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WAGGING THE PLUTONIUM DOG

James M. Acton

Japanese Domestic Politics and Its International Security Implications

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CONTENTS

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SUMMARY

Japan is the only non-nuclear-weapon state with a program to extract plutonium from the spent fuel produced in nuclear reactors—a process termed reprocessing—to fabricate more fuel. Because plutonium can be used directly in the manufacturing of nuclear weapons, Japan has, in keeping with internationally recognized best practice, pledged not to produce more plutonium than it can consume. Serious questions are emerging, however, about whether it can uphold this commitment.

Japan's Entrapment

- Japan is entrapped in reprocessing. Commitments made by the national government to local communities to facilitate the development of Japan's nuclear industry and, in particular, its industrial-scale reprocessing facility, Rokkasho Reprocessing Plant (RRP) make RRP's operation effectively inevitable.

- Entrapment results in domestic pressure to operate RRP. In 2012, that pressure forced the administration of then prime minister Yoshihiko Noda, which sought to phase out nuclear energy, into supporting reprocessing.

- Following the March 2011 Fukushima Daiichi nuclear accident, Japan faces severe challenges—including domestic politics—in bringing nuclear reactors back into operation. Over the next decade, Japan is very unlikely to restart more than about half of the reactors designated for plutonium consumption.

- Within a decade, Japan will probably be producing more plutonium than its reactors can consume.

Takeaways for Japan and the International Community

Japan could take steps to reduce its supply of plutonium. It could operate RRP at a lower throughput and negotiate with the United Kingdom, and possibly France, over their taking ownership of Japanese plutonium stored in Europe. Japan might also conduct research into alternative means of disposing of plutonium, possibly in collaboration with the United Kingdom and the United States.

While operating RRP, Japan could take the steps necessary to create the option of phasing out reprocessing in the future. Such steps would include changing the law to permit funds set aside for waste management to be used for the direct disposal of spent fuel and ensuring that Japan's planned geological repository is licensed for spent fuel. Japan would also need to secure additional interim storage facilities for spent fuel, possibly by offering greater financial incentives to any prefecture willing to host one.

The Japanese government must take ownership of the problem. No realistic solution can be implemented solely by the private companies that own Japanese plutonium and operate RRP.

The government should develop a plutonium management strategy as soon as possible. Waiting will merely exacerbate the challenges.

Other states considering reprocessing should design programs so they do not become entrapped. A critical step would be to ensure adequate storage space for spent fuel.

INTRODUCTION

Since the mid-1970s, the United States has made ever more strenuous efforts to minimize stockpiles of nuclear material around the world. These efforts are partially motivated by, and usually explained in terms of, preventing nuclear terrorism by ensuring the security of materials that can be used directly in the manufacturing of nuclear weapons—separated plutonium and highly enriched uranium (HEU) most significantly. Since 2009, when he pledged "to secure all vulnerable nuclear material around the world within four years,"[1] U.S. President Barack Obama has invested unprecedented political and financial capital in U.S. nuclear threat reduction programs. Although his four-year goal was not met, his administration has succeeded in removing or denaturing almost 3 metric tons of foreign HEU and plutonium—significantly more than the United States had secured in the previous three decades.[2] Moreover, Washington has also made progress in widening international support for fissile material minimization efforts. Most notably, at the 2014 Hague Nuclear Security Summit, 53 world leaders pledged, for the first time, to minimize civilian stocks of both HEU and plutonium.[3]

U.S. President Barack Obama has invested unprecedented political and financial capital in U.S. nuclear threat reduction programs.

Fissile material minimization efforts were originally motivated by nonproliferation—preventing the further spread of nuclear weapons among states—and this remains one of the goals, even if, for reasons of diplomatic courtesy, Washington rarely says so explicitly.

Because fissile material accumulations significantly reduce the time required to manufacture nuclear weapons (or, equivalently, increase the number of nuclear weapons that can be manufactured in a short time), they exacerbate proliferation risks. International Atomic Energy Agency (IAEA) safeguards, which non-nuclear-weapon states party to the Nuclear Non-Proliferation Treaty are required to accept, mitigate these risks somewhat, but do not solve them given that their purpose is to detect—not prevent—the diversion of nuclear material, that is, its removal from declared and monitored activities. The stockpiling of nuclear material, which reduces the time available for responding to a diversion, makes an effective response to proliferation threats more difficult and less likely. It is for this reason, for example, that the nuclear agreement with Iran that was concluded in July 2015 commits Tehran not to produce any HEU (or, indeed, to enrich to anywhere near that level) and to reduce its stockpile of low-enriched uranium drastically (given that this stockpile could be converted into HEU relatively rapidly).

Currently, no state is producing HEU for nonmilitary purposes, but six do have civilian reprocessing programs, which aim to separate plutonium from spent nuclear fuel for the purpose of manufacturing more fuel.[4] Along with the United States and various other countries, all six of these states have committed to adhere to the IAEA's *Guidelines on Plutonium Management*, which explicitly recognize the proliferation risks associated with separated plutonium and underscore the "importance of balancing supply and demand."[5] As such, these states have made a political commitment not to stockpile more separated plutonium than the so-called working stocks they need to have on hand to implement their fuel-cycle policies.

Of the six states with civilian reprocessing programs, only one—Japan—is a non-nuclear-weapon state.

Of the six states with civilian reprocessing programs, only one—Japan—is a non-nuclear-weapon state. Japan's commitment to and compliance with IAEA safeguards have been exemplary. However, starting in the 1980s, there were growing concerns that Japan lacked the ability to use the plutonium it planned to separate and, as a consequence, was on course to stockpile large quantities of the material.[6] In response, Tokyo pledged, in 1991, not to separate plutonium that it could not burn in its reactors and has repeated this no-excess pledge on many occasions since.[7] It further strengthened this pledge in 1997 by agreeing to adhere to the IAEA's *Guidelines on Plutonium Management*.

Yet, because of various delays in implementing its recycling program, Japan's stockpile of separated plutonium now exceeds any reasonable definition of working stocks. It has accumulated about 11 metric tons of the material onshore from production in a domestic pilot-scale

facility and from the reprocessing of Japanese spent fuel in France and the United Kingdom. Another 36 metric tons of separated plutonium are still located in those states, waiting to be returned.[8] (For context, the IAEA assumes that 8 kilograms is "the approximate amount . . . for which the possibility of manufacturing a nuclear explosive device cannot be excluded."[9])

All future reprocessing of Japanese spent fuel is due to take place onshore at Rokkasho Reprocessing Plant (RRP), which has a design capacity of roughly 8 metric tons of plutonium per year. Extensive repairs to this facility, to correct serious design flaws revealed during testing, were completed in 2013. Japan Nuclear Fuel Limited, the plant's owner and operator, now intends to reopen the facility in March 2016, after the Japanese regulator has certified its compliance with new safety standards—although further delays are almost certain.[10]

Even before the accident at Fukushima Daiichi Nuclear Power Station in March 2011, Japan was facing problems in securing enough reactor capacity to ensure that the expected plutonium supply from RRP could be consumed. The accident has severely exacerbated these challenges. At the time of this writing, in June 2015, no Japanese power reactors are in operation. For a variety of reasons, including domestic politics, many will never reopen; the others appear set to come back into operation very slowly. Many nonproliferation experts, particularly in the United States, have argued that, to avoid stockpiling yet more plutonium, Japan should now delay the restart of RRP indefinitely or even shut it permanently.[11]

In fact, since the Fukushima Daiichi accident, Japan has considered doing just that. In the summer of 2011, the government launched a major review of Japanese energy policy. Pushed by a tide of public concern about nuclear safety, it eventually decided on the goal of eliminating nuclear energy by the 2030s, and was advised that it should also abandon reprocessing by the Japan Atomic Energy Commission—the cabinet's most important advisory body on nuclear energy and the government organization responsible for nonproliferation.[12] The result was a serious discussion about shutting RRP.

This discussion was short-lived, however. It sparked a furious backlash from the tiny community in the remote part of northern Japan that hosts RRP and strongly supports its operation. Remarkably, this community had garnered the power, should the plant be shut, to threaten a domestic crisis by demanding the removal of the spent fuel that was already stored there, and a simultaneous international crisis by refusing to import nuclear waste from abroad that Japan was contractually obliged to accept. These threats were so potent that the administration of then prime minister Yoshihiko Noda was forced into supporting the continuation of reprocessing, even while advocating for a phaseout of nuclear energy.[13] The result of this inherently contradictory policy would have been the accumulation of huge quantities of plutonium.

In the end, the Noda administration's plan could not even gain the approval of the whole cabinet (for reasons unrelated to nonproliferation). Then, in December 2012, the Liberal Democratic Party defeated Noda's Democratic Party of Japan at the polls. Subsequently, a new coalition government, led by Prime Minister Shinzo Abe, adopted an apparently more coherent energy plan, under which Japan will continue with both reprocessing and nuclear power.[14] However, the process of crafting the Noda administration's energy plan provides a graphic illustration of just how entrapped in reprocessing—or, at least, in the operation of RRP—Japan has become.

First described by the political scientist William Walker in regard to the United Kingdom's reprocessing program, entrapment occurs when the web of political, legal, and financial commitments required to facilitate major projects severely reduces a government's flexibility to adapt to changing circumstances.[15] In the British case, the most important commitments were, coincidentally, contractual obligations to reprocess Japanese spent fuel.

