

Nuclear Proliferation in Plain Sight: Japan's Plutonium Fuel Cycle—A Technical and Economic Failure But a Strategic Success

Shaun Burnie , Frank Barnaby , with Tom Clements , Aileen Mioko Smith and Kendra Ulrich

Précis

Five years after the March 11th 2011 earthquake and tsunami destroyed four reactors at the Fukushima Daiichi site, Japan's nuclear industry remains in crisis. Three reactors are operating as of February 1st 2016, a reduction of 94% of reactors since 2011. Prospects for a restart of even half of the 54 reactors formerly operating are almost zero. For decades the center of the nations nuclear and energy policy was based on the utilization of plutonium to fuel fast breeder reactors, together with the use of plutonium MOX fuel in commercial power reactors. The program has absorbed trillions of yen yet has utterly failed to deliver the energy security used to justify it. The contradictions and technical and financial obstacles, all of which have been evident since the 1970's, have reached a new critical juncture. Key elements of Japan's plutonium program are on the edge of complete failure – from the MONJU fast reactor to the Rokkasho Mura reprocessing plant. Major developments in the last months would suggest

that fundamental change is on the horizon. However appearances are deceptive. The nuclear establishment is putting in place mechanisms to try and save a program that was always much more than 'just' energy security, but also national security. It is Japan's de facto nuclear weapons status that will increasingly come to the fore, as the justification for the peaceful use of plutonium is exposed further as a delusion. As nuclear proliferation and conflict points escalate in East Asia, Japan's stockpiling of thousands of kilograms of weapons usable plutonium with no credible peaceful use is driving further proliferation in the region. Two years before the extension of the U.S. Japan nuclear cooperation agreement, the legal basis for the nations plutonium program, the time for a rethink, long past, is more urgent than ever.

Introduction

In the twilight world of Japan's nuclear program, where nothing is what it seems, the MONJU fast breeder reactor symbolizes a nuclear policy that

is based on a dangerous fantasy, but remains entrenched within the Japanese establishment. Conceived nearly six decades ago, the stated aim of Japan's nuclear program was to attain energy security through fast reactors, 'breeding' plutonium, which is then reprocessed and re-used to fuel more fast breeder reactors.¹

Then it became clear that large-scale fast breeder reactor deployment would not happen in the short term. No matter: Japanese policy morphed into plans to use its mounting plutonium stockpiles to fuel conventional light water reactors. This plan too has since gone awry. Yet in spite of monumental failure, Japan's nuclear energy policy remains largely unchanged. Disturbingly, the policy has delivered in strategic terms: Japan is a nuclear superpower – with a stockpile of weapons-usable plutonium amounting to about 48 tons. Fully 10 tons of this stockpile is located in Japan, the rest being in the UK and France. Current plans anticipate far more plutonium being repatriated to Japan for the eventual operation of the Rokkasho-mura reprocessing plant.

At the same time, there appear to be seismic shifts in the overall fuel cycle program. On November 4, 2015, Japan's Nuclear Regulatory Authority (NRA) declared the agency charged with overseeing the MONJU reactor, the Japan Atomic Energy Agency (JAEA), to be "*unfit*" (*futekito*)² as a managing authority. It bears noting that the JAEA is a government body

under the Education, Culture, Sports, Science and Technology Ministry. The NRA Commissioners then made the unprecedented decision to recommend that the Government either identify a new agency to oversee the MONJU reactor, or, if that proves impossible, to permanently shut it down.³

And on November 16, Japan Nuclear Fuel Limited (JNFL), the utility-owned company that oversees the Rokkasho-mura complex in Aomori prefecture, announced at an "extraordinary press conference" yet a further delay in operation of the 2.1 trillion yen reprocessing plant. This delay, expected to last until 2018, was the 23rd postponement of operations since the facility's construction was completed. In addition, JNFL announced a delay (until sometime in 2019) in completion of the plutonium fuel fabrication plant J-MOX.⁴

In yet a further signal of the tensions and challenges within Japan's nuclear industry, the Federation of Electric Power Companies (FEPC), which represents the nation's ten nuclear power utilities, announced on November 20th the indefinite postponement of a target date for loading plutonium Mixed Oxide (MOX) fuel into 16-18 light water reactors.⁵ The plans to use MOX fuel have for the past two decades been the justification used for Japan's accumulation of plutonium through reprocessing.⁶ Hence, four months before reaching their target date of March 2016, FEPC was acknowledging the reality

that not one reactor was currently operating with MOX fuel, and that only two out of forty three viable commercial reactors were actually operating.

Admitting reality has never been a strong point for Japan's nuclear industry, neither over the decades nor today. Yet each of these fuel cycle developments in recent months are significant in their own right. And taken together, they reflect the deep and historic crisis within Japan's nuclear industry and the dismal prospects for successful implementation of Japan's nuclear fuel cycle policy. One would think that time is running out for MONJU, which has consumed 1 trillion yen (US\$10 billion) to build and maintain as of 2012.⁷ And the other developments suggest equally poor prospects for the rest of the vast nuclear fuel cycle infrastructure. However, nothing is simple when it comes to nuclear policy in Japan, particularly when it comes to plutonium. Decades of failing to deliver the energy that was used to justify trillions of yen in public investment have led to repeated calls for its revision and cancellation.⁸ And yet it still survives.

This article reviews the status of Japan's nuclear program, the scale of the infrastructure and projects launched during the past decades and what lies behind its continuation, including partnerships with overseas programs, upcoming threats and their implications. Finally, it looks beyond the energy security considerations to the

strategic rationale which has played a central role over decades and remains a key driver for maintaining a program that long ago lost any economic or energy rationale. It is the strategic role of Japan's plutonium program, and the fact that it has led to the accumulation and stockpiling of reactor grade fissile material capable of being used to manufacture reliable sophisticated nuclear weapons,⁹ that will increasingly move center stage in East Asia. With no credible peaceful use for its stockpile and plans to increase its stocks with the operation of the Rokkasho-mura reprocessing plant, Japan will find it increasingly difficult justify to the international community that its program is intended for peaceful use.

When Pluto Boy Meets Sodium

Twenty years ago the future of Japan's nuclear power program hit an obstacle which it has yet to overcome. The MONJU Fast Breeder Reactor (FBR) owned by the Japanese government agency PNC, and located in Fukui prefecture, suffered a catastrophic breach in its cooling system. On December 8, 1995 a tube carrying liquid sodium, the cooling medium of choice for FBRs, ruptured. The tube leaked hundreds of kilograms of sodium, which reacted explosively with atmospheric oxygen and moisture, producing intense heat that warped steel structures. The operator took two hours to secure shutdown.¹⁰ With the exception of a few brief months in 2010, the MONJU reactor has failed to operate ever

since. This is in spite of all the efforts of the nuclear establishment to promote the advantages of MONJU and the plutonium fuel cycle, including the ill-conceived 'Pluto Boy' cartoon character who enjoyed drinking plutonium nitrate.

For years prior to the April 1994 start-up of MONJU, the anti nuclear movement had warned successive Japanese governments of the safety and security risks of operating an FBR. Local Fukui citizens filed the first lawsuit against the construction of the reactor in 1985. After nearly two decades of intervention they secured victory in the Nagoya High District Court in Kanazawa, in a ruling that nullified the original construction license.¹¹ Critical analysis of the safety and nuclear proliferation risks of operating a reactor designed to produce plutonium beyond weapons-grade (yes, there is a material called "super grade plutonium") exposed the threat of Japan's program and its potential to be used in the production of nuclear weapons.¹²

In April 2014, the Abe government restated Japan's decades long policy, that the MONJU FBR would form the basis of research and development of fast breeder reactors. As the government agency JAEA continues to claim, *"MONJU in its turn will provide valuable information for the establishment of commercial FBR technology,"*¹³ the target date for a fleet of commercial FBRs has now been pushed back to 2050. When it is clear that renewable energy is

the energy technology of this century,¹⁴ it defies all logic that Japan's energy policy plans for 2050 remain centered on developing a technology conceived in the middle of the last century. But the complete failure of fast reactors to deliver has been global. Projections made in the 1970s by the Nuclear Energy Agency (NEA) of the OECD and endorsed by the International Atomic Energy Agency (IAEA) were that there would be 200 commercial fast breeder reactors by the year 2000.¹⁵ However, other than a few experimental reactors, there were in reality, none.¹⁶ But Japan is not alone in continuing to pursue fast reactor technology. In that sense, Japan's continued annual burning of billions of yen worth of government-funded R&D is not unique. Japan, in its waste of fiscal and other resources, is only part of a much larger international network of scientists, engineers, major corporations, policy makers and institutional bodies. The MONJU reactor, as one of the few available reactors worldwide (at least in theory, given its non operational status) plays a major role in this multi-national program.¹⁷ During the coming year, this international role will be prominent among the JAEA's rationales for continuing the MONJU project.

The most active players in fast reactor technology development include the Republic of Korea, China, Russia, India, France and the United States, together with programs run under the auspices of the NEA and the IAEA. In particular,

Japan's relationship with the United States and France are critical to understanding both the history of its FBR and wider plutonium program, as well as its future prospects.

Japan has a decades-long collaboration with the U.S. for developing plutonium technologies. The United States was the pioneer in fast reactor development from the 1940s, including the Experimental Breeder Reactor (EBR). In 1951, the EBR became the world's first reactor to generate electricity. However, the EBR's design was such that as power increased it had a positive feedback – the so-called "positive power coefficient of reactivity."¹⁸ In 1955, during an experiment to obtain information about this instability, the reactor had a partial (40–50 percent) core meltdown. The damaged core was removed and the reactor was repaired and operated until shut down in December 1963.¹⁹ Thereafter, fast breeder reactor development continued, but plans for commercial fast breeder reactor deployment were scaled back during the 1970s due to proliferation assessments initiated by the Ford²⁰ and Carter administrations. Specifically, there were concerns that FBR deployment would lead more nations to become nuclear weapons capable. Combined with escalating costs and technical failures, major FBR development was finally terminated, first by the U.S. Senate with its vote to end the funding of the Clinch River Breeder Reactor Project in 1983,²¹ and the Clinton administration with the closure

of the EBR-II in 1994.²²

However, true believers in plutonium-based nuclear technology centered at Department of Energy (DOE) national laboratories, including Argonne, Oak Ridge and Savannah River Site, continued to receive federal funding for research on the nuclear fuel cycle. They also continued to lobby for a revival of fast reactors. This pressure led the G. W. Bush administration to attempt a reboot of the technology with the launch of the Global Nuclear Energy Partnership (GNEP) in 2006. GNEP was promoted as a solution to the inherent nuclear weapons proliferation risks of nuclear power, in particular plutonium-based fuel cycles (and uranium enrichment). The GNEP was to see the number of states with access to uranium enrichment and plutonium reprocessing restricted, and it was also to establish a global "cradle to grave" nuclear infrastructure.²³ Fresh enriched uranium fuel would be provided to states signed up to the non-proliferation objectives of GNEP. The spent fuel discharged from the reactors would be shipped to regional fuel cycle centers where it would be reprocessed. The resultant separated plutonium would be used to manufacture Mixed Oxide (MOX) fuel for use in light water reactors and Generation IV fast reactors. According to GNEP rhetoric "*these [reactors] would be only built in states designated as trustworthy in non-proliferation terms*" - a contradictory, ineffective and unsustainable basis for a policy based on the

proliferation of nuclear weapons usable plutonium technology and materials.

GNEP, ill considered and controversial from its launch, gave a boost to the international fast-breeder priesthood. As a decades long partner of the United States, Japan was fully supportive of GNEP. MONJU's 'operator', the JAEA and Rokkasho-mura 'operator' JNFL seized on the opportunity of GNEP as a way to establish international (and domestic) legitimacy for their facilities.²⁴ Mitsubishi Heavy Industries (MHI), the designer of the Joyo FBR at O-arai, in Ibaraki prefecture, and MONJU, also used the GNEP to promote its follow-on Demonstration Fast Reactor.²⁵ Similarly, the Japanese government at this time saw strategic advantages in supporting the roll out of GNEP, led by such officials as its then Ambassador to the IAEA, Yukiya Amano, who today is the Director-General of the IAEA.²⁶

For good reasons, the first Obama administration officially terminated the domestic arm of GNEP. Yet the international program remains in place,²⁷ and domestic funding continues, now in the guise of the DOE Advanced Fuel Cycle R&D Program (FCRD).²⁸ The result of this failure to act in the interests of non-proliferation and finally terminate all major research, sees today the continuation of information exchange between the U.S. and Japanese bodies within the framework of the Civil Nuclear Energy Research and Development Working Group (CNWG).²⁹ The CNWG was established by the U.S.-Japan

Bilateral Commission on Civil Nuclear Cooperation in 2012 to enhance coordination of joint civil nuclear R&D efforts between the United States and Japan, building upon the collaborative R&D objectives of the U.S.-Japan Joint Nuclear Energy Action Plan (JNEAP), created in 2007. The CNWG is now coordinating cooperative nuclear energy R&D in several of the topical areas previously supported under the JNEAP, including advanced reactor and fuel cycle technologies, as well as a number of new areas endorsed by the Bilateral Commission, such as existing reactor fleet sustainability.

One further tie-up between Japan and the U.S. is the General Electric – Hitachi S-PRISM (Power Reactor Innovative Small Modular) fast reactor design. The S-PRISM is a commercial rebrand of the Integral Fast Reactor (IFR), based on the EBR-II and terminated by the Clinton administration. It lives on by currently being promoted as a 'solution' to the UK's vast plutonium stockpile. Rather than operated as a breeder reactor, a number of S-PRISM reactors (operating in tandem small modular fashion) would 'burn' plutonium.³⁰ As with other fast reactor designs, the proponents focus on the theoretical benefits of what is only a blueprint,³¹ and conveniently ignore both history and technical and economic realities.³² S-PRISM remains an option under consideration by the UK government with a decision on which technology to deploy possible during 2016. If chosen, the S-PRISM option

would be a testament to the persistence and resilience of the nuclear establishment (it is not just in Japan) and the consequences of past political decisions taken to terminate programs that failed to kill them off in their entirety. The facts were neatly summed by the nuclear engineer, Dave Lochbaum:

*"The IFR looks good on paper. So good, in fact, that we should leave it on paper. For it only gets ugly in moving from blueprint to backyard."*³³

The other major driver of fast reactor development, and with a historic linkage to Japan, is France's decades long breeder and plutonium reprocessing program. In contrast to the United States, where administrations have at least challenged the proliferation risks of plutonium based fuel cycles, the French state has led the world in exporting both technology and materials with no serious regard for the consequences.³⁴ In terms of FBR development, as with others, France failed to commercialize the technology.³⁵ In 1974, when justifying the construction of the 1200 MW Superphenix FBR, the Atomic Energy Commission (CEA) projected that 20 percent of France's electricity would be generated by fast reactors. The CEA as the agency responsible for developing French nuclear weapons also had a broader interest in FBR technology.³⁶ If anything, the CEA was more bullish than its counterpart in Japan in predicting the rise of the breeder: in 1976, its Director, André Giraud, forecast 540 commercial breeders

in the world by the year 2000, of which 20 would be in France, and predicted that by 2025, *"the number of Superphénix-size fast breeder reactors units worldwide would reach exactly 2,766."*³⁷ Superphénix, which began operations in 1986, suffered multiple technical failures including a sodium leak, was shutdown in 1996 and had its operating license revoked in 1997. It had operated less than half the time, and its overall load factor (availability to generate electricity) in its ten years of operation was less than 7 percent. Giraud's predictions of the future deployment of FBR's proved false. As of 2010, none were operating in France and no reactor of the capacity of Superphénix existed worldwide.

