeder reactors, there are no precedents of successfully commercializing fast reactors.

On September 17, 2014, at a joint seminar held by the Center for Strategic and International Studies (CSIS) and Hitotsubashi University, six U.S. experts and six Japanese experts discussed the proliferation impact of Japan's nuclear fuel cycle policy . These experts deemed that Japan’s nuclear fuel cycle plan was originated from the concern of scarcity of uranium resources and energy security, but this logic is widely deemd as not applicable any more. If Japan wanted to completely solve the problem of energy security, it should develop renewable energy sources or nuclear fusion technology. If they want to reopen the Rokkasho plant, they should make clear that its sole purpose was to meet the demand of energy but not for other reasons. An alternative option is to consider posing some necessary limit on Japan’s nuclear fuel cycle plan, or change the purpose of the Rokkasho plant.

Reports published by U.S. Center for Public Integrity claimed that, although U.S. government openly assert it had no special concern on the issue of Japan’s nuclear materials, it told Japan covertly many times that it had seen lax security at Japan’s nuclear sites as terror risk. The accuracy of IAEA’s measures of safeguards to the Rokkasho plant is just 99%, which means that every year there will be plutonium enough to make up to 26 nuclear bombs missing and cannot be tracked.

# 5. Risks Arising from the Imbalance of Supply and Demand of Nuclear Materials in Japan

Japan's supply and demand of nuclear materials is seriously unbalanced. With the Rokkasho reprocessing plant going into operation, The situation will be worse and may lead to a vicious circle. The fact that Japan will accumulate more and more weapon-grade fissile materials, especially separated plutonium, will put Japan, its neighboring countries and the whole world at risk. The risks may include:

## 5.1 Nuclear Safety Risk

Japan is a country easily hit by natural disasters such as earthquake and tsunami. The nuclear facilities in Japan therefore have inherent safety defects. Take the Fukushima accident for example, the Report by IAEA Director General[54] on this accident pointed out that Japan had problems such as insufficient preparation for severe natural disasters, weakness in regulotary framework and in nuclear power plant design, etc. Meanwhile, after the Fukushima accident, the international community is calling for higher safety standards for nuclear energy. The Japanese government is still being questioned on such issues as damage control and information transparency. In particular, the problem of leakage of condaminated water remained unsolved.

With the imbalance of supply and demand of nuclear materials in Japan, the production, transportation and storage of the accumulated fissile materials, especially the separated plutonium, will increase nuclear safety risks in Japan's nuclear energy development as well as its related nuclear facilities. Due to the wide-ranging impacts of nuclear accidents in terms of space, time and psychological impact, any act that may increase the risk of nuclear accident could result in serious consequences to Japan and its neighboring countries.

## 5.2 Nuclear Proliferation Risk

Since the 1960s, Japan took as a national policy the Three Non-Nuclear Principles of nonproduction, nonpossession and nonintroduction of nuclear weapon. In the 1970s, Japan joined the *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT) as a Non-Nuclear Weapon State. Meanwhile, Japan developed the capability of uranium enrichment and reprocessing which could be used to produce weapon-grade materials in the name of peaceful use of nuclear energy. Now Japan has its complete nuclear fuel cycle, and is the only country among NPT Non-Nuclear Weapon States to possess the commercial-scale reprocessing and enriching capability at the same time. In fact, Japan is capable of developing nuclear weapons.

Many people are of the view that, as the only country ever hit by atomic bombs, Japan would not develop nuclear weapons. The Japanese government has all along emphasised that it will stick to the “Three Non-Nuclear Principles” as well. In recent years, however, Japan has broken through the constraints imposed by its "Peace Constitution" in a step-by-step manner; there has been a greater tendency toward abandon the policy of defence limited to its own territory and coastal water; and Janpan keeps going its way to become a military power in the world. The right-wing forces in Japan are gaining ground and clamored to develop nuclear weapons from time to time. The former Governor of Tokyo Shintaro Ishihara asserted that Japan should possess nuclear weapons and advocated for a nuclear-armed Japan in an interview with Agence France Presse on 15 November, 2011. Japanese right-wing extremist Toshio Tamogami claimed that Japan should have nuclear weapons if it wants to be a powerful country in international politics when interviewed by a magazine. All these cannot but make the international community including Japan’s neighboring countries doubt its true intention. Japan has also broken its promise on “no excess plutonium”. People have to worry whether the “Three Non-Nuclear Principles” would become a mere scrap of paper too.

## 5.3 Nuclear Terrorism Risk

Since the September 11 attacks, terrorism has become a real and common threat to the whole world. Due to the mass destruction and psychological effects that can be caused by nuclear weapons and nuclear explosive devices, nuclear terrorism has become the ultimate weapon for terrorist organizations. Many terrorists have blustered about acquiring a nuclear weapon, or producing a “dirty bomb” by acquiring fissile materials. Against this background, the US initiated the Nuclear Security Summit process which was supported by the international community including Japan. The UN General Assembly and the IAEA have done a large amount of work in this regard to raise global awareness and strengthen the capability to counter nuclear terrorism.