By contrast, domestic politics, which was a relatively minor consideration in the United Kingdom, is the most important mechanism entrapping Japan. Specifically, Japanese local politicians have acquired a remarkable ability to prevent significant changes to the country's nuclear policy. They have assumed the status of veto players—individual or collective decisionmakers whose agreement is required for the status quo to be changed—to use the political science jargon.

These local politicians have now placed the national government in an uncomfortable double bind.[16] Any renewed attempt to back away from reprocessing would be met with fierce resistance from the local politicians connected with RRP. Meanwhile, the local politicians connected with reactors will severely complicate the task of consuming the plutonium that RRP produces. As a result, there is a serious risk that, within a decade, Japan's already-significant stockpile of separated plutonium will start to grow rapidly.

Even if Japan's plutonium policies are being driven by domestic politics—and not the maintenance of a nuclear weapons option, as is often argued[17]—it would, for at least three reasons, be shortsighted to conclude that the country's existing plutonium stockpile (let alone the possibility that it may grow rapidly) does not pose serious security risks.

First, all plutonium stockpiles, wherever they are located and regardless of why they were acquired, exacerbate the risk of nuclear terrorism. Abe himself acknowledged this concern in a joint statement with Obama.[18]

Second, some of Japan's neighbors believe (incorrectly) that Tokyo is accumulating plutonium for military purposes. China has been particularly vocal in its criticism, and although its statements are partly political opportunism at a time of particularly poor Sino-Japanese relations, they probably also reflect genuine concern about Japan's long-term intentions.[19]

As a result, by producing yet more plutonium without a credible plan to use it, Japan is likely to exacerbate regional tensions further.

Third, Japan's stockpiling of plutonium sets a precedent that could make it more difficult to limit the fissile material holdings of states that do pose more serious proliferation risks. Domestic politics is once again at issue: a government is likely to find it easier to explain and sell, as it were, limits on its nuclear program (whether negotiated or unilaterally undertaken) to domestic stakeholders if such limits are widely accepted internationally. Comparisons to other states—including Japan—are, for example, common in the internal Iranian discourse over limiting its nuclear program and may also influence the domestic debate in states that acquire fuel-cycle capabilities in the future.[20]

Given these risks, Japan has a clear interest in ensuring that it lives up to its commitments by not accumulating even more plutonium and, ideally, drawing down its existing stockpile over time. Developing a credible way forward requires understanding the nature of the challenges Japan faces, the most important of which is the domestic politics that creates pressure to separate plutonium while hindering Japan's ability to use it. To this end, this study analyzes both the causes of Japan's entrapment in reprocessing and the challenges it now faces in trying to burn plutonium after the Fukushima Daiichi accident, before discussing a politically realistic way forward.

LOOKING BACK: HOW JAPAN BECAME ENTRAPPED IN REPROCESSING

AOMORI, ROKKASHO, AND THE POLITICS OF SPENT FUEL

The roots of Japan's entrapment lie in policy decisions made decades ago. Following the lead of the United States (which was Japan's principal nuclear technology supplier), the Japan Atomic Energy Commission (JAEC) identified the goal of reprocessing spent fuel in its very first long-term plan, drafted in 1956—a decade before the country's first nuclear power reactor became operational. Initially, Japan had to rely on foreign reprocessing services, and its utilities signed contracts with the United Kingdom and France in the 1970s and 1980s. As part of these contracts, Japan agreed to repatriate the nuclear wastes that are an inevitable by-product of reprocessing. Some high-level waste from the United Kingdom and some less radioactive material from France are still to be returned, along with separated plutonium in the form of mixed oxide fuel.[21]

Tokyo's ultimate goal, however, was always to acquire an indigenous reprocessing capability. To this end, after a pilot facility began to separate plutonium in 1977—against considerable opposition from the United States, which had come to oppose reprocessing by then—the search for a site for an industrial-scale facility began. The utilities responsible for generating electricity were nominally in charge of this project and, in 1984, their umbrella organization, the Federation of Electric Power Companies, formally approached Rokkasho Village in Aomori Prefecture, in the far north of the main Japanese island of Honshu, with a request to host a number of nuclear facilities, including the reprocessing plant.

The selection of this site, apparently at the "suggestion" of the federal government, appears to have been motivated as much by regional development goals as any technical merits it

offered.[22] Rokkasho Village and the surrounding Shimokita Peninsula were one of the least-developed parts of the country. Moreover, a series of government-led development initiatives over the previous twenty-five years had all ended in failure. In the first such project, a company to manufacture sugar out of domestically grown beets was established in 1959.[23] However, the project was terminated when the government permitted sugar imports from abroad, depressing prices. Three further projects finished equally inauspiciously because, it is widely believed in Aomori, of a lack of commitment by the central government.

This "history of betrayal"[24]—to use the words of Naomichi Fujikawa, a senior official in the Aomori prefectural government who was deeply involved in the siting decision—created strong local concerns that the reprocessing project, like the others that had preceded it, would be canceled. These concerns were magnified as the project fell progressively further behind schedule and its costs kept rising. They are manifested today in the way that prefectural and village officials tend to stress the binding nature of their agreements with the federal government.[25] Indeed, the Aomori government has published and disseminated a book containing these agreements.[26]

Aomori Prefecture's concerns about what might happen if the project were canceled were thrown into sharpest relief by the prospect of spent fuel and high-level nuclear waste being shipped into the prefecture. The complex at Rokkasho includes storage facilities for the nuclear waste produced by both Rokkasho Reprocessing Plant (RRP) *and* the reprocessing of Japanese spent fuel in France and the United Kingdom. There is no other site in Japan licensed to store them.

Aomori politicians did not want to become responsible for managing this waste for the long term, and right from the start of the project, its fate was an issue. In 1985, while the prefecture was considering whether to host the facility, it was assured by the national government that the ultimate disposal of the waste from reprocessing would not be Aomori's responsibility.[27] In 1994, the prefecture secured a promise from Tokyo that such disposal would not take place in Aomori and also that high-level waste would be stored at Rokkasho for no more than fifty years.[28] Then, in April 1995, the governor of Aomori at the time, Morio Kimura, prevented the docking of a ship carrying the first batch of high-level waste from France. He only relented, after a day-long standoff, when he secured another pledge from the federal government that Aomori would not become a permanent disposal site.[29] Although this pledge was essentially a repeat of the one made the previous year, the governor did demonstrate his willingness to block a foreign ship from docking—with the consequent risk of an international incident—thus creating a powerful source of leverage on the central government in Tokyo and effectively establishing himself as a veto player.

In January 1997, at about the same time that the spent-fuel storage ponds at RRP were completed, Japan Nuclear Fuel Limited (JNFL) began negotiations with Aomori over what is called a safety agreement and was a prerequisite to transferring spent fuel into

the ponds.[30] At the time, JNFL hoped to commence shipments in April of that year. The plant was beset by serious construction delays, however, and there was considerable local concern that the project might be canceled and the spent fuel left there indefinitely.[31]

An eighteen-month-long standoff ensued, during which Kimura blocked, this time for three days, the docking of a ship carrying high-level waste from the United Kingdom.[32] It was eventually resolved in July 1998 when JNFL agreed to a memorandum, originally proposed by Kimura at the start of negotiations, which states that if it becomes "extremely difficult to ensure the execution of reprocessing . . . JNFL shall promptly take necessary and appropriate measures including the removal of the spent nuclear fuel from the site."[33]

Almost 3,000 metric tons of spent fuel, containing about 30 metric tons of plutonium, are stored at RRP today. There is an almost universally held assumption among Japanese officials and experts that, if the reprocessing program were terminated and this spent fuel were removed from Aomori, it would have to be transferred back to the reactors where it was produced—a horrendously complex and controversial task, as proponents of reprocessing are quick to emphasize.[34] In fact, the threat to expel spent fuel from Aomori has become a second powerful means—alongside the threat to prevent the import of nuclear waste from abroad—for the prefecture to coerce the central government. Thus, in spite of massive cost overruns—construction of the plant had cost ¥2.2 trillion (about $22 billion) as of 2013, compared to an estimated ¥760 billion (about $5.6 billion) at the time of the 1989 license application—there was never any serious discussion about cancelation prior to 2012.[35]

Rokkasho Village, unlike Aomori Prefecture, views the risk of reprocessing being terminated mainly in economic terms. Most of the community has been won over by the economic benefits of RRP, in spite of persistent unease about the spent fuel and high-level waste being stored at the site. The original decision to host the facility was controversial. In 1986, there were violent clashes between fishermen and riot police.[36] But, as the facility's economic benefits have gradually been felt, local critics have largely fallen silent (even if the Fukushima Daiichi accident did lead to an uptick in concern). Reflecting a sentiment that is widely held today, Tooru Sasaki, a former head of the Aomori Policy Planning Division, concluded that Aomori's governor at the time of the siting decision "wasn't wrong. Rokkasho has the highest income of any village within the prefecture."[37]

The economic benefits from the plant have been accrued in various ways. In 1974, Japan created a system of subsidies (including direct payments and discounts on electricity rates) for the communities that host nuclear power facilities.[38] In 2013, Aomori Prefecture received ¥17.7 billion (about $177 million) in such subsidies (about 2.5 percent of its total annual expenditure),[39] while Rokkasho Village received ¥3 billion (about 19 percent of its expenditure).[40] Aomori's subsidies result from its hosting a number of nuclear facilities,

but Rokkasho's are almost exclusively related to the reprocessing facility, the high-level-waste storage facility, and a co-located enrichment plant.[41]

Aomori also levies taxes on a range of nuclear activities, including the import and storage of spent fuel and the production of high-level waste from reprocessing. The total income from these taxes is currently expected to be about ¥19 billion annually (approximately $160 million per year at current exchange rates), though not all of this revenue is associated with reprocessing specifically.[42] In addition to receiving a share of this income, Rokkasho Village also collects its own fixed asset taxes (a property tax on businesses). The nuclear facilities represent, by far, the single largest contribution to this revenue stream, which totaled about ¥5.25 billion (approximately $62 million) in 2010—an amount that is more than seven times larger, on a per person basis, than the national village average.[43] The reprocessing plant is a key source of local employment and has stimulated the economy indirectly, given that many local firms were employed as subcontractors in the plant's construction.