The French nuclear establishment, as in Japan, have however not given up on the FBR. The development of so-called Generation IV reactor technologies is centered on the *Advanced Sodium Technological Reactor for Industrial Demonstration* (ASTRID) FBR program. A 600 MW demonstration sodium cooled FBR, the CEA is nearing completion of the "pre-conceptual" design stage of ASTRID. The basic design phase has now been extended to run from 2016-2019. The CEA received 650 million Euros (84 billion yen) in 2010 to fund ASTRID to the end of the design phase.³⁸ The French nuclear village of contractors - including EDF, AREVA, Alstom, and Bouygues - all have a financial stake in ASTRID.

Similarly, Japan's nuclear village is actively

involved. Following Abe's energy policy announcement in 2014, he and French President Hollande signed an accord in Paris for further nuclear collaboration, including between the ASTRID project and MONJU.³⁹ In June 2014, the so-called "five-party conference" was held in Tokyo, consisting of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of Economy, Trade and Industry (METI), FEPC, the Japan Electrical Manufacturers' Association (JEMA) and JAEA. They all agreed on ways to cooperate with the ASTRID project.⁴⁰ In August 2014, JAEA, Mitsubishi Heavy Industries Ltd. and Mitsubishi FBR Systems, Inc. concluded an agreement with the CEA and Areva NP on implementing cooperation for both the ASTRID project and a sodium-cooled fast reactor.

In fact, the ASTRID project is already behind its original schedule, while the CEA does not provide public details on costs. One assessment in 2010 suggested that an ASTRID-size FBR would cost up to 4.2 billion euros (546 billion yen), though the evidence suggests this figure is a significant underestimate.⁴¹ Most of the financing is proposed to come from European institutional loans, EU incentives and grants such as the EC's European Sustainable Nuclear Industrial Initiative (ESNII), plus hundreds of millions from private investors. In 2012, the CEA was predicting construction approval in 2018, with construction due to start in 2020, and

operation from 2025.⁴² It is virtually certain that all of these schedules will be missed and the cost estimates exceeded.

ASTRID is France's contribution to the little known Sustainable Nuclear Energy Technology Platform (SNETP), a European Union funded project, which to a significant degree concentrates on supporting fast reactor development. As the SNETP claim, their aim is:

*"To ensure the long-term sustainability of nuclear energy, Gen IV Fast Neutron Reactors should be available for deployment by 2040 or even earlier. Therefore an ambitious yet realistic R&D and demonstration program is to be put in place."*⁴³

To this extent, the Europeans seem even more deluded over the prospects for fast reactors than their counterparts in Japan. But as with Japan, this has little to do with reality, or even finding credible methods for future energy production.

Without doubt, France will be lobbying Japan not to abandon MONJU. The limited options, due to so few FBR's being available worldwide, means that a degree of dependence exists between the two nations. The CEA is already collaborating with JAEA in support of the ASTRID fast reactor,⁴⁴ with experiments at the O-arai facility in Ibaraki.

As the future of MONJU appears to hang in the balance, it is therefore important to realize that

FBR programs persist internationally despite their near complete failure. Where does this leave Japan's future plans and why will its cancellation not be the choice of the present Japanese government?

MONJU is considered essential by the Japanese nuclear establishment if it is to develop sodium-cooled fast reactors in the timeframe of 2050. While the Fukushima Daiichi accident has set back all nuclear projects, the Chairman of the Atomic Energy Commission, Shunsuke Kondo, was able to tell his audience at the IAEA in 2013, that, *"the full power operation of MONJU ... will contribute to the establishment of the technological basis for a safe, reliable SFR (sodium fast reactor) to be located in an area of high seismicity."*⁴⁵

And MONJU certainly qualifies as a reactor in high seismic activity, as the Citizens Nuclear Information Centre warned in 2010:

*"Serious questions also remain regarding seismic safety. As a result of changes to the seismic safety assessment system, two active faults below the Monju site that were previously denied have now been recognized. In response, JAEA raised the predicted "design basis earthquake ground motion". However, Monju was built 20 years ago to meet a design basis that was set 30 years ago. JAEA says the revised assessment is based on the real strength of the buildings and equipment, but the fact is that the safety margin has been reduced. Doubts also remain about the size of the revised design basis earthquake ground motion. In particular, uncertainties relating to (a) the fault plane, (b) the rate at which seismic energy is diffused, and (c) the vertical ground movement suggest that JAEA's estimate is too low."*⁴⁶

The fact that MONJU is close to the Shiraki-Nyu active fault, and that crush zones of the normal fault type were confirmed below the reactor, does not exactly inspire confidence in the assurances of the JAEA.⁴⁷ The NRA reported in October 2015 that the fault line under MONJU was "likely inactive."⁴⁸

In fact, in the surreal world of the Japanese nuclear establishment, the catastrophic seismic event that destroyed four reactors at Fukushima Daiichi is being used in part to justify the continuation of MONJU and fast reactor research development. As the JAEA explained this one year after the disaster, future sodium fast breeder reactors:

- will excel in safety and reliability;
- will have a very low likelihood and degree of reactor core damage, and
- will eliminate the need for offsite emergency response.

*"After the Fukushima NPS accident, these goals are of increasing significance because the unexpected offsite emergency response has been realized actually in Japan."*⁴⁹

Japan's nuclear industry and regulators considered the risk of a catastrophic nuclear reactor core meltdown having "offsite" consequences as near impossible. But in actuality the risk was well known; it's just that its possibility was ignored. After more than six decades of vast public investment (US\$17 billion from 1974-2011 on breeder reactor research, development and demonstration alone⁵⁰), none of the objectives set by the JAEA have been attained by them or any other research body anywhere. But inertia, vested industrial and strategic interests, combined with an absence of serious regulatory or political oversight, has allowed

unattainable objectives and dangerous nonsense to persist. Meanwhile public funding of research on design safety of the demonstration sodium FBR continues.⁵¹

Even before the Fukushima nuclear accident, the time-schedule for developing the follow-on to MONJU had slipped. The Fast Reactor Cycle Technology Development Project (in some postmodern irony perhaps the project acronym is labeled FaCT), was launched in the mid 2000s,⁵² with the aim of a design selection and construction of the demonstration 500 MW Japan Sodium Fast Reactor (JSFR) from 2015, with operation from 2025. The reactor concept is for a plutonium MOX core, operated to a burn-up of 150 gigawatt (GW) days per ton (the period of time the fuel remains in the reactor prior to reload). In 2009 MHI was claiming that a follow on 1 GW commercial fast breeder would be operational by 2035, followed by a larger 1.5 GW design from 2050. Thereafter, MHI predicted that,

*"FBR commercial reactors should start operations one after another almost every year after 2050."*⁵³

None of this is credible, but that does not mean the FBR program will be cancelled.

Plutonium Futures And Japan's Nuclear Policy

Japan's six decades long commitment to the development of fast breeder reactors is integral to

its overall nuclear energy policy, including the management of spent fuel arising from the nation's light water reactors, plutonium MOX fuel use, high level waste disposal, as well as the geo-political and strategic security issues in East Asia and globally. To that end, any change in the policy commitment to fast breeder reactors, such as a decision to permanently shutdown the MONJU reactor, would have immediate and profound consequences.

In the case of nuclear energy policy, to terminate the FBR program would be to remove a central pillar of the overall nuclear fuel cycle, and in particular it would fatally undermine the case for reprocessing or chemical separation of plutonium. The argument made by successive governments over the years was that without reprocessing there would be no separated plutonium to fuel the first generation of FBR's. The separated plutonium oxide is mixed with uranium oxide and manufactured into MOX fuel at a fabrication plant, with a high percentage of plutonium (typically up to 30%), and then loaded as MOX fuel into the core of the FBR. The breeder reactor is then operated with a range of 'blankets' of uranium – formed using uranium-238 – these blankets are then bombarded by neutron radiation from the fissioning core, and through neutron capture the uranium-238 becomes plutonium-239. The blanket fuel (and spent fuel from the reactor core) is then reprocessed, and so the cycle proceeds. That's the theory.

To meet this future demand for plutonium a formal decision was taken in 1962 for Japan to construct a 'practical scale' reprocessing plant.⁵⁴ While it was clear from the early 1970s that the FBR program would not roll out as envisaged, plans for reprocessing continued, both domestic and overseas. One reason was that there was still a belief that at some point FBRs would be built on a large scale - it remained national policy. As noted above this view was widespread amongst the nuclear establishment globally. Another reason was connected to domestic public opinion on nuclear power. Large-scale construction of conventional light water reactors, which took place from the 1970s, was in part achieved through a commitment to local communities that the spent nuclear fuel that would be generated and discharged in the annual refueling would be removed. A typical Pressurized or Boiling Water Reactor (PWR/BWR) at this time would discharge 20-30 tons of spent fuel each year of operation. A nuclear plant was not to become a de facto nuclear waste site. This commitment reduced local opposition to the siting of reactors. The priority of nuclear plant operators was to build and operate, and therefore the financial penalty of reprocessing would be offset against revenue secured through electricity sales. Equally, the industrial and political interests that would be served by developing reprocessing cannot be understated, with all of the major contractors (Mitsubishi, Toshiba, Hitachi, etc.) as well as successive Liberal Democratic Party

politicians nationally and at the prefectural level, all benefiting. The momentum was already so great in the 1970's that there were no prospects for a change of direction.

During this period and through to the end of the century, Japan's reprocessing program followed two tracks, overseas export of spent fuel and domestic development.

With no large-scale domestic reprocessing facility, Japan from the 1970s shipped thousands of tons of spent fuel to the UK and France for reprocessing, thus removing the highly radioactive spent fuel from Japanese reactor sites. In total, 4,183 tons of spent fuel were shipped to the Sellafield reprocessing site in the north of England,⁵⁵ and 2,944 tons shipped to the Cogema site at La Hague in northern France.⁵⁶ It is the reprocessing of this fuel that has generated the largest share of Japan's separated plutonium of 37 tons currently stored in Europe.

At the national level, in 1967 Japan committed to the construction of its first domestic reprocessing plant at Tokai-mura in Ibaraki prefecture, with approval granted in 1970. However, construction during the early to mid 1970s was one of the most controversial issues in U.S.-Japanese bilateral relations. Both the Ford and Carter administrations opposed commercial spent fuel reprocessing on proliferation grounds, whereas Prime Minister Fukuda described securing operation of the Tokai plant as a *"life and death"*

issue.⁵⁷ As with the later Rokkasho-mura plant, Tokai-mura was based on French technology supplied by Saint Gobain Nucleaire (SGN) a subsidiary of Cogema, the state nuclear company. France also sought to supply the same technology to the Republic of Korea and Taiwan during the same period, while both nations were attempting to develop nuclear weapons capabilities. Whereas the U.S. successfully blocked both Korea and Taiwan from acquiring a reprocessing plant, it failed to stop Japan. During protracted negotiations, the U.S. considered options that would not undermine its non-reprocessing non-proliferation policy. The Carter administration was unable to prevent Japan from proceeding with Tokai-mura, so attempted to secure a commitment from Japan that it would limit reprocessing to meet its plutonium demand for its fast breeder program so as to avoid the build up in plutonium stocks and the Tokai-mura would be operated so that the final product was a mixture of plutonium and uranium oxides, rather than separated weapons-usable plutonium. This so-called co-processing method was in reality a political and technical fix that in no significant way reduced the proliferation consequences of permitting Japan to begin domestic reprocessing.⁵⁸

The U.S., by approving Tokai-mura's operation, failed to meet the requirements of its own non-proliferation policy. As specified by Secretary of State Cyrus Vance, the agreement with Japan

over Tokai-mura should support efforts to discourage reprocessing for use in light water reactors and avoid premature reprocessing and plutonium stockpiling for commercial breeders.⁵⁹ All that has unfolded in the subsequent four decades has exposed the failure of Japan and the U.S. to these meet these objectives. However, President Carter's policy compared to that of subsequent administrations should be considered a high point in U.S. non-proliferation efforts to reduce the threat from nuclear energy programs based on plutonium use.

Tokai-mura operated from 1977-2007, and while the plant never reached its design capacity of 210 tons of spent fuel each year, in total it reprocessed 1,140 tons of conventional light water reactor fuel, as well as experimental plutonium MOX fuel from the Fugen ATR. More importantly, it provided the technical basis for Japan's long-term aim of gaining experience in plutonium separation technology and high-level nuclear waste handling. Associated facilities at Tokai-mura supported the fast breeder program, including tests on separating blanket breeder fuel from the Joyo FBR. It also laid the basis for the application in 1989 for a new large-scale domestic reprocessing plant at Rokkasho-mura in Aomori prefecture, northern Honshu.

Associated with the MONJU FBR is an engineering plant for fast reactor fuel reprocessing, the Recycle Equipment Test Facility (RETF) built at the PNC Tokai-mura site from

January 1995.⁶⁰ Controversial from the start, the facility was designed to separate plutonium from the spent fuel of the MONJU reactor, as well as its breeder blanket and that of the Joyo FBR. The maximum design throughput of fuel each year was seven tons. The RETF became the center of an international dispute in 1994 when it was disclosed that much of the technology planned for the facility had been transferred illegally to Japan from the U.S. in violation of both domestic U.S. legislation and under the terms of the 1988 U.S. Japan Peaceful Nuclear Cooperation Agreement.⁶¹ The interest within the fast reactor community in Japan in obtaining Sensitive Nuclear Technology (SNT) was due to the specific challenge of reprocessing breeder blanket plutonium, which has a very high percentage of the isotope plutonium-239, thus increasing the risk of criticality during separation. This 'super-grade' plutonium is above weapons grade in its purity and therefore of particular concern from a proliferation perspective. While the Clinton administration announced the immediate termination of this particular collaboration,⁶² as noted, cooperation in breeder reactor and reprocessing research and development has continued. Due in large part to the failure of the MONJU project, the RETF has to date not operated.

Plans for an associated plutonium fuel fabrication plant and a larger demonstration reprocessing plant (for fast breeder fuel),

scheduled for construction start in 2015 and operation by 2030, have not progressed in recent years – but nor have they been cancelled. A commercial fast breeder reactor reprocessing and fuel fabrication plant is also planned to operate from 2040.⁶³ In reality, none of these projects, likely to cost tens of billions of dollars, are viable, but they remain within overall Japanese nuclear policy plans.

Unfit for Purpose – The Challenge to MONJU and the RETF

Twenty years after the sodium fire at MONJU, the NRA on November 4th 2015 decided that a new entity would be required to manage the FBR) at Tsuruga in Fukui prefecture.⁶⁴ The new body, if established, would be tasked with demonstrating that the reactor can be operated safely.

The NRA asked that MEXT identify a new agency, or, if that proves impossible, permanently shutdown the reactor. The NRA Commissioner's decision was their first ever "admonition", in this case against the MONJU operator deeming it not qualified to run the reactor. Shunichi Tanaka, the NRA chairman, stated at an emergency meeting that, "*Our assessment is that the agency is unfit to manage and operate Monju...The agency cannot solve its problems on its own, and we will make our own judgment.*"⁶⁵

The JAEA President, Toshio Kodama, told NRA

officials that the JAEA is taking measures to review its inspection regime, and seeking the NRA's understanding by stating, *"No entities other than the JAEA can manage Monju."*⁶⁶ We in part agree with Kodama – there is no agency that can successfully and safely manage MONJU, and that includes the JAEA – but that's due to MONJU's design, its technology and external hazards to plant. The confusion over where this process is heading was highlighted when an NRA official admitted that *"Establishing yet another government body is no longer a solution after the government's repeated attempts to create new entities to run Monju failed to realize safe operation..."*⁶⁷

In response to the NRA demand, the Government established a review panel which met for the first time in late December 2015. The head of the MEXT eight-member panel, after the first meeting, said he doesn't have a clear outlook at present for who could be a successor to JAEA, but that the possibility of permanent closure was low as, *"engineers' knowledge of such an advanced reactor and the large-scale investment to date should be put to maximum use."*⁶⁸ MEXT is to report on the results of the review within six months.

