

Japan's Nuclear Fuel Cycle Futures

Evaluating the Nonproliferation Impact of Japan's Nuclear Fuel Cycle Decisions

SUMMARY OF A WORKSHOP CO-HOSTED BY THE CSIS PROLIFERATION
PREVENTION PROGRAM AND HITOTSUBASHI UNIVERSITY



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The March 2011 accident at the Fukushima Daiichi nuclear power plant triggered a public crisis of confidence in Japan's nuclear energy program. Once reliant on over 50 nuclear power reactors for 30% of its electricity generation, none of the reactors are in operation today. Instead, Japan has relied on importing coal, gas and oil with predictable, negative effects on its trade balance, environment, and economy.

In the last three years, Japan has done some soul-searching about the future of nuclear energy. It has moved from a disavowal of nuclear power in the immediate aftermath of the crisis to a fuzzy future wherein nuclear power is an important baseload power source but will decline in share compared to other energy sources. The Abe administration, which supports nuclear power, has called for flexibility, preferring not to set specific goals for nuclear power generation.

Nonetheless, the Japanese government has passed some important milestones. Concurrent with government investigations into the root causes of the accident, Japan has restructured its nuclear regulatory system, creating a new Nuclear Regulation Authority and set new safety requirements. Nuclear utilities have begun the process of applying for licenses to restart reactors. The government is reducing the size and the role of the Japan Atomic Energy Commission (JAEC), which in the past has set long-term nuclear energy strategies and had a budget oversight function. The Japanese government has also begun to address broader questions regarding the future of other elements of its nuclear program – specifically its nuclear fuel cycle including spent fuel reprocessing.

On September 17, 2014, the Center for Strategic and International Studies (CSIS) and Hitotsubashi University co-hosted a workshop at the International House of Japan in Tokyo to explore the nonproliferation implications of Japan's nuclear fuel cycle decisions. Six American and six Japanese experts reviewed the status of Japan's nuclear program, challenges and opportu-



A view of the garden at the International House of Japan.

nities regarding its spent fuel management, perceptions of Japan's nonproliferation credibility, and options for moving forward. A few salient themes emerged:

1. Japan's fuel cycle plans for decades assumed nuclear energy would continue to flourish in Japan. Today, Japan needs to explore tools and measures to consume current excess plutonium and decide on the future of recycling of plutonium.
2. The need for flexibility in planning Japan's nuclear energy future is both pragmatic and understandable but emphasizing flexibility could be interpreted as unwillingness to deviate from established pathways despite drastically changed circumstances.
3. The primacy of local interests and politics in fuel cycle decisions is not well understood in the United States or outside of Japan in general.
4. Japan should clearly demonstrate its plan for reducing its plutonium stockpile and its intentions for plutonium use in the future. Flexibility coupled with principles or with certain restraints could be helpful in allaying concerns.
5. The Japanese public is more concerned about safety, rather than nuclear proliferation. The inconsistency of reactor and fuel cycle decisions are more worrisome to those abroad than those at home. Nonetheless, the public debate needs to integrate the two.
6. Observers of Japan concerned about latent nuclear weapons capabilities often focus more on reprocessing than enrichment, yet both entail proliferation and security risks.
7. There is an apparent and/or perceived disconnect between the political leadership of some parties and the nuclear power sector on the question of proliferation and national security dimensions of the fuel cycle choices that they have to make.



Workshop participants discuss the future of Japan's nuclear fuel cycle.