The reprocessing plant is a key source of local employment and has stimulated the economy indirectly.

Although both Aomori Prefecture and Rokkasho Village have benefited economically from reprocessing, it is not surprising that the latter worries mainly about the economic effects of terminating reprocessing, whereas the former is also concerned with the fate of spent fuel and high-level waste. Rokkasho benefits economically from the reprocessing plant much more, in relative terms, than the prefecture. Aomori, by contrast, must grapple with issues relating to the management of spent fuel and high-level waste, if for no other reason than a lack of expertise and capacity in the village. Nonetheless, even if the two entities have slightly different emphases to their concerns, they share a clear common interest in ensuring the project's continuation. They have also developed the means to try to deter the central government from changing policy. These means were put to the test in 2012.

WAGGING THE DOG

In June 2011, three months after the Fukushima Daiichi accident, then prime minister Naota Kan created the Energy and Environment Council (EEC), consisting of cabinet ministers, to forge a new energy policy. In 2010, the last full year before the accident, nuclear energy was used to generate about 26 percent of Japan's electricity, and the government's energy plan from that year called for this contribution to increase to around

50 percent by 2030.[44] As part of the review, the Japanese bureaucracy was tasked with studying three options under which nuclear energy's contribution would be reduced to 0 percent, 15 percent, or 20–25 percent (a fourth option—maintaining existing policy—was briefly considered but quickly rejected).

The JAEC was asked to make recommendations for the fuel cycle under each of these scenarios and created a subcommittee to consider the question in more detail. At a March 2012 meeting, the subcommittee was advised by the Office for Atomic Energy Policy, which is part of the Cabinet Office and serves as the commission's secretariat, that phasing out nuclear energy while continuing to reprocess would carry "a high possibility of failure."[45] It appears to have meant that it would be difficult to ensure that all separated plutonium would be consumed. The commission shared this concern and recommended, in its final report from June 2012, that reprocessing should be abandoned if nuclear energy were phased out. It called for reprocessing to be continued in the other cases (albeit side by side with direct disposal in some circumstances).[46]

At this stage, however, there was a widespread assumption that the EEC would *not* support the complete phaseout of nuclear energy. At the time the review got under way in mid-2011, the government sent out mixed messages about whether it would support a complete phaseout.[47] As 2011 wore on, ministers largely stopped talking about a phaseout and, by 2012, appeared set to pick the 15 percent option.[48] As a result, although the JAEC had recommended in mid-2012 that phasing out nuclear energy would require abandoning reprocessing, there was no impetus to plan for such an eventuality and, indeed, no evidence that any planning took place.

Unsurprisingly, therefore, the policy review did not spark too much concern in Aomori Prefecture or Rokkasho Village initially. In the fall of 2011, Rokkasho did little more than call for the current fuel-cycle policy to be maintained.[49] Aomori Governor Shingo Mimura took various opportunities, meanwhile, to remind bureaucrats involved in the review about the central government's promises to Aomori. In January 2012, for example, at a meeting with the JAEC, the governor explicitly threatened that, if reprocessing were terminated, he would expel not only the spent fuel being stored in Aomori but also the high-level waste that had been imported from France and the United Kingdom.[50] (Whether he actually had the power to demand the removal of this waste is unclear, but he certainly did have the power to prevent ships carrying high-level waste from using port facilities in Aomori, as his predecessor had done, and could thus prevent the import of more.) These statements were, however, unremarkable; he had said similar things to the same committee even before the Fukushima Daiichi accident.

It was public pressure that shook up the process. For over a year after the Fukushima Daiichi accident, the anti-nuclear movement failed to gain much traction. Then, in the summer of 2012, a series of large-scale protests against nuclear energy were mobilized.[51]

At government-organized meetings, almost 70 percent of participants expressed support for a phaseout.[52] By late summer, ministers began to consider the zero option seriously. On August 21, then minister for national strategy Motohisa Furukawa who chaired the EEC, came out publicly in favor of a phaseout, even as his boss, Noda, who had become prime minister in September 2011, was still talking more cautiously about reducing Japan's dependence on nuclear power.[53]

Given the JAEC's recommendation that if the country were to phase out nuclear energy it should also cease reprocessing, a serious threat to RRP had emerged. Aomori Prefecture responded swiftly. On August 22, the same day that Noda met with anti-nuclear protesters, Mimura submitted a petition to the central government that called upon it to "give sufficient consideration" to Aomori, and he hinted publicly at (though did not explicitly repeat) his previous threats.[54] He also met privately with five cabinet members.[55] It seems very likely that he was more direct in private because, shortly afterward, these ministers started to recognize Aomori's concerns publicly. On September 4, Goshi Hosono, the minister responsible for managing the nuclear accident, mentioned the visit by Mimura and emphasized the importance of Aomori's contribution to the fuel-cycle project.[56] On the same day, Yukio Edano, who was the minister of economy, trade, and industry at the time, made a similar point at a meeting of the EEC.[57]

Under intense pressure from the public to phase out nuclear energy and intense pressure from Aomori and Rokkasho to continue with reprocessing, it opted to do both.

Two days later, on September 6, the Democratic Party of Japan (DPJ) released its energy plan, which called for the complete elimination of nuclear energy. It stopped short, however, of calling for reprocessing to be terminated and advocated instead for a review of the fuel-cycle program, while emphasizing the need to gain Aomori's understanding of any future policy changes.[58] These concessions did little to mollify Aomori or Rokkasho. The following morning, the chairman of the Rokkasho Village council, after a meeting with the president of JNFL, publicly threatened that, if reprocessing were terminated, he would expel all spent nuclear fuel and high-level waste and prohibit the import of any more.[59]

The EEC blinked. A week later, it released its draft energy policy. Under intense pressure from the public to phase out nuclear energy and intense pressure from Aomori and Rokkasho to continue with reprocessing, it opted to do both. It did not even try to present

this decision as a rational policy choice. Rather, it stated baldy, as its *only* justification for continuing with reprocessing, that

> commitments were made to Aomori Prefecture that nuclear fuel cycle policy must be promoted consistently and steadfastly in medium and long terms, . . . and that, if reprocessing projects should be found extremely difficult to surely implement, necessary and appropriate steps be swiftly taken, which include relocation of spent fuels by Japan Nuclear Fuel Limited . . . to outside its facilities. These commitments should be honored.[60]

The EEC did not explicitly restate Japan's policy against stockpiling excess plutonium, let alone present a credible plan to use the plutonium that was to be separated at RRP while phasing out the nuclear reactors that were the only means to consume it.[61] Nominally, it fell to the JAEC to protect nonproliferation interests. However, the commission had steadily lost power over the decades. Moreover, it had been further weakened by this time, even though it had no role in safety, because it was widely seen as being part of the so-called nuclear village—the group of politicians, energy company executives, bureaucrats, and scientists that advocated for nuclear energy in Japan and was widely blamed for the Fukushima Daiichi accident.[62] As a result, there was no effective nonproliferation champion in government.

Did the EEC need to back down? Critics of Japan's reprocessing policy have since argued that Aomori Prefecture and Rokkasho Village's threat was not credible, because relocation of the fuel would have been a virtual impossibility and would have deprived them of significant revenues. These critics have argued that the central government could have "negotiated fairly" with Aomori and Rokkasho to enable the continued storage of spent fuel there even after terminating reprocessing.[63] They may be right. If negotiations had taken place much earlier in the process, it is just possible a solution could have been found. That said, the outcome to such negotiations would, at best, have been highly uncertain; given the history of betrayal to which Naomichi Fujikawa referred, Aomori and Rokkasho might well have been strongly disinclined to acquiesce to the abandonment of reprocessing in favor of yet more promises from the central government.

Moreover, in understanding what did happen—as opposed to what should have happened—three points are critical. First, the future of reprocessing was considered too late in the review to permit negotiations with Aomori over its termination. Second, what matters is not whether Aomori's threat was actually credible, but whether it was perceived as credible. The government's behavior strongly suggests that it was. Third, the threat was not only to expel the spent fuel being stored in Rokkasho, but also, inter alia, to bar the import of more nuclear waste from France and the United Kingdom. The credibility

of this part of the threat is hard to doubt. Blocking nuclear waste from entering Aomori would probably have been politically advantageous to the governor and would have come at a relatively modest financial cost to the prefecture.[64] It would, however, have imposed a potentially enormous political cost on the central government in the form of an international incident with two key partners. Many supporters of reprocessing regarded the threat of creating such an incident as a trump card. A Rokkasho Village councillor, Isao Hashimoto, described the need to accept high-level waste from abroad as the government's "Achilles' heel," reasoning that even if Tokyo were willing to break its commitments to Rokkasho Village, it wouldn't dare to break those with foreign countries.[65]

LACK OF SPENT-FUEL STORAGE AT REACTOR POOLS

Although the proximate cause of the Noda administration's decision to continue with reprocessing was the threat from Aomori and Rokkasho, this outcome was probably overdetermined. Even if the local community had been supportive of a shutdown, at least two other pressures might well have forced the government into operating RRP, at least for an interim period. A lack of storage space for spent fuel at reactors was perhaps the most vexing.