There is little prospect that MEXT will conclude that MONJU should be permanently shutdown, east due to the negative impact it would have on the entire nuclear fuel cycle and ultimately, the current governments energy

policy. Rather than establishing a new body, the JAEA is likely to undergo a cosmetic reshuffle in a misguided attempt to convince the people of Japan that something has changed.

Meanwhile, in December a second lawsuit was filed to prevent operation of MONJU, when 106 people in 12 prefectures who live within 250 km of the reactor filed suit at the Tokyo District Court.⁶⁹ Plaintiffs correctly expressed doubts about the MEXT review panel's veracity, saying its members do not include anyone critical of the fast-breeder reactor and the hope that the lawsuit will lead to a thorough public debate on Monju.

The financial challenge to MONJU and the associated RETF also increased in November 2015, when the Japanese government initiated an administrative review of its 2016 budget. Specifically under review was 13.6 trillion yen of proposed expenditure (out of a total 102 trillion yen budget) for government ministries in fiscal 2016. The Administrative Reform Council, under the Cabinet Minister Taro Kono, as Andrew DeWit reported, included two prominent critics of Japan's nuclear program, as well as Kono himself, who has challenged current nuclear policy, specifically reprocessing and plutonium use.⁷⁰ *"In my portfolio, I can ask them if the money is spent wisely and that's what I have been doing and the nuclear fuel cycle is no exception...The PM's directive is very clear. If we point out any items that are not spent well it has to be out of the budget"* Kono said in early

December.⁷¹ Included in the review was expenditure for continuing the RETF project, and annual government subsidies of 20 billion yen for the maintenance of MONJU, and 10 billion yen for bringing the MONJU reactor through the NRA regulatory review process.⁷² The construction cost, which was originally estimated at 35 billion yen (\$285 million) when the project was conceived in the 1970s, now exceeds 1 trillion yen. A decision to terminate funding would have deprived METI and MEXT of the ability to continue the projects. Minister Kono presented the results of the review to Prime Minister Abe on November 27th 2015.⁷³ The Cabinet approved the 2016 budget in late December 2015.⁷⁴ While the maintenance budget of 18 billion yen for MONJU was approved there was a reduction of 1.2 billion yen, and the 10 billion yen requested by MEXT for bringing the reactor into NRA compliance was not funded. In addition 200 million yen associated with the RETF was also eliminated.⁷⁵ All of this is progress of sorts, signaling that even a government committed to nuclear power and the nuclear fuel cycle recognizes that the program is not working. However, the funding continues and until a decision is made to finally terminate MONJU and the associated RETF, they will continue to absorb tens of billions of yen over the coming years.

The 150 Billion Dollar Question – What Future for Rokkasho-mura?

Construction of the Rokkasho-mura reprocessing

plant began in 1993. The plant is designed to reprocess 800 tons of commercial reactor spent fuel each year of operation over a period of four decades. It is the largest such facility in any nation that is not a declared nuclear weapons state. JNFL, the company established to operate the plant, is 75 percent owned by the nine nuclear power utilities, together with Japan Atomic Power Company, and 25 percent owned by Japanese banks, manufacturers (Hitachi, Toshiba and Mitsubishi Heavy Industries), and insurance companies.⁷⁶ The plant itself is based on the Cogema/AREVA UP3-800 plant at la Hague in Normandy, France, together with technology from domestic operations at Tokai-mura, as well as from the UK and Germany. Particularly important has been the decades long collaboration between JNFL and Cogema/AREVA.⁷⁷

In 2012, the Japan Atomic Energy Commission estimated that the cost of building the Rokkasho Reprocessing Plant and operating it for 40 years would range between 14.4 and 18.4 trillion Yen (equal to U.S.\$118-151 billion in 2015 rates).⁷⁸ The cost would depend on the final percentage of electricity generated by nuclear power plants over the coming decades. The estimate for following the no reprocessing route, and opting for direct disposal of spent fuel was less than half this cost at 8.7 trillion Yen. As of 2013, the construction cost had been 2.13 trillion yen (US21 billion). However, current METI thinking (at least

those who support Rokkasho) is that further inevitable cost increases are marginal over the lifetime of the project, and will have minimal impact on the overall cost of nuclear generated electricity.⁷⁹ This is not necessarily, however, the view of Japanese nuclear utilities, and certainly not that of critics.

In the late 1990's work was suspended on construction at Rokkasho-mura while utilities reviewed whether or not to abandon the project. This was due to the clear failure of the program and the rising costs of completing the plant. Unfortunately, under the pressure of Kansai and Chubu Electric Power Companies, the decision was taken to proceed with the completion of the plant. The first spent fuel reprocessing – so called active tests – began in March 2006, at which point the plant became contaminated with high-level nuclear waste. It was planned to begin commercial operation in 2008. However, operations did not proceed as JNFL anticipated. The active tests led to numerous problems, with the first leak of radioactivity within a month of the start of tests. Processing of liquid high level waste (HLW), and the associated vitrification plant has become a major obstacle, with failures in the furnaces and its production of vitrified glass blocks.⁸⁰ Up to 2010, operations of the plant continued to be interrupted by technical failures. One example was in 2007, when testing was suspended after it was revealed that seismic design failures in major equipment had been

overlooked.⁸¹ In August 2010 commercial operations were postponed for two years, by which time 425 tons of spent fuel had been reprocessed, yielding 2.3 tons of fissile (3.6 tons total) plutonium.⁸²

The Fukushima Daiichi accident from March 2011, including the resultant revised post Fukushima safety guidelines, have further complicated the timeframe for operation of Rokkasho-mura, not least concerning whether the plant is capable of meeting seismic hazards.⁸³ External electrical power supply to the Rokkasho-mura complex was lost as a result of the March 11 earthquake.⁸⁴

*"There is no problem in geological conditions from a seismological point of view."*⁸⁵

There are major technical and safety issues that pose questions about whether Rokkasho-mura will ever operate as designed, not least that it is a pick-and-mix plutonium plant incorporating technology from at least four nations. Many of these issues were raised before construction and operation began at the plant.⁸⁶

The earthquake risk to Rokkasho-mura has long been an issue of concern to civil society groups challenging its construction. A continental shelf edge fault runs north to south for about 80 kilometers off the Pacific coast of the Shimokita Peninsula in the prefecture, the location of the Rokkasho-mura plant.⁸⁷ In 2007 it was highlighted that critical equipment at the plant

did not meet seismic criteria – including the spent fuel shearing machine and fuel handling equipment in the spent fuel pool, and equipment in both the separation building and the low-level waste processing building. The equipment in question was designed in 1993 by Hitachi Engineering and Services.⁸⁸ In 1996 an employee noticed that an incorrect calculation had been made in regard to earthquake safety, but he did not report the mistake. A recalculation showed that the equipment failed to meet earthquake safety design standards and that it would not withstand the type of earthquake envisaged by these standards. That was in 2007.

The March 2011 earthquake refocused attention on seismic hazards, including at Rokkasho-mura. Prior to construction the maximum design earthquake for the Rokkasho-mura reprocessing plant was M6.5.⁸⁹ However, in 2013, JNFL revised its seismic risk assessment at the plant on the basis that a hypothetical inter-plate earthquake with a magnitude of M9 could occur off the Pacific coast and assuming that an inside oceanic plate earthquake of the scale similar to that of the 2011 Miyagi Offshore Earthquake (M 7.2) could occur on the site. JNFL assessed the seismic risk for Rokkasho and concluded that the maximum ground motion (Design Basis Ground Motion – DGBM) could be up to 450 Gal, coincidentally the same level of DBGM adopted in the 2006 Seismic Safety Assessment. JNFL proposed to the NRA that to allow for some margin it would set DBGM

at 600 Gal. In the case of Class S facilities, which are the most critical in the event of a severe seismic event, JNFL concluded in 2013 that their safety has been confirmed, therefore *“making it unnecessary to apply further seismic reinforcement.”*⁹⁰ The NRA in its new guidelines, reclassified some equipment at Rokkasho-mura into Class C,⁹¹ therefore requiring JNFL to reinforce some facilities at the plant.

However, there is clearly a major seismic problem with Rokkasho-mura which has not been addressed. In 2012, Yasutaka Ikeda, assistant professor of geomorphology at Tokyo University, disclosed that a nearly 100-kilometer (60-mile) fault runs under the Rokkasho-mura plant. *“Even though experts’ opinions are divided on whether this fault is active or not, I think the possibility of it being an active fault is extremely high, given the evidence...This fault could cause an 8-magnitude earthquake, so any nuclear-related facilities in the region are in danger.”*⁹²

If the NRA were to declare that the fault line is active then operations at Rokkasho-mura would not be permitted. Given the strategic importance of the Rokkasho-mura project for the entire nuclear program of Japan, it must be considered unlikely that the NRA will reach such a determination.

In reality, whether a fault is declared active or not, the web of fault lines in close proximity to and in some cases under Japanese nuclear

installations are a clear and present danger. Professor Katsuhiko Ishibashi, who resigned from the panel that drafted the revised seismic guidelines in 2007 due to the influence of the nuclear industry exerted to weaken them, has warned that a strong earthquake of up to 7.3 magnitude could directly hit an area where even perfect seismic research could not discover an active fault line.⁹³ The present focus on active or not active in that sense is in part a public relations exercise to provide an assurance that a/the regulator in Japan has adopted the lessons of the Fukushima-Daiichi accident, and that b/there is a substantial or even zero risk of an earthquake leading to a major nuclear accident when it is confirmed that a nuclear plant does not sit above an active fault. Securing this delusion is a condition for nuclear operations to resume in Japan. To be clear, the seismic threat to Rokkasho-mura, a facility storing 3000 tons of high level spent fuel (the equivalent of 30 nuclear reactor cores), as well as liquid high level waste and plutonium, cannot be ignored.

Another Delay

In a significant development, JNFL in November 2015 announced another delay in commercial operations of the Rokkasho-mura reprocessing plant, and the associated plutonium fuel manufacturing plant, J-MOX.⁹⁴ Citing the need to improve safety, the start date was pushed back from March 2016 to the first half of fiscal 2018 for the reprocessing plant, and one year later for the

J-MOX. For both facilities, the unanticipated length of the NRA review process and strengthening seismic resistance were cited by JNFL as the reasons for further delay. While undoubtedly true, other factors must be considered when viewing the commercial operation of the Rokkasho-mura plant. Not least is the fact that there is no present demand for plutonium within Japan's nuclear program.

Justifying start of commercial operations of Rokkasho-mura in early 2016 was always going to be a challenge. A plant designed to separate 8000kg of reactor grade weapons usable plutonium each year, while at the same time there remains a stockpile of over 37 tons in Europe and 10 tons in Japan, and with only two commercial reactors operating with MOX fuel) - it was clearly a step too great even for the Abe government and the nuclear village.

Sending the right signals, creating the illusion of policy consistency and progress towards realization of the sixty year dream of the plutonium fuel cycle, is in many ways more important than the reality. To admit that the policy is technically and financially bankrupt would be to bring down the system, including the nuclear power companies – which as a group are some of the most powerful industrial actors in Japan. There really were no prospects for Rokkasho-mura to operate in 2016 and the question is whether 2018 will be marked by the announcement of yet another postponement, the

24th.

A final note on the costs of Rokkasho-mura. One lesson among many that policy makers, government and industry have either forgotten, never learnt or just continue to ignore, was that estimating the costs of nuclear projects, including reprocessing, have proven wholly unreliable. Providing an accurate estimate of the likely costs of operating Rokkasho-mura during its last planned decade of operation as JNFL and others have done, which on the current trajectory might be sometime between the 2050s and never, is clearly impossible. That uncertainty should be uppermost in the minds of electric power companies facing a very different electricity market over the next few years and the coming decades and when currently they have no idea how many of their reactors will actually be operating. The present model of financing Rokkasho-mura operations is not viable. However, as with the overall fuel cycle policy, rather than admit the obvious that it makes no sense in energy or waste management terms, the solution being developed in Japan are an attempt to save the whole edifice from collapse.

The Failure of Plutonium Demand and MOX Fuel Use In Japan

*"Japan scrupulously maintains the national policy of not possessing plutonium stocks beyond the amount required to implement its nuclear recycling programs."*⁹⁵

From 1991, the Japanese government committed to a *"no plutonium surplus policy"*, whereby it would not have any plutonium which does not have specific use. The declaration was meaningless then and even more so today. In 1991 Japan's plutonium stockpile amounted to 9,000 kg. At that time the Atomic Energy Commission projected plutonium demand would rise to between 80-90 tons by 2010.⁹⁶ In August 2003, the Japan Atomic Energy Commission (JAEC) announced its new guideline for plutonium management in advance of the planned commissioning of the Rokkasho-mura plant.⁹⁷ The requirement was for utilities to provide annual demand figures before reprocessing of their spent fuel at Rokkasho-mura. In 2009, FEPC released plans for Japan's utilities to use plutonium in MOX fuel supplied by the Rokkasho-mura plant. It envisaged the annual demand for plutonium of between 5.5 and 6.5 tons of fissile plutonium (about 8.3-9.8 tons total plutonium) each year from 2015.⁹⁸

As of December 2014, Japan's plutonium stockpile was 10.8 tons at domestic facilities, and 36.9 tons in Europe, with the exception of the operation of the MOX-fueled Takahama reactor units 3 and 4 scheduled for late January and February 2016, and Ikata 3 later this year, there is no demand for plutonium.

If any other non nuclear weapon state had acquired this amount of plutonium without having any commercial use there would rightly

have been clear international condemnation. How did Japan end up violating its own international nuclear non proliferation commitments?

Japan's MOX fuel program and therefore plutonium demand projections, have been a near complete failure from the start. As a series of scandals and public opposition unfolded in the late 1990s, the program prior to the Fukushima accident in March 2011 was already years behind schedule and limited to a few reactors. In September 1999, citizens groups exposed the fact that vital quality control data for MOX fuel then being shipped to Takahama unit 4 owned by Kansai Electric had been falsified.⁹⁹ Over a period of two months both the utility and MOX producer BNFL at the Sellafield reprocessing site in England denied falsification. The plans to load the fuel proceeded, despite the filing of a lawsuit in Osaka by citizens using detailed analysis of the original quality control data they had obtained. The day before the court judgment, Kansai Electric held an emergency press conference to confirm that quality control data for the MOX fuel had indeed been falsified. Plans to load were scrapped, the fuel was eventually returned to the UK, MOX plans for Takahama were put back a decade, and BNFL never supplied MOX fuel again to Japan. The scandal cascaded to the TEPCO Fukushima Daiichi plant, when 1000 Fukushima and Japanese citizens filed papers with the Fukushima District Court seeking an

injunction against MOX use. The case rested on successfully challenging the quality control procedures for MOX fuel also delivered in September 1999.¹⁰⁰ In this case the plutonium fuel was manufactured by Belgonucleaire in Belgium using plutonium separated at the Cogema (AREVA) la Hague plant. The court ruled against the citizens, but stated that fuel quality control data should be released by Cogema/AREVA. A company even less committed to transparency than most, this data was not forthcoming and has never been released. The public and legal controversy around plans to load MOX fuel in Fukushima Daiichi unit 3 led to a ten year delay, following the decision of prefectural Governor Eisaku Sato in 2002 to rescind his approval for MOX use.¹⁰¹ Eleven years after receiving the MOX fuel from France TEPCO finally loaded the 32 assemblies of MOX fuel, containing approximately 255kg of plutonium, into Fukushima Daiichi unit 3 between August and September 2010. The MOX fueled reactor operated for the six months from September 28 2010 until March 11 2011. It is worth highlighting that if TEPCO had not been prevented from rolling out its MOX plans in the late 1990's, multiple reactors at its Fukushima Daiichi and nearby Fukushima Daiini plant could have been using MOX fuel in March 2011. Prior to the March 2011 accident, TEPCO planned to increase MOX fuel loading unit 3 from 32 assemblies to 144 assemblies (containing approximately 1.1 tons of plutonium) over a period of three fuel

cycles.¹⁰² A decade long MOX program would also have generated many tons of spent MOX fuel. Both of these developments would from March 11 2011 would have led have to a greater release of radionuclides into the environment, including plutonium from the MOX fueled reactor core and the spent fuel pools.¹⁰³ The consequences of the Fukushima Daiichi accident, severe as they were and continue to be, could have been a lot worse.