THE DISCUSSION

The workshop kicked off with a survey of nuclear power globally and within Japan. Although Asia will experience growth in nuclear energy, nuclear power seems less promising in other regions, particularly where investments in energy efficiency are more rewarding than they are for new nuclear construction. The challenges to nuclear power continue to include policy, public acceptance, pricing, efficiency and the erosion of electricity demand in some places. Russia's build-own-operate (BOO) model, as well as its soft loan offerings to prospective customers, has allowed Russia to largely dominate the export market, but eventually, Russian money will run out. Overall, the BOO trend has the potential for short-circuiting the institutional development of regulations if not implemented correctly, especially if small modular reactors emerge as turn-key products in the next decade. Japan's own nuclear export plans are unlikely to provide a basis for nuclear recovery in Japan; if the reactor numbers fall and lifetimes are not extended, it's not clear that Japan can maintain a substantial manufacturing capacity and will likely follow the same hollowing out as U.S. nuclear manufacturing in 1980s and 1990s.

In Japan, the Strategic Energy Plan affirmed nuclear power as an important source of base-load energy, while declaring that dependence on nuclear power will decline as energy efficiency and renewable energy increase. The Strategic Energy Plan stated that a stable energy supply, cost reduction, global warming, and maintaining nuclear technologies and human resources would all be taken into account. Utilities have complained however that the government has not identified specific targets for reliance on nuclear energy.

Several factors will present difficulties for nuclear energy generation in Japan, including the number of reactors that will be restarted, the limitation of 40-year lifetime for reactors, and difficulties in replacing plants or building on green-field sites. For its part, the Strategic Energy Plan has supported Japan's earlier nuclear fuel cycle policy, adding the notion of flexibility to respond to unforeseen developments. At the same time, Japan has embedded in its policy a commitment to not possess excessive reserves of plutonium, and to conduct appropriate management of Pu utilization to achieve that goal.

At the Rokkasho Reprocessing Plant (RRP), 99% of the construction work is complete, including testing of the vitrification process. The final commissioning test has not been completed, and RRP is still undergoing the safety assessment process for new regulation by the Nuclear Regulation Authority (NRA). Long-term questions include the timing of full capacity operation of RRP and continuation of the light water reactor (LWR) mixed oxide fuel (MOX) program. Before Fukushima, utilities expected to fuel 16-18 reactors with MOX by 2015. About 5 tons of plutonium (Pu) would be consumed under this scenario. However, the NRA is reviewing the restart of eight reactors that would burn MOX fuel, and the future of the Rokkasho and Japan Nuclear Fuel Ltd.'s (JNFL) MOX fuel fabrication (J-MOX) facilities is not yet determined.

In September 2014, the Japan Atomic Energy Commission released figures on Japan's plutonium balance at the end of 2013. Amounts of separated plutonium increased slightly because of shipments of MOX from Europe to Japan. At the end of 2013, Japan had roughly 36.3 tons of Pu stored abroad and 10.8 tons of Pu stored in Japan (of which 4.35 tons of Pu is stored at the reprocessing facilities, 3.35 tons at the fuel fabrication facility owned by JAEA, and 3.1 tons in other locations). Finally, the search for a site for high-level waste disposal has not progressed beyond research and development.

The variables that will affect Japan's plutonium balance include

- how many and when LWRs will restart
- amount of reserve capacity in spent fuel pools
- how many LWRs will use MOX (including those that will use full MOX cores)
- initial operating capacity of RRP
- when Monju restarts
- start of the J-MOX fuel fabrication plant
- disposition of Pu in Europe (swapping or production of MOX)

Looking further into the future, participants discussed how Japan's nuclear energy program is likely to diverge from past plans. For example, a second reprocessing plant appears now extremely remote, as does the fast breeder program. However, participants did not rule out fast reactors for minor actinide reduction.

POLITICAL CONTEXT

In addition to all the technical variables associated with reactor restarts and the fuel cycle program, political variables must also be taken into account. The see-sawing on nuclear power overall has made consistency challenging. In the view of one participant, the Democratic Party of Japan's (DPJ) policy of "Nuclear Zero" had been formulated too quickly with little debate. Policymakers were unable to reconcile support for the RRP in Aomori with a phase-out of nuclear power. The policy process also did not seriously address the buildup of separated plutonium, which led to concerns expressed by the United States. More precisely, Japan's possession of excess separated plutonium without a specific purpose could undermine the U.S.-Japan bilateral nuclear agreement.