When nuclear fuel is discharged from a reactor, it must be stored underwater in adjoining spent-fuel pools. In Japan, because spent fuel was expected to be reprocessed, these pools were designed with only relatively limited capacities. Because of delays in starting industrial-scale reprocessing, there is now a lack of available space for spent-fuel storage. On average, 69 percent of the available pool-storage capacity at Japanese reactors is currently being used—although at some reactors, utilization rates are significantly higher.[66] One concern about terminating reprocessing, which Edano highlighted at the meeting of the EEC on September 4, 2012, was that spent-fuel pools would fill up, forcing reactors to close.[67] This was not an immediate problem since there were, at the time, only two reactors operating in Japan. It was, however, viewed as a serious medium-term problem because, although the council ended up supporting the long-term elimination of nuclear power, it believed that this energy source was needed during the transition and hence sought to restart reactors as soon as possible. This problem was compounded by Aomori and Rokkasho's threat, given that relocating the spent fuel stored at RRP would have taken up the majority of the remaining space in pools at reactor sites.[68]

Many other countries have managed a shortage of storage space by removing spent fuel from pools after an initial cooling period (at least five years but often longer) and then placing it in air-cooled dry casks, which are typically stored on the same sites as reactors. In Japan, however, only two small dry-cask storage facilities at reactor sites are operational (at Fukushima Daiichi and Tokai). An additional off-site facility in Mutsu City is essentially ready to start

receiving fuel—but this facility is located in Aomori Prefecture, and Mimura has stated that its operation is contingent upon a continued national commitment to reprocessing.[69]

The feasibility of terminating the reprocessing program immediately and completely in September 2012, while continuing to rely on nuclear energy for at least some time, therefore hinged on commissioning dry-cask storage facilities before reactors started to run out of storage space for spent fuel and were forced to shut down.[70] The prospective dates of shutdowns were rather uncertain because they depended not only on the rate at which reactors produced spent fuel but also on exactly which reactors were restarted, when the restarts occurred, and whether the spent fuel in Aomori was actually moved back to reactor sites. Perhaps the best that can be said is that the government would have had a few years to get dry-cask storage facilities up and running at those reactors facing the most acute spent-fuel storage problems.[71]

This timeline would have been rather challenging. Licensing a facility and procuring dry casks typically takes a few years. Moreover, securing consent for dry-cask storage from local communities tends to be difficult, and even more time-consuming. Once again, the desire not to become a de facto permanent storage site for spent fuel is a major cause of resistance. This resistance is particularly strong in prefectures that do not benefit, or benefit only marginally, from the electricity produced in the reactors that they host.

The desire not to become a de facto permanent storage site for spent fuel is a major cause of resistance.

For example, Kansai Electric Power Company's three nuclear power plants are located in the western part of Fukui Prefecture and are within that company's service area; however, the much more populous eastern part of the prefecture is serviced by a different power company. Fukui's governor, Issei Nishikawa, has argued that the prefectures that benefit most from these reactors should take on the responsibility of managing their spent fuel.[72]

Individual towns in Fukui can sometimes be more flexible. In 2004, for example, Mihama Town asked Kansai Electric Power Company to conduct a feasibility study for an interim storage site on its territory, presumably because it wanted the tax revenues from the facility and to ensure that its reactors, which are a key source of employment, would remain operational.[73] However, the plan was dropped because of opposition from the governor.[74]

To complicate matters further, even in prefectures that do receive the electricity from their nuclear reactors, consent to build a dry-cask storage facility can be slow in coming. For example, a 2008 plan from Chubu Electric Power Company to build a dry-cask storage

facility at Hamaoka Nuclear Power Plant foresaw the facility becoming operational in seven years.[75] Because construction and licensing takes only two or three years, this timeline implied four or five years would be needed to secure local consent, even though, to make the proposal more palatable, it was presented as part of a package that also involved building a new reactor to prevent job losses resulting from the shutdown of two older units.

Given the potential for serious local opposition, there was a real risk that, had the government terminated reprocessing in September 2012, some reactors might have run out of storage space for spent fuel and been forced to close. To be sure, this outcome was not an absolute certainty. The tax revenues and subsidies associated with hosting dry-cask storage facilities coupled with the job losses that would have resulted from reactor closures might have been enough to overcome any opposition. Furthermore, in the past, the central government has generally not attempted to convince local communities to accept dry-cask storage (possibly because it might undermine the rationale for reprocessing). A major push by the central government in favor of dry-cask storage might also have helped alter local calculations.

That said, the somewhat chaotic process of creating a new energy policy did not exactly encourage the careful crafting of a well-designed plan to develop dry-cask storage in parallel with a decision to terminate reprocessing. Ultimately, therefore, the lack of storage space for spent fuel was a second factor that made an immediate exit from reprocessing in 2012 extremely difficult.

FINANCING THE ROKKASHO REPROCESSING PLANT

A third factor was the financing arrangements for RRP and, in particular, the need for JNFL to pay off its loans. This problem attracted less attention than the others, but its consequences would probably have been felt much sooner—almost immediately, in fact—had the Noda administration terminated the reprocessing program in September 2012.

The funding arrangements for RRP are (predictably) complicated.[76] Initially, about half the construction costs were covered directly by the utilities in the form of advance payments to JNFL, that is, payments for future reprocessing services. These payments ceased in 2005 when the government created a so-called reprocessing fund to pay JNFL for the construction, operation, and eventual decommissioning of the facility. The utilities transferred the internal reserves they had accrued for reprocessing into this fund and are required to contribute to it, on an ongoing basis, by levying a surcharge on electricity bills. The utilities can draw from this fund to pay for reprocessing and, importantly, it appears as an asset on their balance sheets. In addition, at various points during the construction

of RRP, JNFL also took out commercial loans, which were guaranteed by the utilities. In 2013, these loans totaled ¥920 billion (about $9.2 billion).[77]

By law, the reprocessing fund, which stood at ¥2.5 trillion in 2013, cannot be used for any other purpose.[78] A government decision to terminate reprocessing would, therefore, have had two deleterious effects. First, it would have deprived JNFL of its primary source of income and would have left it unable to repay any of its loans, for which the utilities would then have been responsible. Second, because the utilities would have been unable to draw from the reprocessing fund, it would have wiped a significant asset off their balance sheets. The utilities were already in a precarious financial position in the summer of 2012, given that almost all nuclear reactors were offline following the Fukushima Daiichi accident. There was concern, therefore, that a government decision to terminate reprocessing could have had spillover effects that would have damaged the entire Japanese economy, especially the financial sector.[79]

At one level, there was an obvious solution to this problem: change the law to allow the reprocessing fund to be used to pay off existing loans. This step would not have created new unfunded liabilities for spent-fuel management because, according to the JAEC's own estimates, reprocessing is more expensive than direct disposal.[80]

In practice, however, there were two challenges to doing so. First, in the febrile and unpredictable political environment at the time, there was no guarantee at all that the Diet would have agreed to the necessary legislation; phasing out nuclear energy was controversial, and some members who wanted a phaseout might still have supported the continuation of reprocessing. Second, because the EEC failed to address the fuel cycle until very late in its deliberations, it did not give itself enough time to develop an exit strategy that would have eased the concerns of the financial markets. In fact, according to its minutes, this issue wasn't even discussed at the critical meeting of the EEC on September 4, 2012.[81] The reason for this omission is unclear (and worrying from the standpoint of democratic accountability), but it does illustrate how little consideration was given to the practicalities of terminating reprocessing.

ENTRAPMENT REDUX

Two considerations seem to have been noticeably absent from the government's decision to maintain reprocessing: hedging and the sunk-costs fallacy.

Certainly, the Noda administration's plan to phase out nuclear energy attracted some domestic criticism that it would deprive Japan of the ability to manufacture nuclear weapons

quickly. Former Liberal Democratic Party (LDP) defense minister Shigeru Ishiba was the most notable of these critics, stating "having nuclear plants shows to other nations that Japan can make nuclear weapons."[82]

There is no evidence, however, that hedging, as it is called, was a consideration for the distinctly more dovish DPJ government. Moreover, Ishiba's vague reference to "nuclear plants" is telling. Japan's nuclear program may have started, at least in part, as a hedge, and some politicians apparently continue to view it as such (indeed, exactly the same could probably be said for most states with nuclear power programs). However, this form of existential hedge—which essentially goes no further than maintaining a nuclear infrastructure—is quite different from the claim that Tokyo has a deliberate strategy of stockpiling plutonium to enable rapid proliferation.