TEPCO's plans for MOX fuel use at its largest nuclear plant at Kashiwazaki Kariwa in Niigata prefecture were also blocked by citizen actions. The loading 28 plutonium MOX assemblies (containing 205kg of plutonium) into unit 3 delivered from France in spring 2001, were challenged through a referendum of 4000 local inhabitants in Kariwa village. Fifty three percent voted to reject MOX fuel use and forty-two were for its use.¹⁰⁴ Again, at the time of the July 2007 Chuetsu earthquake at least one reactor at the Kariwa site would have been loaded with MOX fuel.¹⁰⁵ Fifteen years on the plutonium MOX fuel continues to sit in the spent fuel cooling pool at the Kashiwazaki Kariwa plant destined never to be used.

Clearly, even before the Fukushima Daiichi accident, plans to load MOX fuel in 16-18 reactors by 2010 had failed. By the industry target date of 2010, four reactors were using MOX fuel for the first time - Genkai unit 3 operating with 16 assemblies of plutonium fuel from November

2009; 16 assemblies of MOX fuel loaded into Ikata unit 3 as of March 2010; 32 assemblies loaded into Fukushima Daiichi unit 3 from September 2010, and eight assemblies in Takahama unit 3 from December 2010. In the case of Genkai unit 3, an additional 16 assemblies of MOX fuel were loaded into the reactor between March 9-12th 2011, however the reactor did not restart following the accident and remained shutdown. It is currently under review by the NRA.

In conclusion, of the 6,154kg of plutonium shipped by sea to Japan from the UK and France since 1992, a total of 1,888kg has actually been used in commercial nuclear reactors as of December 2015. As of March 2016 a total of 1,417kg of plutonium fabricated into MOX fuel in Europe will remain in storage at commercial reactor sites as of December 2015; specifically at Genkai (801kg plutonium), Ikata (198kg), Hamaoka (213kg), Kashiwazaki Kariwa (205kg plutonium). The two reactors Takahama 3 and 4 will begin operating with MOX fuel from January and February 2016, with 24 assemblies containing 1,088kg of plutonium and 4 assemblies containing 184kg of plutonium, respectively.

For a quarter of a century controversial sea shipments of plutonium, conducted at great expense and risk to the environment, were condemned by coastal nations in the Caribbean, South and Central America, Southern Africa, the South Pacific¹⁰⁶ and South East and East Asia – in total over 80 countries.¹⁰⁷ The justification given

by successive Japanese governments with the approval of the U.S. State Department, was that the nuclear material was required to fuel their nuclear reactor program. As with much of the rhetoric and reality of Japan's program, these justifications were a delusion.

In addition, a further 165kg in plutonium MOX fuel intended for the MONJU FBR and Joyo FBR remains in storage, as well as 433kg of plutonium contained in critical assemblies at Tokai and Oarai research centers.¹⁰⁸

Japan's Nuclear Power Crisis

Japan's future demand for plutonium is directly tied to the future of its commercial nuclear reactors. As a consequence of the March 2011 Fukushima Daiichi accident, all nuclear power plants over a period of two years were shutdown. There are major technical, political, economic and legal uncertainties that make accurately predicting the number of reactors that will eventually restart in Japan impossible: the Japanese government does not know; the utilities don't know; and, the financial markets don't know.¹⁰⁹ What we do know is that the majority of the Japanese public opposes the operation of any nuclear reactors. Projections from pro-nuclear analysts, including METI related think tanks, on nuclear restart schedules in recent years have proven to be wrong, and of such wide range as to be almost meaningless; in particular the METI funded and influential IEEJ in December 2013

was predicting between 6 and 22 reactors would restart during 2014,¹¹⁰ one year later it was giving a range of between 2 reactors and 20 and even a "hypothetical" 32 reactors during 2015.¹¹¹

In contrast, only two reactors were operating as of December 2015, with nuclear generated electricity remaining under one percent of the nation's electricity supply. This follows no nuclear output at all in 2014, and less than 2 percent in 2013 and 2012, compared to the peak of 29.8 percent in 2010.

The immediate prospect in 2016 is for three additional reactors to begin operation - Takahama 3 and 4 in January and February, and Ikata 3 by mid-year. These are all planned to operate with a percentage of MOX fuel. There are enormous uncertainties over the restart of additional reactors during 2016. Additional restarts could include one unit at Tomari, and perhaps Genkai 3 and 4. It is not a coincidence that of the six or seven reactors that could be operating by March 2017, five will be operating with a percentage of plutonium MOX fuel. There are a number of reasons for this, unconnected to the plutonium fuel cycle policy, with the age of the reactors being an important factor (the aforementioned reactors are generally the least aged in the fleet). However, it is also true that by operating five reactors using plutonium MOX fuel, an attempt is being made to legitimize the overall fuel cycle program, demonstrating that there is a demand for plutonium. This is also

directly linked to the justifications that will be required to start commercial operations at the Rokkasho-mura plant.

Prospects over the next 10 to 15 years look severe for the eventual number of reactors resuming operation.¹¹² Currently, in addition to two reactors operating, at Takahama, a further 21 (including MONJU) are under NRA review for compliance with the revised 2013 post Fukushima guidelines.

The Uncertainty Of Future Reactor Operation and MOX Fuel Use

Of the 24 commercial power reactors (not including MONJU) that have since July 2013 applied to the NRA for review prior to restart, ten are licensed to operate with plutonium MOX fuel.

The precise plutonium demand figures for each reactor and MOX fuel loading schedules are not generally made public. To estimate possible future scenarios its necessary to understand some basics on MOX fuel, though individual reactor operation, including fueling schedules may vary significantly. The number of fuel assemblies for a typical 1GW Pressurized Water Reactor (PWR) - for example Takahama 3 - is 157. If one third of this core of assemblies were to comprise MOX fuel, it would require 52 assemblies, containing a total of approximately 2.3 tons of plutonium. In the case of a typical 1GW¹¹³ BWR - for example, Kashiwazaki-Kariwa 3 - the total number of fuel

assemblies is 764. If it were to be one-third fueled with MOX fuel, it would require 254 assemblies containing 1.9 tons of plutonium. For the Advanced Boiling Water Reactors (ABWR) at Hamaoka, Shika, and Ohma, the number of assemblies on average is 872, with one third MOX fuel requiring 290 assemblies, containing 2,200kg of plutonium. In the case of Ohma, the current plan is for the reactor core to be a full MOX fuel, which would in theory require 1.7 tons of plutonium during each refueling. The actual amount of plutonium in each MOX fuel assembly ranges between 4-8 percent.

The fuel cycle plan for commercial reactors is that they are refueled every 12-18 months, depending on the fuel burn-up strategy at each reactor. Refueling sees one-quarter to one-third of the core replaced with fresh fuel. Thus, and on the basis of one-third reload, the annual demand for plutonium contained in MOX fuel for a typical PWR would be 760kg, and for a BWR 633kg. For the ABWR, depending on fuel cycle, the annual plutonium reload could be in the range of 733kg.

Japan's Theoretical Plutonium MOX Reactors

Reactor	Age	Shutdown	Restart Year	Plutonium in 1/3 reactor core	Annual Plutonium Demand based on 1/3 MOX core	Plutonium Demand by 2025 - Total	Prospects
Takahama 3	1984 – 31 years	20/02/12	2016	2300kg	760kg	6,840kg	Unclear MOX future -
Takahama 4	1984 – 31 years	21/07/11	2016	2300kg	760kg	6,840kg	Unclear MOX future -
Ohi 3	1991 – 24 years	02/09/13	2017/18?	2300kg	760kg	6,080kg	No approval for MOX yet – legal challenge on operation
Ohi 4	1993 – 22 years	15/09/13	2017/18?	2300kg	760kg	6,080kg	No approval for MOX yet – legal challenge on operation
Kashiwazaki-Kariwa 3	1993 – 22 years	19/09/07	No	1900kg	633kg	Uncertain	No prospects for restart

Fukushima Daiichi 3	1974 – 37 years	11/03/11	No	225kg at time of meltdown	NA	No	NA
Genkai 3	1984 – 31 years	11/12/10	2016/17 ?	2008kg	760kg	6,080kg	Unclear MOX future
Hamaoka 4	1993 – 22 years	25/01/12	No	1900kg	633kg	Uncertain	No prospects for operation – MOX approval from Shizuoka rescinded
Onagawa 3	2002 – 13 years	10/09/11	No	2200kg	733kg	Uncertain	No prospects for restart -
Shimane 2	1989 – 26 years	27/01/12	2017 ?	1900kg	633kg	5,064kg	MOX future unclear
Tomari 3	2009 – 6 years	05/05/12	2016/17 ?	2008kg	760kg	6,080kg	MOX future unclear
Ikata 3	1994 – 21 years	29/04/11	2016	2008kg	760kg	6,840kg	MOX future unclear
Shika 2	2006 – 9 years	11/03/11	Unclear	2200kg	733kg	Uncertain	No prospects for restart, due to seismic/legal
Ohma	Under construction	2021 target date	unclear	Full core MOX 5100kg	1700kg	6,888kg (on basis of full core, plus one third reload by 2025)	Questionable if it will ever operate, due to seismicity and political opposition, and technical
MONJU ¹¹⁴	08/12/95	Unclear		Full MOX Core		Uncertain	Unlikely to operate in coming years
Plutonium Total					7,653kg annual	51,384 kg	Not credible

To achieve a one-third MOX core, a commercial reactor starts with a smaller number of assemblies and increases the number over a period of three or more years. The Takahama reactor 3 for example, when it restarts in early 2016, will contain 24 assemblies of MOX fuel containing 1269 kg of plutonium. Additional MOX fuel assemblies would have to be manufactured and shipped from France, most likely during the first half of 2016, if Kansai Electric wished to move to a one third core. The same would apply to MOX fuel loading in Genkai, Ikata, Tomari, Ohi and Shimane over the coming years. The above table gives the best industry case scenario for plutonium demand in Japan over the coming ten years. Of course, achieving a one third MOX core for the above reactors is a long way from being secured, and therefore plutonium demand could, and almost certainly will be, less.

On paper, it would seem that if the eight reactors listed above with a significant chance of restart, plus the Ohma ABWR, moved successfully to MOX fuel use during the next 10 years, Japan would import the remaining stocks of 37 tons plutonium from Europe, and at the same time require full-scale operation of the Rokkasho-mura plant to meet an annual demand of around 7.6 tons of plutonium each year. In total, it would have loaded over 51 tons of plutonium into nine reactors. JNFL's latest plans (unrealistic as they are) for Rokkasho-mura operation would yield an additional maximum of 46.2 tons of plutonium by 2025.¹¹⁵ Thus while Japan would have loaded an enormous stock of plutonium as MOX fuel by 2025, it would still have an excess stockpile of 42.2 tons of plutonium. The difference from today is that much of this would be located in Japan, compared to the present day where Japan's domestic stockpile is just over 10 tons. Whatever the program of plutonium use during the coming years, it is inevitable that Japan will continue to fail to meet its own international commitment to not stockpile more plutonium than is required in its nuclear fuel cycle.

Japan's nuclear utilities are in crisis, with many reactors unlikely ever to restart operation, including some of those intended to be MOX fueled. Accurate projections on how much plutonium MOX fuel will be loaded into which reactors are impossible, and therefore Japan's

plutonium demand is unknown. What is predictable is the supply side, up to a point. We know there are over 37 tons of Japanese plutonium in Europe, and over 10 tons in Japan. There are major uncertainties over the prospect during the next 10-15 years of a major proportion of this material being loaded as MOX fuel. Therefore by 2030, much of this existing separated plutonium will remain unused (and increasingly unusable).¹¹⁶ Thus how tenable is it that Japan will be able to justify the separation of even more plutonium with the operation of the Rokkasho-mura plant – capable in theory of separating up to 8 tons of plutonium each year?

The political reality is that unless a solution can be found for Japan's European stock of plutonium (transfer of ownership to the UK or France, for example, as has been suggested) it is unclear how a future Japanese government will explain the operation of Rokkasho-mura to the international community. The most interested observers are Japan's nearest neighbors in East Asia as well as the United States. In the case of Japan's plutonium stockpile currently in France, AREVA has every intention of manufacturing it into MOX fuel and delivering to Japan – which would maximize the income for AREVA, a company in deep crisis. With the restart of Takahama MOX fuel use, there is every likelihood of a fresh MOX shipment as early as the first half of 2016.¹¹⁷ Japanese utilities, with the exception of JAPCO, all have MOX fuel supply

contracts with AREVA, originally scheduled to be delivered over the fifteen years to 2020.¹¹⁸ This is clearly not possible. The fact that the utilities have no idea when or if many of their reactors will restart, or the prospects for MOX fuel use, matters little to AREVA. Japanese utilities, and therefore electricity consumers, pay an annual fee to AREVA for the storage of the plutonium oxide at la Hague based on a euro per kilogram rate. In fact, AREVA appears to be as out of touch with reality as the Japanese nuclear industry, with the French state company still claiming on its December 2015 website 'AREVA – forward looking energy' that:

*"Japan will soon be loading MOX assemblies into some of its reactors for the first time. Japanese electric utilities plan to load 16 to 18 additional reactors with MOX between now and 2010 (sic). The first AREVA MOX fuels have already been delivered to Japan."*¹¹⁹

The Japanese plutonium stock stored at the Sellafield site in England has the additional complicating factor that the Sellafield MOX Plant (SMP) no longer exists due to its complete failure to operate as planned. There is therefore no fuel fabrication plant in the UK capable of manufacturing Japan's plutonium into MOX fuel.¹²⁰ Designed to produce 120 tons of MOX fuel each year, containing around 5-6 tons of plutonium, it should have manufactured over 1000 tons in its first decade. Instead it sporadically operated for 9 years, successfully

produced 13 tons,¹²¹ and was scrapped in 2011. Nuclear policy failure is not a unique phenomenon to Japan.¹²² Transfer of ownership of the Japanese stock of plutonium to ownership of the UK seems a possibility. The UK currently has a stock of 140 tons of plutonium for which it has no solution. An additional 20 tons transferred from Japanese utilities would not create that great an additional challenge – given the scale of the existing challenge. One major obstacle from such a transfer taking place is that it would be confirmation that Japan's fuel cycle policy has failed – something neither utilities or Government are currently prepared to admit.