For twenty years, Japan has had a policy of "no surplus plutonium", i.e. plutonium without a specific use. Since 2003, the JAEC has asked utilities to submit an annual plutonium usage plan. Last year, the JAEC and the Federation of Electric Power Companies (FEPC) of Japan announced that utilities will clarify the plutonium utilization plan before the recovery of plutonium will be resumed at RRP.

Given that Japanese nuclear fuel cycle policy assumed continued nuclear growth, recent shifts will require Japan to explore tools and measures to eliminate excess sepa-



Peter Hayes, Alan Hanson, and Chris Gadomski in attendance at the workshop.

rated plutonium. In the short term, this could include transferring ownership of plutonium to the United Kingdom and France, but there are questions about who would pay and whether France has capacity for fabricating more MOX fuel. It is not clear that the United Kingdom and France will have many incentives to retain and/or use Japan's plutonium. In the longer term, deploying reactors to consume plutonium (like the high-temperature gas-cooled reactor or an integral fast reactor) could help.

The rationale for the fuel cycle program has changed over the years. Although initially based on assumptions of uranium scarcity and energy security, or a quest for a 'national' or semi-national source of energy, that rationale is no longer widely considered valid. Instead, the domestic political concerns of the Aomori prefecture have prevailed. At this point, many in the Japanese government believe that Rokkasho is past the "point of no return," given over \$20 billion of investment. However, sunk costs are more politically than economically salient. The question to consider is what future costs the residents of Aomori prefecture may exact.

Participants discussed allegations about internal discussion in the Ministry of Foreign Affairs in the late 1960s and a secret study by the National Defense Agency (now the Ministry of Defense) on the need for Japan to maintain the economic and technological potential for manufacturing nuclear weapons. At the time, Japan was concerned about China's nuclear weapons development, as well as the credibility of the U.S. nuclear umbrella, and a possible decoupling of security interests between the United States and Japan. More recently, Shigeru Ishiba, a senior Liberal Democratic Party (LDP) official, stated in October 2011 that "we have to keep operating a nuclear fuel cycle backed by enrichment and reprocessing [...] a necessity of technical (potential) deterrence has been increased rather than decreased."

Several participants acknowledged that Japan is a latent weapons state by virtue of its overall fissile material production and advanced industrial capabilities. One participant noted that Japan, if it decided to build a bomb, would not use reactor-grade plutonium, which would be of poorer quality for a nuclear weapon. Nonetheless, talk of a “technical deterrent” to some observers signals intentions. In short, public statements about Japan’s nuclear program matter.

There was a wide range of views on a few issues, including the best scenario for nuclear power in Japan, the potential for fast breeder reactor commercialization, and threat perceptions in the region. In the view of one participant, the best scenario would be a slow, incremental, and deliberate phase-out of nuclear power, assuming that fast breeder reactors cannot be made safe enough or cost-effective. Although recognizing that China’s “concern” about Japan’s plutonium is hypocritical and politically driven, there are indications that China nonetheless sees Japanese weaponization as a real possibility. Chinese officials are likely content with a U.S. veto over South Korean or Japanese nuclear weapons. Regardless of what Japan decides on Rokkasho, it will still have huge stocks of spent fuel. Some rethinking on how to deal with those stocks is necessary.

INTERNATIONAL CONTEXT

In one participant’s view, Japan should be planning for drastically different futures for North Korea (collapse or capitulation). Either way, Japan would be better off reducing its plutonium stockpiles. A few options for deepening the perception of Japan’s nonproliferation commitment are possible. One path is pursuing a nuclear weapon free zone (NWFZ). Another pathway is creating mechanisms for ensuring mutually assured interdependence, whether in the realm of space and rocket programs, expanded safeguards, etc. Combined with reciprocal inspections in other states of mutual interdependence, Japan can do anything it perceives as necessary for its program.