Separately, some analysts have argued that the persistence of reprocessing in Japan is a sunk-costs fallacy: the misguided desire not to waste unrecoverable costs that have already been incurred.[83] Indeed, sunk costs may well weigh on the minds of the Japanese bureaucrats responsible for energy policy.[84] They probably also help explain why the LDP, which fostered Japan's nuclear program during a period of almost-uninterrupted rule lasting for more than half a century, continues to support reprocessing.

However, sunk costs cannot explain why Japan decided to persist with reprocessing in 2012. After all, the DPJ-led government then in office had no particular commitment to reprocessing and was swept into power, in August 2009, on a platform that promised change; it painted overturning existing policy as a virtue. Indeed, if sunk costs really had been a serious concern, the government would presumably have balked at seeking to phase out nuclear energy by the 2030s, which would have entailed closing a number of nuclear reactors prematurely.

In fact, the Noda administration's primary motivation was avoiding the future political and financial costs associated with changing policies. Had the EEC attempted an immediate termination of Japan's reprocessing program in the late summer of 2012, it would have been faced with a daunting to-do list:

- Negotiate with Aomori Prefecture and Rokkasho Village to convince them not to insist upon the removal of the spent fuel already stored there and to continue to accept nuclear waste from abroad;
- Negotiate with the host communities of nuclear reactors to convince them to accept dry-cask storage (followed by the rapid design, licensing, and construction of such facilities); and
- Negotiate with the Diet to permit a change in the law to enable the reprocessing fund to be used to bail out JNFL.

Individually, any one of these hurdles might, perhaps, have been surmountable. Taken together they formed what Noda himself described as a "tangled web," which would take years to unravel "strand by strand."[85]

Some of the difficulty that his administration faced was self-inflicted. Because there was an assumption throughout much of the review that nuclear energy would not be phased out, there was, as a corollary, an assumption that reprocessing would continue. As a result, there was simply not the time to develop a credible exit strategy from reprocessing when serious discussions about phasing out nuclear energy began. The government's general weakness—a result of its unimpressive performance in many areas—probably also militated against its undertaking of the complex and politically sensitive project of shutting RRP. The outcome might just have been different if the government had been stronger and had considered reprocessing much earlier in the process of formulating a new energy policy.

That said, many of the challenges that the Noda administration faced were structural: the need to act on all fronts more or less simultaneously, the existence of powerful veto players—most notably local politicians in Aomori—who had little reason to compromise, the very real risks that any one of the necessary negotiations might fail, the absence of a strong nonproliferation voice within the government, and the entrenched bureaucratic support for reprocessing.

In short, the decision to continue with reprocessing—at least for some time—was effectively inevitable.

What was certainly not inevitable was the administration's subsequent failure to develop a long-term plan to extricate Japan from reprocessing more gradually—"strand by strand." The absence of any realistic alternative to restarting RRP did not remove the risk that phasing out nuclear energy while continuing with reprocessing would result in a large imbalance between plutonium supply and demand. The Noda administration could at least have started the process of developing a credible plan to address this problem.

Its failure to do so may yet have consequences. The Abe administration that took power in 2012, like all of its LDP predecessors, is committed to reprocessing and seeks to start RRP as soon as possible. This is as much a political reality as it is a policy choice, as the domestic pressures to operate the facility remain as strong as ever. However, the government has also recommitted not to possess "reserves of plutonium of which use is undetermined."[86] Moreover, by executing a sensible U-turn on nuclear energy—which is once again seen as an "important base-load power source," according to Japan's new *Strategic Energy Plan*[87]—the Abe administration has created, on paper at least, a way of realizing this commitment. In reality, restarting a number of the reactors designated for plutonium burning is likely to prove extremely difficult. A serious risk remains that Japan's domestic plutonium stockpile will, in the next few years, start to grow rapidly.

LOOKING FORWARD: WHY PLUTONIUM DEMAND IS UNLIKELY TO MEET SUPPLY

FROM FAST BREEDER REACTORS TO PLU-THERMAL

Reprocessing was originally justified in Japan (and elsewhere) as a way to produce plutonium for fast breeder reactors, which are capable of generating more nuclear fuel than they consume and were thus seen as a promising means to promote energy security. However, the technical barriers to the development of fast breeder reactors have proved to be much larger than originally anticipated. In 2010, Tatsujiro Suzuki, an analyst who was subsequently appointed as the vice chairman of the Japan Atomic Energy Commission (JAEC), wryly observed that the Japanese "target date for fast breeder reactor commercialization has slipped by 80 years in a period of 50 years."[88]

By 1984, when it received the first shipment of separated plutonium from France, Japan had just a single, low-powered, experimental fast breeder reactor in operation.[89] Over the remainder of the decade, as the program suffered further setbacks, international concern grew that Japan had no viable means of using the plutonium it was importing. In 1991, the JAEC responded by introducing a policy that Japan would "not possess more plutonium than necessary in the implementation of the nuclear fuel recycling program."[90] More than a statement was needed, however, to ease what the utilities had termed "plutonium pressure."[91]

In 1997, therefore, Tokyo decided that, as a stopgap measure while fast breeder reactors were being developed, plutonium would be consumed in existing power reactors in the form of mixed oxide (MOX) fuel—a plan it termed plu-thermal.[92] To this end, the Federation of Electric Power Companies announced that the utilities aimed to burn MOX in sixteen to eighteen reactors by 2010.

Significant progress was made in implementing this plan prior to the Fukushima Daiichi accident—although there were difficulties and setbacks. Long delays were encountered in the construction of a MOX-fuel-fabrication facility that Japan originally sought to have in operation by 2000.[93] In the end, construction of what came to be called J-MOX only started in 2010. Japanese utilities were able to compensate for this delay by sourcing all of their MOX fuel from France and the United Kingdom (until the latter encountered problems with MOX fabrication that it has yet to solve). But without J-MOX, Japan could not use any of its plutonium separated onshore.

Reactors presented other challenges. The single most important reactor for MOX burning was Ohma, which was built specifically for that purpose and was designed to consume more than twice as much plutonium as any existing reactor.[94] Its construction was, however, severely delayed. In December 1998, when public hearings about the reactor were held prior to licensing, it was supposed to become operational in 2007.[95] As it turned out, construction did not even begin until May 2008. By the time of the Fukushima Daiichi accident in 2011, construction was "more than one-third complete" and Ohma's planned start-up had been moved back to 2014, a target that still seemed overly ambitious.[96]

Japanese local officials almost certainly have more ability to influence reactor operations than their counterparts in any other country.

Local politics—once again—also presented a major challenge. Japanese local officials almost certainly have more ability to influence reactor operations than their counterparts in any other country. By convention, nuclear power plant operators are required to conclude safety agreements with the surrounding municipalities. These agreements specify that the prefectural governor and the local mayor must consent to major changes in reactor operation, such as the use of a new type of fuel. Safety agreements, which are often described as gentlemen's agreements, are not legally binding—but they might as well be. The need for utilities to gain the "understanding," to use the Japanese term, of local communities about changes to reactor operation has become an inviolate requirement.[97]

Opposition to MOX burning was intense in a number of municipalities and led to considerable delays.[98] By 2009, the target date for full implementation of the MOX-use plan had slipped by five years to 2015.[99] Nonetheless, by March 2011, nine reactors had received local consent and MOX fuel had actually been irradiated in four of them. Moreover, the opposition to MOX burning was generally dissipating, and most of the remaining municipalities were expected to consent—eventually. There were, however, two

or three reactors where the prospects for MOX burning were, at best, highly uncertain: Kashiwazaki-Kariwa,[100] where one or two units were due to be used, and Tokai Daiini.[101]

Even before the Fukushima Daiichi accident, therefore, it seemed likely that full implementation of the MOX-use plan would have to be further delayed, and there was some room for concern about whether consent for sixteen reactors, let alone eighteen, could be secured.

THE POLITICS OF REACTOR RESTARTS

The Fukushima Daiichi accident has thrown Japan's nuclear energy sector—and, as a result, its MOX-use plan—into disarray. By law, Japanese reactors must be stopped for safety inspections once every thirteen months (at which time refueling also takes place). However, following the Fukushima Daiichi accident, the Nuclear and Industrial Safety Agency, which was then Japan's regulator, prohibited reactors from restarting, pending a more comprehensive safety review. Just two units at Oi passed this review and were permitted to restart before a new regulator, the Nuclear Regulation Authority (NRA), started its work in September 2012. This new body revised Japan's regulatory standards and then started the long process of assessing reactors' compliance. During this process, the two units at Oi were shut down and, since September 2013, Japan has had no operating reactors.

The Fukushima Daiichi accident has thrown Japan's nuclear energy sector—and, as a result, its MOX-use plan—into disarray.

The NRA's assessment involves a complex, three-step approval process, of which the first step, involving an analysis of the plant's overall safety features, is the most significant. At the time of this writing, in June 2015, four reactors (the two-unit Sendai plant and units 3 and 4 at Takahama) have cleared this initial hurdle, and are at various stages in the approval process. Meanwhile, another reactor (Ikata unit 3) appears likely to gain stage-one approval shortly.[102] Sendai unit 1 is expected to be the first reactor to restart; the most recent target set by its owner, Kyushu Electric Power Company, is August 2015.[103]

There are four potential barriers to restarting a reactor and then using it to consume plutonium. First, the utility must decide that it actually wants to restart the reactor. Because of the cost of the safety enhancements needed to meet the new standards, utilities have so far decided to decommission five older and smaller units.[104] Second, the NRA must certify the reactor's compliance with the new safety standards. Third, the relevant local authorities must

consent to the reactor's restarting. Finally, consent for MOX burning must also be in place. In practice, this final step will either involve convincing local authorities to give consent or ensuring that it is not retracted.