Looking to the future for reactor restarts in Japan, a scenario of nine reactors, currently listed above as approved to operate with plutonium MOX fuel could possibly restart in the next 10 years. That is to discount the risk of technical failure accident, and legal and political challenges. Based on past performance, there is little prospect of all these reactors attaining a one-third MOX core within the coming decade. Therefore, Japan's annual demand will perhaps run at between 1-2 tons of plutonium from about 2018 (this would require at least one MOX fuel shipment each year from Europe). At that rate, it would be sometime between 2036 and 2055 before Japan's plutonium stock in Europe was used. Yet that timescale is not possible. Three of the eight reactors, Takahama 3 and 4 and Genkai 3, will surpass 40 years operation in 2024 and it is

unclear whether they will operate beyond that. A further six reactors will pass that age by 2034. Japan's nuclear share of electricity by 2030 could be as low as 1.8 percent, rising to a possible 6-8 percent. It is unclear whether there would be any MOX fuel use in the small number of reactors available to achieve this level of nuclear generation. In short, there are considerable uncertainties for the prospects of attaining a MOX fuel use of 1-2 tons plutonium each year.

Given the crisis in the utilities' existing commercial reactor fleet, the strategic importance of the Ohma reactor is paramount. The Ohma ABWR is a special case within the overall Japanese nuclear power program; in fact, globally it is unique.¹²³ The reactor, located on the tip of Aomori prefecture, is owned by the Japan Electric Power Development Co Ltd (EPDC/J-Power), a utility that, with one exception, has no experience of operating a nuclear reactor. The current idea is that this facility will be loaded with a core consisting of 100 percent plutonium MOX fuel.¹²⁴ In contrast to all other conventional light water reactors in Japan and worldwide, where MOX fuel loading is normally 30 percent, plans to operate Ohma with a full MOX core raise even greater safety issues, as well as significant doubts as to whether this project is at all viable.¹²⁵

The closest comparison to Ohma, a "conventional" reactor operating with a high percentage MOX core, was the FUGEN ATR. The

ATR was a small experimental heavy water moderated Boiling Water Reactor which operated at the PNC site at Tsuruga in Fukui prefecture.¹²⁶ As a heavy water prototype reactor, it bears little comparison with what is planned at Ohma. During its lifetime the ATR operated with up to 77 percent of its core being MOX fuel. In its operating lifetime from 1979-2003, it loaded 1.8 tons of plutonium in MOX fuel.¹²⁷ The ATR program, of which FUGEN was the first and only reactor, was terminated by the electric utilities in 1995 due in large part to the economic burden a planned large scale ATR program would have entailed. It was a rare example of a national policy platform rejected in its entirety. There is a more direct connection between FUGEN and Ohma. Both are owned by EPDC, which until 1997 was a government owned power company, subsequently operating under its brand name of J-Power. The Ohma site was selected for a larger demonstration reactor ATR to follow on to FUGEN, but, after 12 years of consideration and investment in research and design, it was canceled in August 1995, again in part due to the failure to demonstrate its economic viability.¹²⁸ The 'compensation' for EPDC/J-Power was that a decision was made to build in its place the ABWR at Ohma. The history of this project illustrates how even when a rare decision is made to terminate a specific nuclear project, in Japan the system ensures that the corporations, contractors and the political class do not lose out.

Construction of Ohma began in 2008 following METI approval, with the original plan to begin operation in 2012, then set back to 2014. Construction was suspended when 40 percent complete at the time of the March 2011 earthquake, while construction resumed again in October 2012. The current operational target date is 2021. The first MOX fuel for the core is to be manufactured by AREVA in France using plutonium from Japan's stockpile at la Hague.¹²⁹ Thereafter, the J-MOX plant is to manufacture the fuel from plutonium separated at Rokkasho-mura. If this schedule is met, which is unlikely, then the plutonium content of the first core could be as large as 5 tons. More likely the core will be a combination of uranium fuel and plutonium MOX fuel. Whatever the eventual configuration, there will be enormous pressure to operate Ohma with the maximum percentage of plutonium to justify the operation of the Rokkasho-mura reprocessing plant.

It is therefore of national importance that in April 2014 the city of Hakodate filed an injunction against the construction of Ohma. The decision to file the lawsuit was passed unanimously by Hakodate city council, which with a population of 270,000, lies as close as 18km from the Ohma site across the Tsugaru straits on the island of Hokkaido. Hakodate is challenging both the central government and J-Power in the first such lawsuit in Japan. The first court session, held in July 2014, saw Hakodate Mayor, Toshiki Kudo,

warn that *"If a severe accident occurs, the municipalities in the area will collapse,"*¹³⁰ arguing that Hakodate and other municipalities within a 30-kilometer radius of the plant should be given the right to consent to the construction. Its a vital and brave legal challenge that will expose the unique safety hazards posed by the reactor and MOX fuel, the failure of the NRA, and the risks in Japan's overall nuclear program. A start-up date in 2021 for Ohma looks unlikely.

In conclusion, there are no prospects that plutonium demand in Japan will rise to meet supply, current or planned, over the coming ten years, even without the operation of Rokkasho. Predicting accurately the future MOX loading of reactors in Japan is effectively impossible. Even with an unrealistic 2 tons annual plutonium loading and a total loading of 20 tons by 2025, plus a partial loading of MOX fuel in Ohma, the current stockpile of Japan's plutonium would be reduced to between 22-25 tons. This does not factor in the operation of Rokkasho-mura, which in theory could be producing up to 8 tons of additional plutonium annually. Current JNFL plans are to reprocess 80 tons of spent fuel from 2018, 320 tons in 2019, 480 tons in 2020, 640 tons in 2021 and 800 tons in 2022.¹³¹ This would yield a maximum of 23.2 tons of plutonium by 2022. Thereafter, an additional eight tons of plutonium would be separated each year. Even on the unlikely assumption of successful operation of Rokkasho-mura, a more likely scenario is that the

amount of spent fuel reprocessed at Rokkasho-mura would be less than its maximum 800 tons – though that would have direct consequences for shipping additional spent fuel to the plant from reactor sites.

The System Positions For Survival

The crisis and enormous uncertainties within the Japanese nuclear power utilities, including prospects for reactor restart, permanent shutdown and the economic impact of electricity market reform, and finally no solution for high level waste disposal, has led to a head on collision with national government fuel cycle policy. The underlying tensions between utilities and government surfaced during late 2015. At a media briefing on November 20th, FEPC chair Makoto Yagi announced that the target of 16-18 reactors to be operating with MOX fuel by March 2016 was being postponed indefinitely. He argued that, *"we can't put out a concrete plan [to load MOX fuel in the reactors] until after the Rokkasho-mura spent fuel reprocessing plant completes and recovers new plutonium,"*¹³²

This announcement deserved broader attention as it effectively tore up the cornerstone of Japan's national fuel cycle policy, including the justification of decades long reprocessing programs in Europe and Japan. Nearly all the background details to this announcement remain confidential. The announcement appears to apply specifically to the future plutonium supply from

the Rokkasho-mura plant, while no mention is made of the supply of 36 tons of plutonium and MOX fuel from AREVA in France (and the UK) and plans to use this in FEPC's reactors. The assumption must be that during the coming years, as a number of reactors restart such as Takahama 3 and 4, MOX fuel use will steadily increase, supplied by AREVA. However, because of the uncertainties on restart, FEPC finds it impossible to commit to any future target either for the number of reactors using MOX or when they would do so.

While abandoning their long stated (and wholly unrealistic) MOX fuel target date is welcome, this does not mean that the power utilities are waking up to the multiple hazards and risks of plutonium MOX fuel use. The crisis faced by utilities means they are looking for any mechanism to reduce their operational costs. The fuel cycle, in particular reprocessing and MOX fuel use, is one of the most significant burdens. By tying the future of MOX fuel use directly to the operation of Rokkasho-mura, the utilities are attempting to leverage the government into providing support – specifically financial.

As a national policy, the utilities are signaling that the government, or more specifically the taxpayer and electricity consumer, must do more to bear the enormous cost of Rokkasho-mura and MOX fuel. During 2015, a METI panel began to consider options for providing additional financial support to the utilities. Future prospects

are that a nuclear feed-in tariff will be proposed whereby nuclear utilities will be guaranteed an electricity price, with the difference between the market price being paid for by customers. This UK imported model to save a near bankrupt nuclear industry has not progressed in Japan – yet. Variations on the above approach include a MOX fuel feed-in tariff to ensure financial support for plutonium fuel use. All of these deliberations effectively take place behind closed doors, allowing little access and affording scant information to the Japanese public who will be required to foot the bill. The discussions will be ongoing through 2016, but it is unclear when any specific proposal will emerge.

At the same time the government is seeking to secure the future funding of reprocessing and MOX fuel as power companies enter a more deregulated electricity market from April 1st 2016. All parties are fully aware that the no reprocessing option, with the Rokkasho-mura plant abandoned, is by far the least cost, with an estimate in 2012 that 8.1-8.7 trillion yen would cover the cost of spent fuel disposal, compared with up to 18.5 trillion for full reprocessing.¹³³ As stated, these figures are not reliable given the uncertainties and timescales involved – but they indicate the cost differential between reprocessing and no reprocessing.

Aware that costs for the fuel cycle will only increase over the coming decades, a new framework was proposed by a METI panel in

November 2015 by which nuclear power utilities would be required to make financial contributions to a new government agency to cover the costs of reprocessing *"regardless of the utilities' business conditions."*¹³⁴ Moving from a "deposit system" to a "contribution system", as discussed at a meeting of Japan's Agency for Natural Resources and Energy (ANRE) and the Atomic Energy Commission in January 2016. The new body would oversee JNFL's operations at Rokkasho-mura. Power companies have so far set aside 5.1 trillion yen in the Reprocessing Fund to cover the cost of reprocessing and MOX fuel use. This falls far short of the likely total costs over a forty year lifetime for Rokkasho-mura, with revenues from nuclear electricity generation effectively frozen over the last two years and more for utilities.

As the Yomiuri earlier commented, *"Since the government promotes the nuclear fuel cycle as a national policy, it is only reasonable for the government to increase its involvement in the project by transferring the management of the reprocessing project...Should the corporate management of leading power companies come under pressure from the increased competition, forcing them to suspend the supply of human resources and funds to the JAEA, the continuation of the nuclear fuel cycle project will be at risk. Unless the nuclear fuel cycle is realized, spent nuclear fuel, now kept in storage at nuclear power plants, will have nowhere to go, impeding the operation of nuclear power*

*plants."*¹³⁵

Under the current law, money in the Reprocessing Fund is paid annually to JNFL and used to repay bank and utility loans used for the construction of Rokkasho-mura. The banks receive an annual payment of around US\$2 billion. This payment would stop if the reprocessing and MOX project was terminated. The new government agency is in part intended to ensure that JNFL and therefore the utilities remain tied into the Rokkasho-mura project. In 2012, then Prime Minister Noda was warned by nuclear industry officials that a halt in payments from the Reprocessing Fund could drive some of the utilities into bankruptcy and create chaos in Japan's financial markets.¹³⁶ The Japanese Cabinet approved on February 5th 2016 a reprocessing corporation bill which will establish a new business structure for ensuring the continued funding for Rokkasho Mura. A bill is to be considered in the House of Representatives of Economy, Trade and Industry Committee during the coming six months.

The Nuclear Waste Crisis With No Solution

Given the disastrous record of the Rokkasho-mura project and future uncertainties, the utilities also understand that they must have alternatives to reprocessing for managing spent fuel. It is this that is perhaps of most concern to those in METI and elsewhere for which the plutonium fuel cycle is the option of choice for

Japan. Only TEPCO had seriously developed dry cask storage up to the time of the March 2011 Fukushima Daiichi accident, both with its on site storage and the decision to construct the Mutsu site in Aomori prefecture. With nearly 3000 tons of spent fuel currently in the storage pools at Rokkasho-mura, most commercial spent fuel remains in the cooling ponds at nuclear power plants across Japan. No further spent fuel is permitted to be shipped to Rokkasho-mura without actual commercial operations – a long standing position imposed on JNFL by the Aomori Governor. As of 2014, a total of 12,400 tons of commercial spent fuel is in pool storage at nuclear power plant sites (excluding spent fuel at Fukushima Daiichi).¹³⁷ When it is understood that one large commercial reactor operates with around 100 tons of fuel, it is clear that the equivalent of around 124 commercial nuclear reactors worth of highly radioactive spent fuel requiring continuous active cooling, presents an enormous radiological hazard to Japan. The vulnerability of a rapid drain down of the cooling water in the event of a major seismic event would be catastrophic.¹³⁸ It was in particular the threat from the spent fuel pools at Fukushima Daiichi and Daini that led the Japanese Atomic Energy Commission to issue a worst case analysis presented to Prime Minister Kan on March 25th 2011. It warned that in the event of loss of all control, including cooling of reactor cores and spent fuel pools, evacuation could be required out to 250km from the plant, a nightmare that

would have involved 50 million people, including the entire population of greater Tokyo.¹³⁹ Little wonder that Naoto Kan warned that it would have effectively been the end of central Japan as a functioning society.¹⁴⁰

The reason why Japan has built up such an inventory of spent fuel at reactor sites is tied directly to the failure of its fuel cycle policy whereby all spent fuel was intended for reprocessing. But ultimately, it has been its operation of nuclear power plants that has created a problem for which there are no solutions on the horizon. The national policy to reprocess all spent fuel was never credible (the current stock of spent fuel would yield in the range of 124 tons of plutonium if reprocessed). With spent fuel volumes increasing each year prior to the March 2011 accident, there was never any prospect of reducing the inventory of spent fuel. Even with Rokkasho-mura operating at full capacity, though wholly unlikely, it would still not be sufficient to reduce Japan's spent fuel inventory. Under the Abe Government's 2030 energy mix target, a total of 35 reactors would be required to operate to supply a 20-22 percent electricity share. This would generate around 1000 additional tons of spent fuel each year. While almost certainly this number of reactors will not be operating by 2030, the point is that current national policy raises the specter of an even greater spent fuel challenge, based as it is on the flawed assumption of successful operation

of Rokkasho-mura.

The hybrid alternative of building dry storage facilities at reactor sites, where spent fuel would be retained on an interim basis prior to eventual reprocessing, has long been considered unacceptable due to the local population and a tacit agreement with the prefecture and local towns that power plants would not become de facto waste storage areas. The utilities and prefectural governments won't admit it – but that is actually what they are already. However, as they seek to restart their reactors, utilities are faced with spent fuel pools already beyond their original design capacity, (high density storage has been adopted by all utilities even though the risks are even greater).¹⁴¹ The power companies are now positioning for the option of dry storage either at the site or a common site away from the power plant.