The large amount of separated plutonium possessed by Japan which could be directly used to produce nuclear weapons, can easily become the target of stealing, robbing and destroying. Unfortunately, there are too many security flaws in the Japanese regulatory system in this regard. For example, since the Japanese nuclear facilities are only protected by unarmed ordinary guards and very few law enforcement officials, will the defence line be easily broken in by terrorists? These have always been the concerns of the international community.

We believe that the Japanese government has noticed the above risks. In the 2014 Nuclear Security Summit, Japanese Prime Minister Shinzo Abe stated that Japan strives all the time to ensure the 3Ss, Safeguards, Safety and Security, which are essential for advancing the peaceful uses of nuclear energy. We are also looking forward to more practical measures taken by the Japanese government.

# 6. Recommendations

It is an inalienable right of all countries to use nuclaer energy for peaceful purposes. The importance of nuclear power to Japan is self-evident given its shortage of resources. Nuclear power accounted for 30% of Japan's gross power generation before the Fukushima accident. The Strategic Energy Plan was published in April 2014 by Japan, defined nuclear power as the "key base-load power source". Japan has already restarted its nuclear power reactors in a step-by-step manner. That is economically reasonable.

However, economic insterests should not be the only factor for consideration, nor should it be the primary one. Taking into account the existing risks of nuclear safety, nuclear proliferation and nuclear terrorism, Japan should observe its policy of "no excess plutonium" and deal with the following issues in a comprehensive and responsible manner for the sake of its own people and other countries: how to deal with its huge stockpile of nuclear materials, how to make a rational plan for its nuclear material consumption and address the imbalance, and how to ensure the safety and security of these materials. All these problems are obvious, and the key for the Japanese government is to face up to the concerns of the international community. Instead of evading them, and it should take effective measures to solve the problems in an appropriate manner.

We would like to make the following suggestions on Japan's nuclear materials:

## 6.1 On Properly Handling Existing Nuclear Materials Stockpile

Plutonium inventory, as the most outstanding and long-standing issue, has been the focus of attention of the international community.

1. The plutonium that Japan has stored in the United Kingdom and France could be transferred. This may involve other problems, such as the willingness of the Receiving Country, receiving capacity and huge financial costs, etc. It is reported that the UK has agreed to receive about 20 tons of separated plutonium stored by Japan on its territory. If this plan goes well, it would undoubted be of great significance and set a good example for dealing with Japan's plutonium stored in France.

2. Regarding the plutonium stored in Japan, a reasonable amount of these plutonium could be reserved for future use, and the rest could be entrusted to the IAEA, and be actually frozen up.

3. In its specific plan of restarting nuclear power plant, Japan may give priomty to restarting the units using MOX fuel in order to consume the existing plutonium inventory as much as possible.

Meanwhile, the uranium inventory should not be ignored. Japan should honor its commitment to reducing the HEU stockpile and converting the relative facilities to use low enriched uranium(LEU). This should be accomplished through detailed plans and pragmatic measures.

## 6.2 On Reducing the Growth of Nuclear Materials

The most important thing for Japan is to formulate a feasible mid-and-long-term plan to balance the supply and demand of nuclear materials. Given the complex nature of such a plan, it is understandable that Japan may need some time to do this. However, Japan should suspend the starting of the Rokkasho reprocessing plant before such a plan is in place.

In addition to reprocessing, Japan should explore other measures for handling and disposing spent fuel, such as developing and adopting the dry storage container, developing and building spent fuel disposal repository, etc.

## 6.3 On Transparency on Nuclear Materials

As the only Non-Nuclear Weapon State with the complete nuclear-fuel-cycle facilities, Japan should be more active in non-proliferation. While enjoying the right to peaceful use of nuclear energy, Japan should take more measures to ensure nuclear non-proliferation, such as increasing transparency, enhancing notification, and exploring mechnisms and measures that could mitigate the concerns of the international community.

1. As a confidence building measure, Japan should reaffirm its policies of , Three Non-Nuclear Principles , and , no excess plutonium, through bilateral exchanges and multilateral fora such as the Nuclear Security Summit and IAEA meetings.

2. Japan should continue to publish detailed data and plans on the production and use of all its nuclear materials.

3. Japan should comply earnestly with its safeguards obligations as a Non-Nuclear Weapon State, and receive stricter and more targeted IAEA safeguards.

4. Japan should also establish a consultative group of international experts to conduct regular exchanges and seek more technical advosory opinions and suggestions on relevant issues.

## 6.4 On Safety and Security of Nuclear Facilities

Japan should raise the safety and security standards for the design and construction of its nuclear facilities, reinforce its abiltiy to deal with nuclear emergencies and strengthen the resistance of the nuclear facilities to natural disasters. Measures should also be taken in such areas as legislation, law enforcement and management to reduce the risks of theft and illegal use of nuclear materials.

Once an accident occurs, timely, accurate and comprehensive reporting and briefing of relevant information to its neighbors and the international community is imperative to prevent the panic caused by poor information after the Fukushima accident from happening again.

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