Each of these steps could prove problematic. In fact, even in the plausible best-case scenario, Japan will be able to burn MOX in only eleven of the sixteen to eighteen reactors earmarked for that purpose.

The current plan calls for MOX fuel to be used in three or four reactors owned by the Tokyo Electric Power Company (TEPCO).[105] TEPCO owns three nuclear power plants: Fukushima Daiichi, Fukushima Daiini, and Kashiwazaki-Kariwa. MOX fuel was actually being used at Fukushima Daiichi unit 3 at the time of the accident. However, units 1 to 4 at that plant were destroyed in the accident, and TEPCO has since announced its intention to decommission the other two units there.[106] Meanwhile, given the anti-nuclear sentiment in Fukushima Prefecture—in the recent gubernatorial election, every candidate supported decommissioning all the prefecture's remaining reactors—it is inconceivable that consent will ever be given to restart any of Fukushima Daiini's reactors.[107]

The prospects for MOX burning at Kashiwazaki-Kariwa are marginally better—but still poor in absolute terms. Relations between TEPCO and Niigata Prefecture were strained even before the accident, and the prefecture had not consented to MOX burning. Unsurprisingly, relations are much worse now. In an October 2012 poll, a majority of Niigata residents opposed restarting the nuclear reactors in their prefecture.[108] More importantly, the governor of Niigata, Hirohiko Izumida, is a high-profile critic of nuclear power in general and TEPCO specifically.[109] Although he has not said definitively that he would refuse consent to restart the reactors, he has set conditions that would allow him to delay the process indefinitely. For example, Izumida has said he will commission his own investigation into the Fukushima Daiichi accident and the effectiveness of the new safety standards.[110] Moreover, even if he were to consent to a restart (which is not completely impossible given the employment consequences of shutting down the plant), it is highly unlikely he would reverse himself on MOX too.

The politics surrounding the restart of Tokai Daiini are similar. Local opposition to a restart is so intense that when the plant's owner, the Japan Atomic Power Company, applied to the NRA for safety certification, it had to emphasize that it was not applying for permission to actually restart the reactor.[111] Moreover, consent to use MOX was not secured before the Fukushima Daiichi accident; gaining it now is likely to be extremely difficult. If these problems weren't enough, Tokai Daiini is also a relatively old unit (it started operating in 1978), creating two additional problems. First, it was not designed with safety features that are now requirements—most notably fire-resistant cabling.[112] Whether the NRA will accept the operator's proposed work-arounds is unclear. Second, for reactors to operate for more than forty years, relicensing is required. This process is a new requirement, and it is unclear what

standards will be applied and hence whether Tokai Daiini will be eligible to operate beyond 2018 (or, if it is, whether the operator will be willing to pay for any required upgrades).

The Japan Atomic Power Company had also committed to burning MOX at unit 2 of its other nuclear power plant, Tsuruga. This reactor is, however, highly unlikely to restart. The NRA has judged that it is built on top of an active fault, which would automatically preclude its restarting under the new safety standards, although the Japan Atomic Power Company is challenging this finding.[113] (For a while, Japanese officials implied that MOX might instead be used in another reactor at the same plant, but the only other reactor at this facility, unit 1, has now been slated for decommissioning.[114])

Finally, in early 2014, the governor of Shizuoka Prefecture, Heita Kawakatsu, retracted consent to burn MOX at unit 4 of Hamaoka—the first, and to date only, such retraction since the Fukushima Daiichi accident.[115] (For its part, the plant's owner, Chubu Electric Power Company, has stated it is currently focused on improving safety and has no target date for MOX burning, but has not retracted its intention to use MOX fuel eventually.[116]) On top of that, the prospects for restarting Hamaoka are uncertain. Kawakatsu is noncommittal on whether there are any circumstances under which he would consent to a restart.[117] However, he is critical of nuclear power in general (though not of Chubu Electric Power Company, specifically) and won reelection in 2013, following a campaign in which nuclear power was a key issue, by pledging to hold a local referendum on the restart of Hamaoko.[118] Taken together, all these factors make the use of Hamaoka unit 4 for plutonium consumption unlikely.

Besides these six or seven most-at-risk reactors, ten or eleven others are designated for MOX burning. If each one of these eleven reactors were restarted (or, in the case of Ohma, started) and consent to load MOX in each one is secured—the plausible best-case scenario—Japan could burn just 4 metric tons of fissile plutonium annually,[119] some of which is to be sourced from Europe. When operated at full capacity, however, Rokkasho Reprocessing Plant (RRP) is intended to produce about 4.5 metric tons of fissile plutonium per year.[120] Under these circumstances, Japan's domestic plutonium stockpile would grow by at least 0.5 metric tons per year and, more likely, by around 1.5 metric tons per year, depending on exactly how much MOX is sourced from Europe.

To be sure, there is some chance—albeit a rather small one—that this prediction is wrong and that one or more of the seven most-at-risk reactors will reopen and be used to burn MOX; it is not impossible, for example, that an anti-nuclear governor in Niigata or Shizuoka could lose reelection to a pro-nuclear opponent.

By the same token, however, there is also a chance—a rather large one—that it will be impossible to burn MOX in some of the other eleven reactors. For example, in the hypothetical scenario that each of these eleven reactors had an 80 percent probability of restarting,

the chance that all of them would do so is less than 10 percent (in fact, the most likely outcome, in this case, would be for eight of the eleven reactors to restart).

In some of these eleven reactors, the prospects for MOX burning are extremely good; in others, the outlook is much less positive.

In reality, of course, the situation is more complicated; in some of these eleven reactors, the prospects for MOX burning are extremely good; in others, the outlook is much less positive. By way of a summary, table 1 lists all of the reactors in Japan designated for MOX burning and rates each on a scale of one to seven in terms of the likelihood of its reopening *and* its being used for plutonium consumption by 2023 (seven indicates a near certainty, and one indicates an actual or near impossibility). The significance of 2023 is that RRP is likely to be operating at full capacity by then, assuming three more years to complete the safety assessment and solve any additional problems encountered during start-up, and five years to ramp up to full production.

The reactors rated one or two are the seven most-at-risk reactors. In assessing the others, the following factors, in order of decreasing importance, are relevant:

- **Seismic concerns.** An NRA investigation team has indicated that it is likely to conclude that a fault under Shika unit 1 is active.[121] If the final report reaches the same conclusion and is adopted by the NRA, this reactor will be forced to close.

- **Local opposition to a restart.** There is significant local opposition to the restart of Onagawa.[122] Less problematically, at three other plants—Shimane, Takahama, and Tomari—the host communities are generally supportive of a restart but the surrounding municipalities are not.[123] Currently, consent from such municipalities is not necessary to restart a reactor. However, if public pressure forces operators to consult with them, much longer delays could arise.

- **Local concern about MOX.** The use of MOX fuel at Shika has been a sensitive issue since 2007, when it was revealed that there had been a criticality incident, or an uncontrolled nuclear chain reaction, at the plant in 1999.[124] As a result, consent to burn MOX was not granted before the Fukushima Daiichi accident and could be even more difficult to secure now. In August 2011, Hokkaido Electric Power Company announced that plans to burn MOX at Tomari unit 3 were on hold, after leaked e-mails from the company revealed that employees had been encouraged to advocate for MOX use at public meetings.[125] Finally, local politicians have also expressed some concern about MOX burning at Shimane unit 2.[126]

- **Legal challenges.** There have been legal challenges to reactor restarts across Japan, most of which have been unsuccessful. A district court in Fukui Prefecture has, however, issued separate injunctions against the restart of reactors at Oi and Takahama.[127] Ultimately, it seems likely these rulings will be overturned on appeal, but they do create additional uncertainty.

- **Status of the NRA's assessment.** Uncertainty about a reactor's future is increased where the operator has not yet applied to the NRA for a safety assessment, and to a lesser degree, where the NRA has not yet completed its assessment.

- **Type of reactor.** There are two types of reactors in Japan: boiling water reactors and pressurized water reactors. The former requires additional safety enhancements and, so far, the NRA has been focusing its efforts on assessing the safety of the latter. The timeline for restarting boiling water reactors is, therefore, unclear.

Ohma is a special case because it is still under construction. Its owner, J-Power, has submitted its safety application to the NRA and hopes to commence electricity production in 2021.[128] However, given the ubiquity of delays in reactor construction (both in Japan and elsewhere), there is a significant chance that its completion could be delayed yet further. Moreover, the chairman of the NRA has indicated a desire to scrutinize this reactor particularly closely, because it will be the first, anywhere in the world, to be loaded entirely with MOX fuel.[129]

All of these considerations strongly suggest that, in addition to the seven most-at-risk reactors, it is likely that a few others will not be available for MOX burning by 2023 (even if it is not possible to specify exactly which ones). A very simple statistical model, based on the ratings in the table, suggests that, in the most likely case, MOX burning will take place in only eight or nine reactors by 2023, permitting roughly 3 metric tons of fissile plutonium to be consumed each year.[130] In this case, Japan's stockpile would grow by 1.5 metric tons of fissile plutonium per year, even if no material were sourced from Europe. If such sourcing does take place, the growth is likely to be around 2.5 metric tons annually.