*“Spent fuel is stored safely and systematically in each nuclear power plant on the premise that it will be transported to the Rokkasho Reprocessing Plant when it becomes ready to receive the spent fuel. The utilities will continue to consider measures to increase the current storage capacity, including the construction and use of both on-site and off-site intermediate and dry storage facilities.”*¹⁴²

In a further significant development in November 2015, the FEPC announced plans to increase spent fuel storage capacity by 4000 tons

by 2020, and a further 2000 tons by 2030.¹⁴³ This is to be done through additional re-racking in existing pools (eight utilities plan this)¹⁴⁴ and dry cask storage. For the first time all utilities are proposing the construction of interim dry storage facilities for spent fuel. So far, only three utilities have specific dry storage plans – TEPCO, Chubu Electric and JAPCO. However, all others (Kyushu Electric, Tohoku Electric, Hokkaido Electric, Chugoku Electric, Hokuriku Electric and Shikoku and Kansai Electric) have commitments to develop their dry storage plans.¹⁴⁵ In the case of Kansai Electric, one of the most aggressive in support of the nuclear fuel cycle based on reprocessing and MOX fuel, it has also adopted a policy to secure dry storage of spent fuel outside of Fukui prefecture as demanded by the prefectural government (so far with no success). Kansai's current schedule is to secure a site by 2020, to be operational by 2030, with a capacity for 2000 tons. The utility shares in a Mitsubishi Heavy Industries (MHI) research demonstration test program underway at the Nuclear Development Corporation (NDC) facility at Tokai-mura, in conjunction with Kyushu Electric and JAPCO.¹⁴⁶

Whatever the success of utilities developing additional storage capacity, the national government holds further leverage to maintain their commitment to reprocessing and MOX fuel use. Any moves to end the Rokkasho-mura project would lead the Aomori prefectural

government to demand the return of the 3000 tons of spent fuel currently in storage at the plant. The July 1998 agreement between Aomori prefecture, Rokkasho village, and JNFL, states: *"In the case where it is extremely difficult to ensure the execution of reprocessing, upon consultation between Aomori Prefecture, Rokkasho village, and JNFL, JNFL shall promptly take necessary and appropriate measures including the removal of the spent nuclear fuel from the site."* Aomori Governor Shingo Mimura has referred to this agreement in recent years including during the Government review of nuclear policy in 2012.¹⁴⁷ Utilities do not have the capacity to take back this waste, nor would they secure local political and public approval. However, the utilities also have leverage: 14 percent of Aomori's annual revenue is derived from spent fuel storage taxes paid by JNFL, something the prefecture could ill afford losing.¹⁴⁸ All parties, including successive Governors, have created a myth for the people of Aomori - that the importation of nuclear spent fuel for reprocessing will not turn their prefecture into a semi permanent nuclear waste site. The reality, and its not unique to Japan, is that this is exactly what Rokkasho-mura has become.

Already controversial, the issue of high-level waste storage will only generate greater public opposition over the next few years. Knowing this, the FEPC is also proposing a public relations

campaign to explain its developing plans. The increasingly clear signal to METI and the national government is that for utilities, dry storage is inevitable. This conveniently serves also as leverage during the negotiations to secure financing and subsidy mechanisms for the utilities to continue to support the high cost reprocessing and MOX fuel program¹⁴⁹ just as they enter a Japan style liberalised electricity market.

However, while the power companies may have reached the conclusion that dry storage is inevitable, public opinion has not. As it becomes more widely known that reactor restarts (already opposed by the majority), will also exacerbate an existing nuclear waste problem, and that the preferred option for utilities is storage on and off site (including in neighboring prefectures), public and political resistance will only increase further. In addition to opposition to on-site spent fuel storage,¹⁵⁰ there is no prospect of utilities securing approval from other prefectures that do not already have nuclear power plants. The nuclear crisis in Japan is so deep and of such a scale, the only credible option for starting the process of reducing the risks from Japan's enormous spent fuel stock is to stop the production of any more spent fuel – which means an end to reactor restart plans. When this is on the agenda, it may become possible to enter into negotiations with communities over dry cask storage and the long-term management of high-level waste.

While there are competing interests at work here, in the end it's about the system ensuring that all parties continue to secure financing for a plutonium and nuclear program that never made economic sense but which cannot be allowed to collapse. The people and business sector of Japan are the ones who will be made to pay the price through electricity rates and taxes for a program that has utterly failed in energy terms. One major reason why present governments have not and cannot allow the whole edifice to collapse is that from the very beginning Japan's pursuit of plutonium involved so much more than 'just' energy.

Atomic Tatemaie and Honne: Japan's Strategic Plutonium Stockpile

"It's a tacit nuclear deterrent," Shigeru Ishiba, former Liberal Democratic Party Defense Minister observed, speaking in 2011 while in opposition.¹⁵¹

The way things are supposed to be, their formal truth and therefore their appearance and perception, are central to understanding the continuation of Japan's nuclear fuel cycle program. Equally, reality and genuine motives are just as important to understand. While not unique to Japan, it is so central to Japanese culture that terminology helpfully exists to aid one's understanding: it is the difference between *'tatemaie'* and *'honne'*. In the case of Japan's nuclear fuel cycle the distinction between the two

runs through the core of the entire program.

As explained by successive governments and utilities, the formal truth justifying the vast scale of Japan's plutonium fuel cycle is that historically it is driven by energy security considerations, is a resource poor nation, and that the deployment of fast breeder reactors and large scale plutonium reprocessing will provide that security – atomic *'tatemaie'*. Its latest incarnation, offered to explain the need for the national government to become more active in overseeing the nation's reprocessing and plutonium MOX program, has seen the energy security card once again deployed, *"A nuclear fuel cycle is very important for Japan, which faces a scarcity of natural resources,"* a senior METI official said in November 2015.¹⁵²

The reality is that Japan's plutonium program has nothing to do with energy security and everything to do with national security.

The possession of thousands of kilograms of plutonium capable of being used to manufacture nuclear weapons clearly also serves Japan's perceived strategic interests but without explicitly having to declare that this is one of its intended purposes – plutonium *'honne'*.

Yet, much of this proliferation, conducted in plain sight over the decades, has been there for all to see. Located in a highly unstable region, with rising tensions, and with enormous uncertainties as to its future security needs,

Japan's development of plutonium technologies and materials serves a future potential military application. This was one of the determinants behind the decisions on the nuclear fuel cycle of the 1950s and 1960s. It gave the nation a future option – one that may never have to be realized, but is there all the same. This also serves its national interest vis a vis its regional neighbors as well in its security relationship with the United States.

The ambiguity of what Japan could do with its plutonium stocks, while remaining an active member state of the Nuclear Non Proliferation Treaty (NPT), demonstrates the major flaws in the non-proliferation regime, where the risks of a nation possessing weapons material is judged on political allegiance and not on the inherent nature of the nuclear material. Japan, along with other official non-nuclear weapon states, insisted on the right to acquire nuclear weapon material for peaceful use during their negotiation of the terms of the NPT during the late 1960s and their ratification of membership. In the case of Japan it took until 1975 for ratification, in part due to concerns within Japan's nuclear establishment that plans for reprocessing and the full development of the nuclear fuel cycle could be curtailed by NPT membership.¹⁵³ The last four decades have shown that they should have had no such concerns.

The Safeguards Myth

In addition to the possession of existing stocks of plutonium, which as detailed above will increase not decline in the coming years, there is the question of the direct proliferation threat posed by the operation of the Rokkasho-mura reprocessing plant and J-MOX facility. The position of the Japanese government and the IAEA is that these plants will operate under strict international safeguards, as required under the NPT and bilateral safeguards agreements between Japan and the Agency.¹⁵⁴ The message from both parties is that this will ensure that plutonium will be accounted for with no risk of the material being diverted for non-peaceful purposes. This is the pretense of Japan's nuclear fuel cycle – added and abetted by the IAEA – the '*tatema*'. The reality is that IAEA safeguards are incapable of meeting their stated aim – that is the '*honne*'.

The IAEA confirms that the design throughout of the Rokkasho-mura plant is 800 tons of spent fuel each year which if completed would yield 8 tons of plutonium, with a storage capacity at the site for 30 tons of plutonium¹⁵⁵ – or around 4 years of operation. Safeguarding such a large amount of fissile material in a non-nuclear weapon state has been a unique challenge for the IAEA¹⁵⁶ – one reason that it has been working with Japan for more than two decades to design and implement a safeguards system for Rokkasho-mura.

Unfortunately, due to the nature of the reprocessing plant and J-MOX plant at

Rokkasho-mura, not unique to Japan but the same for all such 'bulk handling' facilities, this effort is not capable of detecting the diversion of significant quantities of plutonium sufficient to yield multiple nuclear weapons. The IAEA and Japanese authorities remain silent on this fundamental flaw in nuclear safeguards. Fortunately, others have been more transparent:

"No safeguards scheme, including that of the International Atomic Energy Agency (IAEA), can be effective if such sensitive materials and facilities (plutonium and reprocessing plants) are widely available in Non-Nuclear Weapon States." U.S. National Defense Research Institute, Rand Corporation, November 1993.¹⁵⁷

The inability of safeguards to be applied to nuclear weapons material being used in peaceful nuclear programs has been known since the start of the nuclear age.¹⁵⁸ The particular challenge and threat from Rokkasho-mura has long been critiqued.¹⁵⁹ Still the charade continues. The end result is that a safeguards system has been developed for Rokkasho-mura that reportedly absorbs 20 percent of the annual global safeguards budget of the IAEA. All this to create the illusion that Japan, if it ever was attempted, would be unable to divert significant quantities of plutonium without the IAEA detecting it. All for a program that is already awash with a stockpile of weapons material, and for which there is no current or realistic future demand.

Proliferation in Plain Sight

Nuclear establishments (if not politicians) worldwide are aware of the limitations of the IAEA safeguards system. These establishments include Japan's nearest neighbors in East Asia. Hence, it actually serves Japan's strategic interests to create the public illusion of guaranteed peaceful use for its plutonium, while in parallel sending a clear signal that it has the means and the material to use it otherwise. But just in case nations are not alert to the potential of Japan, successive politicians have - over the decades - floated the idea that it has a latent weapons potential. Most recently, in arguing against the phase-out of nuclear power following the Fukushima Daiichi accident, LDP heavyweight and former Defense Minister, Shigeru Ishiba stated in October of 2011 that *"I don't think Japan needs to possess nuclear weapons, but it's important to maintain our commercial reactors because it would allow us to produce a nuclear warhead in a short amount of time"*.¹⁶⁰

Sensing that the entire nuclear program was at risk of termination following the March 2011 Fukushima Daiichi accident, the Yomiuri Shimbun appealed to national security interests by explaining that:

"As Japan has worked to strengthen the Nuclear Nonproliferation Treaty regime through the peaceful use of nuclear power, the nation is

*permitted to use plutonium that can be used as material for nuclear weapons. In fact, this also functions diplomatically as a potential nuclear deterrent.*¹⁶¹

It is this strategic factor that will play a major (but not public) role in determining the future of Japan's nuclear fuel cycle. Decisions on the MONJU FBR and associated reprocessing plant RETF, the medium term future for the Rokkasho-mura reprocessing and J-MOX plants and operation of the Ohma ABWR MOX reactor in Aomori, as well as MOX fuel use in reactors across Japan – all will be determined not just in technical and economic terms, but in the context of Japan's national strategic interests.

Warnings about the proliferation threat from Japan have existed for most of the second half of the 20th century and show no sign of declining during this century. Opposition to Japan's plutonium program has extended from domestic civil society, through leading scientists and policy makers, as well as current and former officials within successive U.S. Governments, and more recently to the Chinese Government.¹⁶²

Just one example of the continuity of opposition to Japan's nuclear program is personified in Spurgeon Keeney Jr. In the aftermath of China's first nuclear weapons test in 1964, Keeney was a member of the Gilpatric Committee which reported to President Lyndon B Johnson on the threat of nuclear proliferation. The Committee's

1965 report, classified for nearly three decades, cautioned the President that,

*"The Chinese Communist nuclear weapons program has brought particular pressure on India and Japan, which may both be approaching decisions to undertake nuclear weapons programs. Although one may be tempted to accept Indian or Japanese nuclear weapons to counterbalance those of China, we do not believe the spread of nuclear weapons could be stopped there."*¹⁶³

Four decades later, in 2005, Keeney co-signed a statement calling for the indefinite suspension of operations of the Rokkasho-mura plant due to the implications for global nuclear non-proliferation.¹⁶⁴ Other signatories, included a host of elite policy makers and scientists in the U.S. nuclear establishment, including former U.S. Defense Secretary MacNamara, Ashton Carter (the current U.S. Defense Secretary), and the current Director of President Obama's, Office of Science and Technology Policy, John P. Holdren. It is clear that opposition to Japan's plutonium program exists within the White House and Defense Department. Underscoring the level of concern over the impact of Japan operating Rokkasho-mura, Holdren stated in October 2015, and in his official capacity, that:

"In the case of Japan, where there is already a sizable stockpile of separated plutonium, we would prefer not to see it grow...*The United*

States has taken the position that it is preferable that countries that are currently not reprocessing should not go into it...Since reprocessing leads to separated plutonium and, in principle, separated plutonium can be used to make nuclear weapons, our general view is that less reprocessing in the world is better than more."¹⁶⁵

Unfortunately, efforts to discourage Japan in its pursuit of ever more plutonium are directly undermined by the Department of Energy, which has no such considerations for the proliferation consequences in East Asia. As we have noted, the DOE continues its decades long relationship in promoting Japan's program. And in 2015, and for the first time, the DOE helped secure consent rights for the Republic of Korea to ship spent fuel for reprocessing and the return of plutonium MOX fuel.¹⁶⁶

Given the explicit opposition to Japan's plutonium program, it remains unclear what impact such high level appeals make on the thinking of the Japanese government. Nuclear power policy in Japan (as with many other countries) is not solely based on considerations of energy security, but also national security. Successive Japanese governments have viewed reliance on U.S. extended deterrence and the guarantee of security provided by the U.S. nuclear umbrella as not wholly reliable. The distrust was one of the principal reasons that the Eisaku Sato government of the 1960's established the Kanamaro group to study Japan's nuclear

weapons options.¹⁶⁷ The 1967 declaration of the three non-nuclear principles,¹⁶⁸ while symbolically important, were only committed to after it was decided that Japan should also ensure, through research and development, that it would retain the option to acquire nuclear weapons. The production of fissile materials and missile technology were at the core of this policy. In the case of fissile materials, as this paper argues, the plutonium stockpile, and equally important, technical and scientific know-how, has been acquired to an unprecedented degree by a non-nuclear weapons state.

In the case of missile technology, as described in groundbreaking research by Pekkanen and Kallender¹⁶⁹ Japan's peaceful space program has evolved explicitly into a program to serve national security interests, as outlined in the Basic Space Law of 2010, providing the nation with the most advanced ballistic missile technology and a "recessed deterrent for Japan."¹⁷⁰ This includes the H and J series of liquid and solid fueled launch vehicles and through the testing in the 1980s and 1990s of the OREX and HYFLEX re-entry systems, providing Japan the technical means to adopt a counterforce strategy (targeting of Chinese missile silos for example). These developments have continued, including with the Hayabusa unmanned spacecraft, which included a re-entry capsule with both a declared civil and military potential application.

"That's the behind-the-scenes reason Japan

decided to develop Hayabusa," says Toshiyuki Shikata, a former lieutenant general in Japan's military. *"It sent a quiet message that Japan's ballistic missile capability is credible."* ¹⁷¹

Extended deterrence and blowback

Recent changes in Japanese defense policy can be seen as further solidifying the nation's security within the context of U.S. military strategy in the western Pacific, and in particular in relation to a containment strategy vis-a-vis China. But it is doubtful whether this will have the effect of convincing Japanese policy makers that their medium- to long-term security is assured and therefore they have the option to abandon nuclear power development. In particular, it is unlikely that it will dissuade them from fast reactor technology and plutonium reprocessing and stockpiling of fissile material. While the actual operation of a plutonium-based fuel cycle has almost completely failed in energy terms, it has given Japan the status of a de facto nuclear weapons state. In the language of military strategy, it is a deterrent capability without recourse to actual weapons development and deployment.

This also serves U.S. strategic interests in East Asia in relation to China. Without U.S. dominance over Japanese defense planning, including the continuation of its nuclear guarantee, the argument made is that Japan would consider the nuclear option. Framed in

this way, the logic argues for maintaining and expanding the current security relationship between Japan and the United States. On this flawed approach to non-proliferation, policy makers in Washington and Tokyo broach no concept of an alternative vision of a peace and security infrastructure in East Asia that would reverse the increasing regional tensions, not rely on nuclear weapons, and avoid the ever present risk of accidental nuclear war.