Another participant agreed that interdependence would make sense in the region and that fast reactors will take time but are not an illusion. Other countries in the region (Russia, China, and India) are all pursuing fast reactors. Although North Koreans may have fears about Japan, their nuclear program is not guided by what Japan does.

Others expressed their skepticism about the ability of establishing a nuclear weapon free zone that includes North Korea. Another participant equated Japan’s latent nuclear weapons capability with those of Germany, Switzerland, and Canada. However, those countries do not reprocess their own spent fuel. The real question is how far those countries are from the acquisition of nuclear weapons, and how much lead-time would be required to build a nuclear weapon. Intentions are key.

One participant shared the view that plutonium clearly is not needed right away and there is no need to rush development of fast breeder reactors, although this is a view

that has been expressed for twenty or more years. If the real problem is ensuring a secure energy supply 50 to 100 years in the future for Japan, the answer may lie in renewables and potentially fusion energy. The fast breeder program should be seen as a hedge against uncertainties involving renewables and nuclear fusion.

Another participant suggested that plutonium isn’t needed to substitute for uranium (more can certainly be found with investment) but it is critical for miniaturization of weapons for missile delivery. With respect to North Korea, a potentially unified peninsula with industrial capability in the South and weapons in the North is a very scary scenario for Japan, which could inspire a desire for a nuclear deterrent in Japan.

Japan must explain to the public and the nonproliferation community the difference between commercial plutonium stocks/uranium and what happens when a country actually wants to pursue this option. Most of the Japanese plutonium is weapons-usable but not weapons-grade, and Japan’s enrichment facility is configured for reactor-grade enrichment. The issue is not diversion, but the know-how that can be misused to build clandestine facilities. In either case, Japan is unlikely to pursue a clandestine approach to fissile material acquisition for nuclear weapons.



Atsuyuki Suzuki, Aiji Yamato, Takuya Hattori, and Tomihiro Taniguchi in attendance at the workshop.

Another participant noted that safeguarding reprocessing, particularly in a large facility like Rokkasho, has its technical challenges. There are a lot of uncertainties regarding measurement; even a 1% error in the measurement would be the equivalent of 3 significant quantities (SQ) worth of fissile material. Furthermore, safeguarding the facilities costs \$100 million (at \$10 million annually), which is beyond the International Atomic Energy Agency’s (IAEA) budget to support. Such safeguards would re-

quire the cooperation and funding of the Japanese government. It is probably easier to safeguard a long-term underground disposal than a large bulk processing facility.

The participant also noted that Japan should consider the perceptions of other countries. In particular, Japan should reflect on how comfortable it is seeing reprocessing and growing stockpiles of plutonium in other countries. A Japanese decision to move forward with reprocessing could influence South Korean and Chinese decisions to move forward with such facilities. Finally, Japan would also have to consider the effects on countries that may eventually seek reprocessing, but do not have an Additional Protocol in force. The perception of the “bomb in the basement” is problematic, even if political leaders didn’t initially understand the implications of the statements such as the ones described above.

Participants discussed a recent suggestion that Japan offer to store all of the excess plutonium under the custody and control of the IAEA. If Japan doesn’t need the plutonium now, then it could easily put it under IAEA custody. Essentially, this system would involve two keys (one Japanese, one IAEA) for access to the plutonium. Japan could provide an end-use statement. Such a measure would demonstrate transparency for those materials for which Japan has no immediate use.

While this idea isn’t new (and one that the United States initially opposed many years ago), some participants noted that this might be difficult for the IAEA to do, and that Japan has already made declarations and sent some of its excess plutonium and HEU to the United States. But there is also a sovereignty question: should Japan be the only country obliged to do that? Why not the United States and Russia? Although some participants suggested that Japan’s unique status as the only non-nuclear weapon state with reprocessing should be reason enough to pursue this, others noted that taking a discriminatory line between nuclear weapon states and non-nuclear weapon states posed a profound question for the nuclear nonproliferation regime.