IS THERE A DEMAND-SIDE SOLUTION?

In light of these challenges, in November 2014, the Federation of Electric Power Companies announced its intention to revise its MOX-use plan to prevent an imbalance in the supply and demand of plutonium.[131] It acknowledged that full implementation of the current plan by 2015 was impossible. It also hinted that the utilities would try to identify additional reactors in which plutonium could be burned—though it did not promise explicitly to do so. There are at least four reasons, however, why this kind of demand-side solution is likely to be extremely difficult to implement.

TABLE 1

Status of Japanese Reactors Included in the Federation of Electric Power Company's Most Recent Plan for MOX Use

Electric Power Company	Reactor	Year of Start-up	Safety Case Submitted?	NRA Approval?	Qu. Pu (metric tons of f-Pu)
Chubu	Hamaoka-4	1993	Yes	No	0.4
Chugoku	Shimane-2	1989	Yes	No	0.2
Hokkaido	Tomari-3	2009	Yes	No	0.2
Hokuriku	Shika-1	1993	No	No	0.1
JAPC	Tsuruga-2	1987	No	No	0.5
	Tokai-2	1978	Yes	No	
J-Power	Ohma	U/C	Yes	No	1.1
Kansai	Oi-3[a]	1993	Yes	No	1.1-1.4
	Oi-4[a]	1993	Yes	No	
	Takahama-3	1985	Yes	Yes	
	Takahama-4	1985	Yes	Yes	
Kyushu	Genkai-3	1994	Yes	No	0.4
Shikoku	Ikata-3	1994	Yes	Draft	0.4
Tohoku	Onagawa-3	2002	No	No	0.2
Tokyo	Fukushima Daiichi-3	1976	Unit destroyed in accident		0.9-1.6
	Kashiwazaki-Kariwa-3[b]	1993	No	No	
	Unspecified	-	-	-	
	Unspecified	-	-	-	

Year of start-up

- U/C: Under construction.

NRA approval?: The reactor has cleared the first (and most significant) stage in the NRA's three-step approval process.

- NRA: Nuclear Regulation Authority.
- Draft: The NRA has issued a draft approval and is seeking public comment.

Qu. Pu: Quantity of plutonium that reactor can burn per year (measured in metric tons of fissile plutonium).

- f-Pu: Fissile plutonium.

Status of MOX use

- Possible: No decision about whether to use this reactor for MOX burning has been taken.
- Planned: Unit is planned for MOX burning, but consent has not yet been given by local authorities.
- Approved: Consent to burn MOX has been given, but MOX fuel has not yet been irradiated.
- Used: MOX fuel has been irradiated.

Status of MOX Use	Challenges to Restart and MOX Use by 2023 (apart from lack of NRA approval)	Prospect
Consent withdrawn after 3/11	See main text	2
Approved	Regional opposition; MOX concerns since 3/11; BWR	5
Approved	Regional opposition; MOX burning plan postponed since 3/11	5
Planned	Seismic concerns; MOX concerns predate 3/11; safety case not submitted; BWR	3
Planned	See main text	2
Planned		2
Planned	Possibility of construction delays	4
One panned; one possible	Legal challenge	6
		6
Used	Regional opposition; legal challenge	6
Approved		6
Used		6
Used		6
Approved	Safety case not submitted; BWR; opposition from host communities	5
Used	See main text	1
Consent withdrawn before 3/11		2
Planned		1
Possible		1

Challenges to restart and MOX use by 2023

- BWR: Boiling water reactor.
- Regional opposition: Opposition to reactor's restart from the regions surrounding a reactor, but not from the host communities.

Prospect: Likelihood of the reactor's being restarted and being used to burn MOX by 2023. Measured from one to seven, where seven indicates almost certainty, and one indicates an actual or near impossibility.

3/11: March 11, 2011 (the date of the Fukushima Daiichi accident).

[a] Kansai Electric Power Company has never specified which units at Oi would be used for MOX burning, but it is likely that units 3 and 4, which are newer and generate more power than units 1 and 2, would be used for this purpose.

[b] Tokyo Electric Power Company originally sought—and received—consent for MOX burning in Kashiwazaki-Kariwa unit 3. After this consent was withdrawn, the MOX-use plan was amended and no longer mentions any specific reactor at this plant.

First, there could be a relatively small number of reactors—perhaps fewer than ten—that are suitable for adding to the MOX-use plan. Most obviously, some reactors not currently designated for MOX burning may not reopen. There are other less apparent challenges too. Local objections to MOX would, presumably, apply to all units at a given site. Thus, if the governor of Shizuoka continues to refuse consent for MOX use in Hamaoka unit 4, he would, almost certainly, adopt the same policy toward both the other active units at that plant, thereby precluding three reactors from being used for MOX burning. Moreover, power companies could well argue that it is not worth the costs to add older reactors to the MOX-use plan. Specifically, some of the reactors that are likely to be restarted are currently between thirty and forty years old, but can operate for no longer than sixty years (and perhaps just forty). A reactor that today is, say, thirty-five years old would probably be forty-five, if not older, by the time it could be used to burn MOX (for reasons explained below), at which point it could only operate for another fifteen years. Moreover, because older reactors tend to produce less power than newer reactors, they cannot consume as much plutonium.

Second, negotiations between the utilities over a new MOX-use plan are likely to be difficult, contentious, and prolonged. MOX fuel is more expensive than normal uranium oxide fuel—by a factor of nine, according to a recent estimate based on government data.[132] As a result, power companies originally agreed to an "equality of misery,"[133] in which each took on its fair share of MOX burning. In the future, however, such equitable burden sharing will not be possible. TEPCO, Japan's largest power company, may well not operate another reactor again, let alone burn MOX. A number of smaller utilities, including the Japan Atomic Power Company and Hokuriku Electric Power Company, may also be forced out of the MOX business, because all of their MOX-burning reactors—if not all of their reactors—may be forced to close. As a result, a demand-side solution would almost certainly require a few companies—Kyushu Electric Power Company in particular—to take on a disproportionate share of the MOX burden, something they are likely to resist strongly.

In the most likely case, MOX burning will take place in only eight or nine reactors by 2023.

Third, even if some power companies do agree to take on more than their fair share, the host communities of their reactors may not. Decisionmakers in the Kyushu area, for example, could well come under intense pressure not to consent to multiple local reactors burning MOX when local officials in Shizuoka or Niigata have withdrawn or refused to grant such consent for any of their reactors.

Fourth, even if all these challenges can be overcome, the time needed to develop and then implement a revised MOX-use plan is likely to be significantly longer than the time needed to restart RRP and ramp it up to full production. It will be very difficult—if not impossible—to develop a credible plan for MOX use until there is much greater clarity about the future composition of Japan's reactor fleet. Unfortunately, it may take years for such clarity to emerge, given the time needed for engineering upgrades, the NRA's assessments, and negotiations with local communities. After additional reactors for MOX burning have been identified, consent from local communities for MOX use must be sought, contracts for fuel fabrication must be signed, and fuel must be produced and delivered.[134] All of this is likely to take at least a decade, if not longer, as illustrated by Japan's experience of trying to implement its original MOX-burning plan.

Even if Japan has enough operating reactors in the future to ensure that, in theory, plutonium demand could be matched to supply, the practical challenges of revising the current MOX-use plan—and doing so on the requisite timescale—are daunting. To make matters worse, the construction of much of J-MOX is currently on hold pending the outcome of the NRA's safety review. Until this facility comes online, Japan will have no way of using its domestically produced plutonium, regardless of its progress in restarting reactors and developing a modified MOX-burning plan.

CONCLUSIONS

IMPLICATIONS FOR JAPAN

Japanese national policy is to operate Rokkasho Reprocessing Plant (RRP) at full capacity as soon as possible while not separating excess plutonium. Given the challenges facing the country in bringing its reactor fleet back online after the Fukushima Daiichi accident, it is highly unlikely that it can fulfill these two goals simultaneously.

In the most likely scenario, RRP will be delayed by only a few more years, and it will be brought into operation without the reactor capacity required to consume its output. As a result, Japan's domestic plutonium stockpile will start to grow significantly, quite possibly by 2.5 metric tons of fissile plutonium (equivalent to 4 metric tons in total) per year—a serious loss for nonproliferation.

To be sure, this outcome is not completely guaranteed. If the Nuclear Regulation Authority (NRA) assesses that RRP is built on an active fault, which appears possible but unlikely, it could rule the plant is unsafe to operate, forcing it to be permanently shut down.[135] Less dramatically, further severe delays to the plant's start-up could result from an unexpectedly prolonged NRA assessment, the installation of major new safety features required by the NRA, unforeseen technical problems after start-up, or some combination of these factors. In this case, it is possible that, by the time the plant is up and running, Japan could have developed and implemented a revised plan for using mixed oxide (MOX) fuel and thus avoid stockpiling more plutonium. However, such severe delays to RRP seem unlikely.[136] Japan also has an extremely strong incentive to avoid this scenario because, without reprocessing, reactors may be forced to close due to a lack of space for spent-fuel storage.

By contrast, Japan's current plan—to start RRP within the next few years with enough MOX-burning reactors in operation to ensure that no more plutonium is stockpiled—is probably the least likely outcome.