However, that is not where security is heading in East Asia. The combination of territorial disputes, military modernization, including nuclear weapons,¹⁷² additional DPRK nuclear and missile tests and a U.S. policy of containment centered around the strategies of U.S. Pacific Command¹⁷³ is of profound concern. Japan's nuclear fuel cycle must be seen in the context of the evolving and deteriorating security environment in Asia.

The example of missile defense and its blowback¹⁷⁴ consequences highlights the rising tensions in East Asia.

The deployment of U.S. and Japanese Aegis-class destroyers in North-east Asia and their capability to intercept ballistic missiles since the 1990s was justified by Washington and Tokyo on the basis of the threat from the DPRK.¹⁷⁵ However, their capacity to intercept missiles also applies to Chinese Inter Continental Ballistic Missiles (ICBMs). This fact is not lost on Chinese policy makers, and the missile-defense program has

played a role in convincing Chinese decision makers of the need to develop Multiple Independently Targeted re-entry Vehicles or MIRVs.¹⁷⁶ In contrast to single nuclear warheads, the MIRVing of ICBMs, entails the emplacement of multiple warheads in each missile, with each capable of being individually targeted. The U.S. initiated MIRV systems during the 1960s both to counter Soviet Anti Ballistic Missile systems, but also to increase the number of targets it could hit. The Chinese development of MIRV systems is certainly a major development, in theory making Japan (and potentially the U.S.) more vulnerable to Chinese nuclear forces. Additional Aegis-class vessel deployments from the U.S., to add to the existing Japanese fleet and U.S. vessels in the region, are planned between 2015 – 2020.¹⁷⁷ But the Chinese development of MIRV can be seen in part as a response to U.S. and Japanese missile defense capabilities. Whereas China has long maintained a nuclear policy of minimum deterrent, for defense planners in Beijing, missile defense increases uncertainty in the capability of its nuclear weapons to deter. The deployment of the MIRV DF-5 ICBM announced by the Pentagon in 2015¹⁷⁸ is one response to the ability of the U.S. and Japan to reduce China's deterrent effectiveness.

Of course, these developments serve all sides: the increased threat from China justifies a response – more missile defense - and justifies more development of nuclear forces in China, and so

on. For those who recall the Cold War, we've been here before. But this time around, it may not end well.

The threat of Japan moving beyond its de facto nuclear deterrent to a declared weapons power, however credible,¹⁷⁹ remains a critical leverage point exploited by successive Governments in Tokyo. This threat is used both towards its regional neighbors, but also to the United States. The persistent doubts about the reliability of U.S. security guarantees to Japan, was one factor in deciding to maintain the ability to develop nuclear weapons.¹⁸⁰ Questions over U.S. security guarantees was raised most recently by Hiroyuki Namazu, Cabinet Counselor at the National Security Secretariat, when speaking in the context of Chinese activities in the East and South China Seas:

"It is understandable that the United States wishes to avoid a military confrontation with the emerging peer powers...There is a natural inclination on both sides to establish stability between them. Such a high level stability is on the one hand a desirable state of the relationship between the two sides but on the other could make the relationship between the emerging peer powers (China) and their neighbors less secure. In invading a smaller neighbor the emerging peer powers may consider it less likely that the U.S. intervenes, indeed the United States itself may hesitate to intervene as the intervention could risk the high level stability with the emerging

*peer powers. In the eyes of the neighboring states American extended deterrence may appear less convincing.*¹⁸¹

Conclusion

After six decades of Japan's pursuit of a plutonium-based nuclear fuel cycle, it would be a mistake to conclude that in 2016 we are at a point when a fundamental change is on the agenda. The nuclear crisis, which has encumbered the power companies since the Fukushima Daiichi accident five years ago, has certainly exposed the flaws and failures of a policy that never made sense in strictly energy terms. As the uncertainties and challenges persist, the collective interests of the members of the nuclear village appear to be fracturing. But that does not mean they are.

While the nature of the 'system' in Japan rarely if ever allows for major change in national policy priorities, the unprecedented forces now challenging the nations bankrupt nuclear energy policy could break a decades long pattern. The insight and analysis of the power dynamics of Japan by Karel van Wolferen, while largely pessimistic, if applied to nuclear energy policy also offer some possibility that change can take place. Although written a quarter of a century ago, his exploration of "the System" encapsulates both the why, and the how of the nuclear policy disaster five years since the melt down of three nuclear reactors at Fukushima Daiichi, and the

dilemma Japan still finds itself in.

*"Japanese policy patterns are nearly always inflexible until a catastrophe occurs or until those who consider themselves victimised manage a veritable chorus of protest. A movement of opposition or complaint is at first usually ignored or suppressed. But when the realization dawns that further suppression will only make the movement stronger, officialdom changes its attitude. Those in charge tend to become more flexible and ready to overlook illegal actions. In cases where a problem suddenly threatens to become acute, the metamorphosis of the officials concerned, from a stubborn and uncompromising attitude to an accommodating stance, is generally very dramatic."*¹⁸²

Where precisely Japan lies along the route to change remains unclear. The Japanese government may on one level believe it has survived the wave of mass public opposition to nuclear power in the period after March 11 2011. The positioning for survival of the overall nuclear fuel cycle policy, as we have summarized, would suggest that we have not reached the point where dramatic change is about to happen. However, while the numbers outside the Diet building are smaller, at the local and regional level citizens are more active than before. Japanese people backed by hundreds of lawyers are challenging reactor restarts, MONJU and Rokkasho-mura, all supported by majority

public opinion that shows no sign of waning. While one could conclude that this vast nuclear program is invulnerable to being challenged, history actually shows otherwise. The people of Fukui, Fukushima and Kariwa all successfully challenged some of Japan's most powerful entities and blocked plutonium MOX use in the late 1990s and 2000s, as with those citizens in Aomori who for decades have fought against Rokkasho-mura, exposing the risks, hazards and illogicality of Japan's nuclear fuel cycle. This opposition has, over the decades long before the Fukushima Daiichi accident, significantly curtailed the original planned scale of Japan's nuclear program. Given the crisis in the nuclear industry in Japan, and the scale of opposition to nuclear plant restarts the prospects for Japan to return to a major nuclear reactor program look poor.

The Abe government knows full well that there are no prospects for rebooting nuclear Japan to the level prior to the tragic events five years ago.¹⁸³ Combine this with the fact that the disaster at Fukushima Daiichi continues, and will do so for decades, the aging of the utilities nuclear reactor fleet, and a plutonium fuel cycle and current nuclear waste policy that threatens to financially cripple power companies already in crisis. Add in the uncertainties of market liberalization of the electricity market and it is clear that the 'catastrophe' that is Japan's nuclear policy and the effective chorus of opposition to its continuation will have no end, not until there

is real change.

On one level, the flurry of announcements from the utilities, the NRA, JNFL and METI in November 2015 could be seen as evidence of a growing conflict and divergence of thinking, but that is only part of the story. The system, which underpins Japanese nuclear policymaking and implementation exists to serve and protect the industrial, commercial, personal and political interests of its members. Sitting on top of this toxic mountain is the national security and strategic interests of Japan. If operation of the Rokkasho-mura reprocessing plant proceeds as planned, Japan will increase its unprecedented plutonium stockpile from the present 47 tons, to more than 90 tons by 2025. Even on an industry best-case scenario of plutonium MOX fuel use in nine commercial reactors, the operation of Rokkasho as planned will lead to Japan's surplus stock to be around 42 tons by 2025. The difference from today is that whereas Japan's domestic plutonium holdings are 10 tons this larger amount will be stockpiled in Japan. The technical and economic failure of Japan's program should not blind us to the fact that it has succeeded – in plain sight - in its strategic objective of becoming a plutonium superpower. The national government's solution to the crisis in Japan's nuclear fuel cycle, the "All Japan" phrase which has emerged in recent months will be a de facto nationalisation of plutonium policy, and underscores the power of the vested interests

but also the inherent weaknesses.

Creating the illusion of a demand side for separated plutonium through MOX fuel use is crucial to the Rokkasho-mura project. Advocating the use of Japan's plutonium in MOX fuelled reactors, and therefore supporting reactor restart, will in reality have the opposite effect in terms of stopping the Rokkasho-mura plant. It won't solve Japan's plutonium stockpile problem. Difficult as it may be for the non-proliferation community to grasp, it is Japan's reactor operation that is producing the plutonium and high level waste which justifies the reprocessing route. Given how embedded this policy is, only turning off the tap will ultimately force a change that will be fundamental. Every reactor that restarts in Japan will provide further legitimacy for the 'system' to maintain plutonium fuel cycle policy. The fact that the utilities are in a historic crisis with no prospects that most of their reactors will restart - ever - provides the most effective leverage point for the change that would best serve non proliferation, energy security and environmental and economic interests of the people of Japan. But then there is the national security card.

Without a change in policy, Japan, and its security guarantor, the U.S., over the coming years will face mounting criticism from East Asian nations over the deliberate stockpiling of an amount of nuclear weapons fissile material unique to a non-nuclear weapons state.

Explicit criticism of Japan from within East Asia has risen to a new level with a series of comments and analysis¹⁸⁴ from the Chinese government and agencies.¹⁸⁵ In October 2015, China's ambassador to the United Nations challenged the legitimacy of current stocks of plutonium in Japan, and that the amount exceeded Japanese needs. In response to Chinese criticism, the Japanese government in October 2015, gave the unconvincing answer that, *"the Government is committed to a policy of not possessing reserves of plutonium that have no useful purpose and is very careful about the supply and demand balance. Japan will continue to engage appropriately and thoroughly in a manner that is transparent to the international community concerning plutonium management."*¹⁸⁶

As we have sought to demonstrate in this analysis, Japan has utterly failed to create an energy use for its plutonium stocks. That absence of a persuasive, energy-based rationale will not change in the future. As to whether Japan's plutonium stocks ultimately have a "purpose," other than an energy source depends on one's perspective. Our conclusion is that Japan's stocks of plutonium and overall program already serve a specific and explicit national security and strategic purpose, a fact that was always intended when the nation first embarked on its nuclear program decades ago. Precisely for this reason, the Japanese government is likely to continue to support the program even at great

cost.

Public attention of Japan's plutonium stockpiles will only increase during February and March 2016 when a shipment of 331kg of weapons grade plutonium, currently in store at the Nuclear Science Research Institute, Tokai, Ibaraki prefecture, will depart Japan for the Savannah River Site in the United States.¹⁸⁷ For the U.S. and Japanese government, the shipment will be hailed as demonstrating their commitment to reducing the threat from fissile materials. Both governments plan to announce the 'success' of the removal from Japan, at the fourth Nuclear Security Summit from March 31st-April 1st in Washington DC, while Japan will be desperate to avoid any discussion of the proliferation and security threat posed by its plutonium fuel cycle program.

While the amount of plutonium is significant in of itself, what both governments will seek to avoid at the summit is any discussion of the nine tons of weapons usable, reactor-grade plutonium that remains in Japan's domestic stockpile, most of which will remain unused in the years ahead. Amidst the media fanfare that will be generated by the shipment and summit, attention should be directed to the overall scale of Japan's existing 48 ton plutonium stockpile of weapons usable reactor grade plutonium, held in country and in Europe, its plans for MONJU and the RETF, and its intention to operate Rokkasho-mura from 2018.

If 331 kg of plutonium warrants removal from Japan on the grounds of its vulnerability and in the interests of securing nuclear weapons material, then there is no credible justification for Japan's current program and future plans to increase its plutonium stockpiling, which could yield as much as 93,000kg by 2025.

Looming on the horizon is the extension of the U.S.-Japan Peaceful Nuclear Cooperation Agreement (the 123 Agreement) in July 2018.¹⁸⁸ This bilateral, signed in 1988, granted Japan advance programmatic approval over a period of 30 years for plutonium reprocessing. It is directly responsible for the stockpile of bomb material now acquired by Japan. If ever there were a time for the United States (not to mention Japan) to rethink its approach, it would be now. Having failed to prevent the proliferation of vast quantities of fissile material, it would be insanity to continue further reprocessing, plutonium MOX fuel use, and stockpiling. Both parties should enter into negotiations for a change in direction. There appears to be no prospect that the lead for this initiative will come from Japan. That leaves it to the current Obama White House, and from 2017, the next U.S. administration, to put at center stage the interests of the people of Japan, along with effective nuclear non-proliferation, peace and security in East Asia. Prospects for this could easily be dismissed as wholly unrealistic given the enormous commercial, diplomatic and strategic interests

involved. The terms of the 1988 agreement will be interpreted by Japan as allowing automatic extension without revision.¹⁸⁹ That will also be the view inside the U.S. Department of Energy. However, it is Japan's nuclear program, including its plans for the plutonium fuel cycle that is in crisis as never before, particularly with only four reactors likely to be operating by spring 2016 and formidable obstacles in the path of reopening other reactors. So the opportunity is there for the taking.

The diplomatic conflict that existed between the U.S. and Japan over Tokai-mura in the 1970s will not be repeated. However, the immensely more complicated nuclear and security environment of East Asia today, is the geo-political context for Japan's vast plutonium stockpiling program. It demands a change of thinking in Tokyo and proactive engagement from Washington. The U.S./Japan 123 Agreement of 1988 was premised on significant nuclear power growth in Japan. Today the program is moribund with the only prospects being a much scaled down reactor program over the coming decades. A strong case can be made that the current agreement is an anachronism given the crisis within Japan's nuclear industry. As the security environment in East Asia continues to deteriorate, time is running out for Japan to reverse gear and abandon its plutonium ambitions.