Japan already has stringent real-time monitoring on its reprocessing program, as opposed to other reprocessing programs. Such a proposal, however, would likely cost very little and would offer some marginal transparency to the program. It could be implemented in a trilateral fashion between the U.S., Japan, and the IAEA. On the other hand, its effects would be marginal and it wouldn’t stop Japan from weaponization if that decision were ever made. Furthermore, it would only deal with the plutonium stockpiles, and not reprocessing itself. Another participant noted that in order to give any sense of custody to the plutonium, it would have to be in the country itself; the physical location of the material matters.

OPTIONS FOR MOVING FORWARD

Participants discussed three basic approaches for Japan to assess their costs and benefits, focusing on recommendations. These included a “business as usual” approach, one of principled restraints on plutonium, and one of repurposing existing facilities.

Business as Usual

This group explored the pros and cons of continuing on the existing path, which was defined as restarting Rokkasho but with some prerequisites:

- Reactors must restart (although there was no agreement on how many would be required).
- Some of the reactors would have to use MOX fuel.
- Dry cask storage at reactors and interim storage would need to move forward.
- Linkage to “appropriate” plutonium stock levels.

The group viewed the main technical costs of this approach as those associated with moving forward with MOX-fuelled LWRs as opposed to fast reactors. The main political costs were regional and international in nature, as opposed to domestic political costs. The benefits, on the other hand, were seen as primarily local financial and political ones for the Aomori prefecture. This approach would also take advantage of sunk costs for RRP and would help reduce the financial strain of importing liquefied natural gas.

In terms of messaging, Japanese officials should differentiate between domestic and international stakeholders. Within Japan, the message should be that reprocessing is tailored to actual needs (it is not reprocessing just for reprocessing’s sake) and that Japan will take a deliberate, phased approach (e.g., restarting reactors before RRP restart, particularly those that burn MOX). Outside of Japan, stakeholders need to know that Japan is pursuing reprocessing along with dry cask storage, that the government is seeking an immediate interim storage solution for spent nuclear fuel (SNF), and that international solutions are limited.

Principled Restraints

This group was tasked with exploring potential restraints on Japan’s fuel cycle program that would contribute to strengthening the nonproliferation regime. Participants discussed a few different ways to follow principled restraints on reprocessing. One approach would be to restrain facility operations (e.g., operating at less than full capacity); another would be to specify a timeframe for resolving issues, handling more immediate spent fuel storage issues before reprocessing. In one sense, Japan is already practicing restraint, since it is foregoing plutonium separation until plutonium usage is defined.

A “running stock” of separated plutonium is necessary for the MOX fuel fabrication process. This is somewhat dependent on MOX fuel consumption, but also on the facility’s throughput. Some participants felt that the current stock (about 4 tons) is about right. Japan could calculate how much MOX it will burn once reactors restart and agree to not produce more than that quantity. This approach, however, would not address the current build-up of separated plutonium. If there is an agreed-upon “excess” amount, Japan could place it under international custody.

In terms of safeguards, there's probably not much more that could be done, but measures to improve nuclear security (e.g., armed police) could be helpful. With respect to slowing the start-up of Rokkasho, this would make reprocessing more expensive per unit cost. On public outreach, the Japanese public is concerned more about safety than diversion. Explaining reprocessing as a way to deal with storage problems might be a helpful approach with the public.

Between sunk costs, difficulty in moving spent fuel around, the lack of public support, and geological challenges, disposal of spent fuel is a long way off. The only alternative is to continue the program as steadily as possible and retain confidence measures. Selling MOX or separated plutonium abroad is not realistic since it is unclear who would buy it. Perhaps Japan could reprocess foreign spent fuel like the United Kingdom and France, but public acceptance is not assured. Custodial control by the IAEA is an option that might help Taiwan and Korea deal with their spent fuel. The international arrangement would help public workers understand why a storage facility is necessary, and it would be a symbol for an international arrangement.