Tokyo should, therefore, develop a plan to ensure that plutonium supply and demand are in balance. In fact, from a security perspective, it would be better for demand to exceed supply so the plutonium stockpile is gradually reduced. To this end, I present a detailed set of policy suggestions in a separate publication; here, the focus is on general principles.[137]

To have any chance of succeeding, a solution to Japan's plutonium problem must accept the realities of Japanese domestic politics. The particularly strained relationship between the center and periphery is a general feature of Japanese politics. On nuclear issues, relations between Aomori Prefecture and Tokyo are unique only in the degree of mistrust: many of the prefectures that host nuclear power plants are also among the country's least developed—which is, of course, precisely why they agreed to accept the plants—and feel similarly marginalized. These tensions might not matter if local politicians did not have the power to veto changes in Japan's nuclear policy. However, Japanese local politicians do have effective veto authority, and they are willing to use it; as a result, realistic policies must seek to navigate around them.

Tokyo should develop a plan to ensure that plutonium supply and demand are in balance.

The steps that Japan could now take fall into one of three categories. In the short term, it could seek to reduce the supply of separated plutonium and to develop alternative ways to dispose of it. In the longer term, it could explore the possibility of shifting to the once-through fuel cycle in which spent fuel that has not been reprocessed is placed in a geological repository.

The most obvious way for Japan to reduce its supply of plutonium—terminating RRP or delaying its operation for some prolonged period—is politically a nonstarter. Operating the plant at a lower throughput—so it processes less spent fuel and produces less plutonium—is a potentially more realistic option. Yet, even this proposal may be challenging to implement because it could spark concern in both Aomori Prefecture and Rokkasho Village that it is actually the first step toward the abandonment of reprocessing. Nonetheless, this idea is still sufficiently promising to be seriously pursued.

It may also be possible to reduce the supply of plutonium imported from Europe. The British government has officially offered to take custody of Japanese plutonium stored in the United Kingdom—if acceptable commercial terms can be negotiated.[138] Tokyo, which

has so far not responded to this offer, could initiate negotiations with London. The British government's lack of a credible strategy for managing its own plutonium stockpile clearly makes this option less than ideal, but from a security perspective, there are advantages to ensuring that as much Japanese plutonium as possible remains in a nuclear-weapon state outside the region. Japan could also explore the possibility of reaching a similar agreement with France. Both states would, however, almost certainly insist on returning all reprocessing wastes to Japan.

Japan could attempt to develop an alternative way to dispose of separated plutonium, thus providing a way to deal with whatever material it cannot burn in reactors. Various alternatives to MOX burning have been proposed, including burying plutonium in deep boreholes or mixing it with high-level radioactive waste, so it requires no more security than normal spent fuel and could ultimately be placed in the geological repository being developed to accommodate Japanese high-level waste. Further research on all the alternatives is required, and Japan could now undertake it, possibly in collaboration with the United States and the United Kingdom, both of which also have large plutonium stockpiles and no credible disposal plans.

Perhaps most importantly, Japan could explore the possibility of extricating itself from reprocessing over the longer term.

Perhaps most importantly, Japan could explore the possibility of extricating itself from reprocessing over the longer term. In addition to the nonproliferation advantages of doing so, there are at least three reasons related to good governance. First, Japan's fast breeder reactor program, which has always been the long-term justification for reprocessing, is in jeopardy following the Fukushima Daiichi accident. Second, it will be increasingly difficult to justify the costs of operating RRP if the number of reactors in which MOX can be burned remains limited over the long term, which is a distinct possibility. Third, Japan has already produced some spent fuel that is scheduled to be reprocessed at a second reprocessing plant that is supposed to follow RRP—and it will produce much more in the future.[139] Given the extraordinary challenges of developing another reprocessing facility—not the least of which is persuading the Diet to spent tens of billions of dollars—Japan could start to explore whether there is an alternative.

To this end, while continuing to reprocess, Japan could take the steps necessary to switch to the once-through fuel cycle, at some time in the future, should it choose to do so. The Japanese government already appears to be taking some very tentative steps in this direction.[140] It supports expanding the country's interim storage capacity for spent fuel, which would help to ensure that reprocessing is no longer needed to prevent nuclear power plants from running out of storage space. However, for such plans to be realized, the government will

need to find some way of altering the calculus of skeptical local politicians by, for example, offering bigger financial incentives to both the host village or town and the host prefecture of dry-cask storage facilities.

Tokyo has also said it intends to start research into the direct disposal of spent fuel. Again, it could go further and work with the Diet to change the law to allow funds that have been put aside for nuclear waste disposal to be used for the disposal of both reprocessing wastes and unreprocessed spent fuel. In addition, the geological repository that Japan is currently trying to develop could be licensed to accommodate spent fuel as well as high-level waste.

What unites this set of recommendations is the need for the central government to take action. With a few exceptions, such as developing a geological repository, Tokyo has generally tried to avoid involving itself in spent-fuel management, arguing that reprocessing is a private enterprise undertaken by private companies. Although this claim is true, as far as it goes, it ignores the context: reprocessing is also Japan's national policy, and the central government has given the utilities no choice but to reprocess. Moreover, in recognition of the acute international security concerns surrounding plutonium, Tokyo has adopted a clear policy that it will not accumulate more of it than Japan can use. As a result, it is right that the Japanese government should now take ownership of this problem.

For its part, the Japanese government may be inclined to wait until it has a better sense of which reactors are likely to operate before developing a strategy. Unfortunately, waiting will probably make the problem even more vexing. The longer Japan Nuclear Fuel Limited publicly sticks to its goal of operating RRP at full capacity as soon as possible (after an initial ramp-up period), the more Aomori Prefecture and Rokkasho Village are likely to be concerned by any future change in policy. Meanwhile, developing a credible plan to use the plutonium separated in RRP—whether through MOX burning or some alternative disposal method—will take time and probably encounter considerable domestic opposition. Facing these challenges sooner rather than later will make it easier to limit the growth of Japan's plutonium stockpile. In fact, it is partly because Japan has underestimated these challenges in the past that its stockpile of plutonium has grown to its current proportions.

IMPLICATIONS FOR REPROCESSING GLOBALLY

From a theoretical perspective, what stands out about Japan's entrapment in reprocessing is the ability of local politicians to constrain the national government's freedom of action on a matter of international importance. The most dramatic manifestation of this effect was overt threats from Aomori politicians to expel the spent fuel being stored in the prefecture and to ban the import of nuclear waste from abroad if RRP were shut down. However, the

quiet but persistent refusal of local politicians to accept dry-cask storage at many reactor sites around the country has also played a major role in entrapping Japan in reprocessing.

Although local politicians in Japan probably enjoy a unique degree of influence in national-level decisionmaking on nuclear policy, similar, if somewhat less intense, dynamics shape fuel-cycle policies in other countries—especially more democratic ones. The result is either plutonium accumulations or the risk of them.

The local economic consequences of terminating the United Kingdom's civilian reprocessing plant, THORP, was one reason (of many) why the British government remained committed to the project in the 1980s and 1990s, even as it terminated research and development into the fast breeder reactors that were supposed to consume the plant's product.[141]

The quiet but persistent refusal of local politicians to accept dry-cask storage at many reactor sites around the country has also played a major role in entrapping Japan in reprocessing.

Local opposition to dry-cask storage in Taiwan has lead Taipei to negotiate a draft contract for reprocessing in France. If this project proceeds, the separated plutonium would not be returned to Taiwan for nonproliferation reasons. However, there appears to be no credible plan for disposing of this material; the draft contract reportedly states that it is to be burned in unspecified "third party civilian reactors."[142] Another plutonium stockpile—this time in France—would be the likely result.

In South Korea, local opposition to dry-cask storage is a major factor behind Seoul's efforts to develop a new electrochemical reprocessing technique called pyroprocessing, which would produce metallic fuel that could be used only in fast reactors. Not only do the decades required to commercialize pyroprocessing and fast reactors severely reduce their utility for dealing with South Korea's urgent spent-fuel storage problem, but if pyroprocessing is commercialized before fast reactors, a plutonium buildup could result.[143]

In addition to warning of the risk that the reprocessing of Taiwanese and South Korean spent fuel could lead to the accumulation of plutonium, the Japanese experience provides other important lessons. Japan's reliance on reprocessing as a spent-fuel management strategy—a consequence, at least in part, of domestic politics—risks compromising its energy security; if reprocessing is delayed for too long, storage space for spent fuel could run out, forcing reactors to close. South Korea and Taiwan will run similar risks if they try to compensate for the absence of adequate spent-fuel storage capacity with reprocessing.

States that choose to reprocess anyway, in spite of the risks, could at least try to design their programs so that they can be terminated without completely intolerable costs. Avoiding entrapment is a good governance measure generally, but it is particularly important from a security perspective because nations entrapped in reprocessing are more likely to stockpile plutonium.

One step would be not to treat reprocessing programs as tools for regional development. Specifically, reprocessing facilities could be located in economically vibrant regions that could withstand the consequences of the plant's being scrapped, and not in highly underdeveloped regions that become reliant on them. Funding for reprocessing plants could also be designed so that, if the plant fails, utilities do not risk bankruptcy. In practice, this would probably mean that governments would need to fund plants directly through tax revenue. Finally, and perhaps most importantly, governments could secure adequate storage capacity for spent fuel to ensure that reprocessing is not necessary to keep reactors in operation. Certainly, each of these proposals would be extremely difficult to implement, and it is possible that any government contemplating them might ultimately decide that the costs of reprocessing outweigh any benefits.

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