This group believed that:

- Japan shouldn't reprocess until after J-MOX starts, so the stockpile of separated plutonium will decline anyway.
- Further reprocessing should be suspended until operationally necessary (point at which MOX-burning nuclear power reactors are "foreseeable").
- Some additional transparency on reactor needs and timing is necessary.
- In terms of the cost, reducing operations at RRP would increase the unit cost of reprocessing, but most of the costs are sunk anyway.
- Japan should emphasize the following messages: these steps are rationally necessary for the fuel cycle, they will retain jobs, and they will reduce the volume of spent fuel in pools.



Laura Rockwood and Olli Heinonen discuss IAEA safeguards at the Rokkasho Reprocessing Plant.

For any of the futures, the Japanese government must deal more concretely with disposal imperative and should examine a wider range of disposal options than just those that conformed to the original vision that maximized reprocessing and recycling, including expanded surface interim storage at existing or new sites, shallow subterranean disposal, and deep borehole irretrievable disposal, at home or abroad.

A few participants with technical and engineering expertise believed that reprocessing should start earlier. Another noted that you might need as much as 8 or 10 tons as an operating stock (in contrast to the 4 tons currently available at J-MOX, which is approximately one year's stock for J-MOX operation). So 4 tons might not be enough for the stable operation of J-MOX. It might also be necessary to start early not just to accumulate the stock but also to gain experience and maintain skills in operation. Japan would have to provide a reason why it couldn't use European stocks of Pu (hard to transport, in powder form, etc.)

Repurposing Rokkasho

This group explored whether the RRP could be operated for purposes other than domestic recycling of spent fuel for Japan. The participants considered three options: 1) using RRP for MOX fuel for LWRs (effectively repurposing RRP away from the truly closed fuel cycle that would use fast breeder reactors); 2) using RRP to establish technology to keep future options open; and 3) multilateral function. In general, the economics of reprocessing make it difficult to justify operating RRP for MOX LWRs except for waste management purposes (i.e., reducing the volume of SNF to reduce the size of an eventual repository). At its current capacity (800 tons per year), RRP could still meet domestic needs, and if interim storage is completed, there could be room at RRP for storing spent fuel (currently, capacity is fully utilized). In considering multilateral options, however, participants acknowledged that capacity was limited, and no one could imagine a strategy where the South Koreans would be involved at RRP. Even if Japan took in foreign SNF, another country would have to take the waste (similar to the United Kingdom and France).

SUMMARY

Japan has steadfastly pursued the closed nuclear fuel cycle for decades. Japan has also undertaken confidence-building measures in addition to developing state-of-the-art IAEA safeguards for the Rokkasho Reprocessing Plant.

The accident at Fukushima in 2011 has delayed certain milestones – like opening the Rokkasho Reprocessing Plant – and raised serious questions about the feasibility of others (e.g., pursuing fast breeder reactor commercialization). After three years, there is more evidence that certain elements of a “business as usual” approach are creeping back into Japan's nuclear policies. This could leave Japan unprepared to respond to future potential crises – whatever the next “big shock” may be.

A clean policy decision on Japan's nuclear fuel cycle is not in the cards, but there are steps that policymakers could take to build trust through transparency, particularly about how certain decisions are connected to others. Leaders in Japan (whether in industry, government or academia) should explain the key operational, economic, and technological considerations that underline fuel cycle policy decisions and how they relate to one another. For example, how many operating nuclear power reactors will make Japanese enrichment and reprocessing cost-effective and why? Flexibility should not be limited to keeping options open, but also in pursuing multiple options simultaneously (e.g., dry cask storage, interim storage and limited reprocessing). Above all, Japan needs to have a credible strategy for limiting plutonium separation that its neighbors and allies find reassuring, despite the lack of interest domestically in this issue.

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