Recommended citation: *Shaun Burnie and Frank Barnaby with Tom Clements, Aileen Mioko Smith and*

Kendra Ulrich, "Nuclear Proliferation in Plain Sight: Japan's Plutonium Fuel Cycle—A Technical and Economic Failure But a Strategic Success" *The Asia-Pacific Journal, Vol. 14, Issue 5, No. 2, March 1, 2016.*

ACRONYMS

ABWR – Advanced Boiling Water Reactor

ATR Fugen – Advanced Thermal Reactor

CEA – French Atomic Energy Commission

CNWG – U.S. Japan - Civil Nuclear Energy Research and Development Working Group

DBGM - Design Basis Ground Motion

DOE U.S. Department of Energy

EBR - Experimental Breeder Reactor

EBR-II – Experimental Breeder Reactor II

EPDC/J-Power - Japan Electric Power Development Co Ltd

FBR - Fast Breeder Reactor

FCDR – U.S. Advanced Fuel Cycle R&D Program

FEPC - Federation of Electric Power Companies

GNEP - Global Nuclear Energy Partnership

IFR - Integral Fast Reactor

IAEA - International Atomic Energy Agency

ICBM - Inter Continental Ballistic Missiles	MIRV - Multiple Independently Targeted re-entry Vehicles
JAEA - Japan Atomic Energy Agency	NDC – Japan Nuclear Development Corporation
JAEC - Japan Atomic Energy Commission	NPT – Treaty on the Non Proliferation of Nuclear Weapons
JAPCO – Japan Atomic Power Company	NRA - Nuclear Regulation Authority
JNEAP - U.S.-Japan Joint Nuclear Energy Action Plan	OECD NEA – Organisation for Economic Cooperation and Development - Nuclear Energy Agency
J-MOX – Japan Mixed Oxide Fuel Fabrication Plant – Rokkasho-mura	PWR – Pressurised Water Reactor
JNFL - Japan Nuclear Fuel Limited	RETF – Recycle Equipment Test Facility
KEPCO – Kansai Electric Power Company	SMP - Sellafield MOX Plant
METI – Japan Ministry of Economy, Trade and Industry	SNT - Sensitive Nuclear Technology
MEXT – Japan Ministry of Education, Culture, Sports, Science and Technology	S-PRISM - General Electric – Hitachi Power Reactor Innovative Small Modular) Fast Reactor
MHI - Mitsubishi Heavy Industries	TEPCO – Tokyo Electric Power Company
MOX - Mixed Oxide plutonium fuel	

Shaun Burnie (Senior Nuclear Specialist, Greenpeace Germany, sburnie@greenpeace.org (<http://apjff.org/mailto:sburnie@greenpeace.org>)) and **Dr Frank Barnaby** (formerly of the UK Atomic Weapons Establishment and Director of the Stockholm International Peace Research Institute, SIPRI, frank.barnaby1@btinternet.com (<http://apjff.org/mailto:frank.barnaby1@btinternet.com>)), together with **Tom Clements** (Director Savannah River Site Watch, tomclements329@cs.com (<http://apjff.org/mailto:tomclements329@cs.com>)), **Aileen Mioko Smith** (Director, Green Action

Japan, amsmith@gol.com (<http://apjif.org/mailto:amsmith@gol.com>)) and **Kendra Ulrich** (Senior Global Energy Campaigner, Greenpeace Japan, kulrich@greenpeace.org (<http://apjif.org/mailto:kulrich@greenpeace.org>))

Notes

¹ See Japan Atomic Energy Commission's (JAEC) first Long Term Plan, published in 1956, explained in "The Fast Reactor and Its Fuel Cycle Developments in Japan: Can Japan Unlock its Development Path?" Tatsujiro Suzuki, *Science and Global Security*, 17:68–76, 2009

² "Monju operator unfit for purpose", Shaun Burnie with Mycle Schneider, IPFM Blog, International Panel on Fissile Materials November 4 2015, see http://fissilematerials.org/blog/2015/11/monju_operator_unfit_for_.html

³ "Regulator to call for new Monju reactor operator to enhance safety", November 4, 2015, see <http://asia.nikkei.com/Politics-Economy/Policy-Politics/Regulator-to-call-for-new-Monju-reactor-operator-to-enhance-safety>

⁴ "Extraordinary Press Conference", JNFL, November 16 2015, <http://www.jnfl.co.jp/english/topics/151116-1.html>

⁵ "Japan postpones plans to use MOX fuel", *Nucleonics Week* November 26 2015.

⁶ Plutonium oxide separated from reactor spent fuel in reprocessing plants is either stored in oxide form, or manufactured into Mixed Oxide MOX fuel, a combination of plutonium and uranium oxides.

⁷ *Nuclear Intelligence Weekly*, November 8 2013, p. 8. as cited in "Plutonium Separation in Nuclear Power Programs Status, Problems, and Prospects of Civilian Reprocessing Around the World", International Panel on Fissile Materials, 2015.

⁸ "Pugwash scientists demand Japan end troubled nuclear fuel recycling program", *Asahi Shimbun*, November 7 2015, http://ajw.asahi.com/article/behind_news/social_affairs/AJ201511070038

⁹ For decades the nuclear establishment in Japan have sought to challenge analysis from U.S. nuclear weapons specialists that the plutonium produced in commercial nuclear reactors is capable of being used in nuclear weapons – for example, see "Can Reactor Grade Plutonium Produce Nuclear Fission Weapons?," Council for Nuclear Fuel Cycle Institute for Energy

Economics Japan, May 2001, see <http://www.cnfc.or.jp/e/proposal/reports/>; In reality this so called 'reactor-grade' plutonium, can be used to make powerful and reliable nuclear weapons, and "Separated plutonium in the fuel cycle must be protected as if it were nuclear weapons." as detailed by Richard L Garwin in a summary analysis in 1998, Senior Fellow for Science and Technology, Council on Foreign Relations, New York see <http://fas.org/rlg/980826-pu.htm>. Garwin worked at the Los Alamos National Laboratory from 1950 to 1993, Sandia National Laboratories where most of his work at Los was involved with nuclear weapons design, manufacture and testing.

¹⁰ "Response team erred in Japan nuke leak," December 12, 1995, <http://www.upi.com/Archives/1995/12/12/Response-team-erred-in-Japan-nuke-leak/3373818744400/>

¹¹ "Major Victory to Blow Nuclear Fuel Cycle Policy" Nuke Info Tokyo No. 93 CNIC, January 4, 2003, <http://www.cnic.jp/english/?p=436>

¹² "The Safety Of Fast Breeder Reactors: The New Threat Of MONJU", Dr. Frank Barnaby and Shaun Burnie, Greenpeace International, March 24 1994, Tokyo/Fukui City, Japan.

¹³ Japan Nuclear Cycle Development Institute, <http://www.jaea.go.jp/jnc/jncweb/02r-d/02index.html>

¹⁴ Renewables Global Futures Report 2013, Renewable Energy Policy's Network, REN, http://www.ren21.net/Portals/0/documents/activities/gfr/REN21_GFR_2013.pdf

¹⁵ "Fuel Cycle Demand, Supply and Cost Trends" by R.B. Fitts and H. Fujii, Nuclear Materials and Fuel Cycle Section, Division of Nuclear Power and Reactors, International Atomic Energy Agency (IAEA), IAEA Bulletin-Vol.18, No.1, 1975, see <https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull18-1/18104881924.pdf>

¹⁶ Fast Neutron Reactors, World Nuclear Association, 15 October 2015, see <http://www.world-nuclear.org/info/Current-and-Future-Generation/Fast-Neutron-Reactors/>

¹⁷ Proliferation report: sensitive nuclear technology and plutonium technologies in the Republic of Korea and Japan, international collaboration and the need for a comprehensive fissile material treaty, Shaun Burnie, Greenpeace International Paper presented to the International Conference on Proliferation Challenges in North-east Asia: The Korean Peninsula and Japan, National Assembly, Seoul, Republic of Korea, April 28th 2005. see,

<http://www.greenpeace.org/international/Global/international/planet-2/report/2006/4/Proliferation-Korea-Japan.pdf>

¹⁸ The EBR and other FBRs, such as Monju, have the risk of a "positive void", meaning that if bubbles form in the sodium coolant, core reactivity tends to increase. Although not an FBR, a positive void was instrumental in causing the 1986 Chernobyl accident. Both these weaknesses could come into play if a loss of electric power caused the primary coolant pumps to stop working. Void coefficient of reactivity is a number that can be used to estimate how much the reactivity of a nuclear reactor changes as voids form in the coolant. A positive void coefficient means that the reactivity increases as the void content inside the reactor increases due to increased boiling or loss of coolant; for example, if the coolant acts as a neutron absorber. If the void coefficient is large enough and control systems do not respond quickly enough, this can form a positive feedback loop which can quickly boil all the coolant in the reactor. See, Restarting Monju - Like Playing Russian Roulette, CNIC, January/February 2010, see <http://www.cnic.jp/english/newsletter/nit134/nit134articles/monju.html>

¹⁹ For an authoritative history of the U.S. breeder program see, Fast Reactor Development in the United States Thomas B. Cochran, Harold A. Feiveson, and Frank von Hippel, in Fast Breeder Reactor Programs: History and Status Thomas B. Cochran, Harold A. Feiveson, Walt Patterson, Gennadi Pshakin, M.V. Ramana, Mycle Schneider, Tatsujiro Suzuki, Frank von Hippel, A research report of the International Panel on Fissile Materials February 2010, see <http://fissilematerials.org/library/rr08.pdf>

²⁰ In a 1976 policy statement, President Gerald Ford declared, *"The avoidance of proliferation must take precedence over economic interests."* He also stated that U.S. domestic policies must be changed to defer *"the commercialization of chemical reprocessing of nuclear fuel which results in the separation of plutonium."* - President Gerald Ford, Statement on Nuclear Policy, October 28, 1976, In 1977, shortly after taking office, President Jimmy Carter, also citing concerns about the consequences of proliferation, *"defer[red] indefinitely the commercial reprocessing and recycling of plutonium in the U.S."* - President Jimmy Carter, Presidential Directive/NSC-8, March 24, 1977, as cited in See DOE's Nuclear Energy Research Programs Threaten National Security Back to the Bush Administration's Nuclear Energy Research and Development Program – Index, October 2003, <http://www.nrdc.org/nuclear/bush/freprocessing.asp>

²¹ "Fast Breeder Reactor Programs: History and Status", Research Report 8 International Panel on

Fissile Materials Thomas B. Cochran, Harold A. Feiveson, Walt Patterson, Gennadi Pshakin, M.V. Ramana, Mycle Schneider, Tatsujiro Suzuki, Frank von Hippel www.fissilematerials.org, February 2010, see <http://fissilematerials.org/library/rr08.pdf>

²² The White House Office of the Press Secretary, Fact Sheet Nonproliferation And Export Control Policy, September 27, 1993, see, <http://fas.org/spp/starwars/offdocs/w930927.htm>

²³ "Planning Proliferation: The Global Expansion Of Nuclear Power And Multinational Approaches," May 18th 2010, Frank Barnaby and Shaun Burnie, Commissioned by Greenpeace International, see <http://www.laka.org/docu/boeken/pdf/6-03-2-30-06.pdf>

²⁴ "JNFL has issued an Expressions of Interest (EOI) to the GNEP Program of DOE", September 8, 2006, see http://www.jnfl.co.jp/english/press_release/presse2006/20060911-1.html

²⁵ "Mitsubishi Activities for Advanced Reactor Development - Sodium-cooled Fast Reactor", Takaya Ito, Shigeru Kunishima, Shigeki Kobayashi, Haruo Mochida, Mitsubishi Heavy Industries Technical Review Vol. 46 No. 4 (Dec. 2009), <https://www.mhi.co.jp/technology/review/pdf/e464/e464042.pdf>

²⁶ "Second Ministerial Meeting of Global Nuclear Energy Partnership (GNEP)," September 18, 2007, see http://www.mofa.go.jp/announce/announce/2007/9/1175499_834.html

²⁷ IAEA International Ministerial Conference on Nuclear Energy, Beijing speech of US Ambassador to China Gregory Schulte on April 20 2009, as reported at www.neimagazine.com/story.asp?storyCode=2052785 (<http://www.neimagazine.com/story.asp?storyCode=2052785>)

²⁸ Fuel Cycle Research & Development, Office of Nuclear Energy, Department of Energy, see <http://www.energy.gov/ne/fuel-cycle-technologies/fuel-cycle-research-development>

²⁹ In January 2015 for example, 78 representatives from the U.S. and Japan met for the Second Sub-Working Group Technical Meeting of the CNWG, where the three sub-working groups reviewed the status of technical cooperation and prepared reports of activities and accomplishments, <http://www.ne.anl.gov/About/headlines/20150209.shtml>

³⁰ "Plutonium Reuse with PRISM", Initial Feasibility Proposal CMS ID # 1-2PA2F8 February 16, 2012, see <http://data.parliament.uk/DepositedPapers/Files/DEP2012-1176/HL1277Hitachi-NDAProposal.pdf>

³¹ GE – Hitachi PRISM, see <http://gehitachiprism.com/what-is-prism/evolution-of-prism/>

³² The issues include no credible commercial case, timeframe for deployment (minimum of 25 years).

³³ "Can PRISM solve the UK's plutonium problem?", Jim Green, Nuclear Monitor, February 26 2014,

http://www.theecologist.org/News/news_analysis/2297881/can_prism_solve_the_uk_s_plutonium_problem.html

³⁴ "How France is Fueling Japan and China's Nuclear 'Race'", Victor Gilinsky and Henry Sokolski, Nonproliferation Policy Education Center, NPEC, November 6, 2015, see

<http://www.npolicy.org/article.php?aid=1296&rtid=1>

³⁵ France operated two small FBR's, the Rhapsodie from 1967-1983 and Phenix from 1973-2009.

³⁶ In total, Rhapsodie and Phenix FBR's produced between 18 and 19.5 percent of the French inventory of military plutonium by 1990, an amount sufficient for 400 - 500 nuclear warheads. In the case of Superphenix it was considered a potential source for military application, but this was abandoned in 1986 – As cited in, "The Unlawful Plutonium Alliance Japan's Supergrade plutonium and the role of the United States", Shaun Burnie and Tom Clements, September, 1994, Greenpeace International,

http://www.srswatch.org/uploads/2/7/5/8/27584045/retf_report_sept_1994.pdf, – and,

"Plutonium and Highly Enriched Uranium 1992: World Inventories, Capabilities, and Policies", David Albright, Frans Berkhout and William Walker, Oxford: SIPRI and Oxford University Press, December 1992; "Super-Phenix: Ashes To Ashes?: Problems and prospects of fast breeder reactors"; Dossier by Walt Patterson for Amici della Terra - April 1984,

<http://www.waltpatterson.org/ashes.pdf>; Dominique Finon, "L'échec des Surgénérateurs,

Autopsie d'un Grand Programme," PUG 1989, 76, as cited in Schneider, Fast Breeder Reactors in France, in Fast Breeder Reactor Programs: History and Status Thomas B. Cochran, Harold A.

Feiveson, Walt Patterson, Gennadi Pshakin, M.V. Ramana, Mycle Schneider, Tatsujiro Suzuki, Frank von Hippel, A research report of the International Panel on Fissile Materials February 2010, see <http://fissilematerials.org/library/rr08.pdf>

³⁷ Conseil Supérieur de la Sûreté Nucléaire, op. cit. Quoted by Jean-Louis Fensch (CEA engineer), as cited by Mycle Schneider, in Fast Breeder Reactors in France, in Fast Breeder Reactor

Programs: History and Status Thomas B. Cochran, Harold A. Feiveson, Walt Patterson, Gennadi Pshakin, M.V. Ramana, Mycle Schneider, Tatsujiro Suzuki, Frank von Hippel, A research report

of the International Panel on Fissile Materials February 2010, see

<http://fissilematerials.org/library/rr08.pdf>

³⁸ "Nuclear Energy For The Future ASTRID, An Option For The Fourth Generation", Christophe Béhar, les Defis de CEA, ISSUE 172, September 2015.

³⁹ "France And Japan Announce Cooperation On Generation IV Astrid FBR", May 6 2014, <http://www.nucnet.org/all-the-news/2014/05/06/france-and-japan-announce-cooperation-on-generation-iv-astrid-fbr>

⁴⁰ "Five-Party Conference on ASTRID", Noriyuki Ishii, Atoms in Japan, JAIF, December 24 2014, <http://www.jaif.or.jp/en/five-party-conference-on-astrid/>

⁴¹ "Funding opportunities and legal status options for the future European Sustainable Nuclear Fission Industrial Initiative of the Strategic Energy Technology Platform", Deloitte SL, February 2010, <ftp://ftp.cordis.europa.eu/pub/fp7/euratom-fission/docs/deloitte-gen4-022010-full-report.pdf>

⁴² "4th-Generation Sodium-Cooled Fast Reactors - The Astrid Technological Demonstrator", CEA, 2012.

⁴³ SNETP, Deployment Strategy 2010, <http://www.snetp.eu/wp-content/uploads/2014/05/ds-a4.pdf>

⁴⁴ "Safety Strategy of JSFR establishing In-Vessel Retention of Core Disruptive Accident", Yoshiharu Tobita, Advanced Nuclear System R&D Directorate, Japan Atomic Energy Agency (JAEA), <https://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-03-04-03-07-CF-NP-TD/T3.4/T3.4.tobita.pdf>. The JAEA SWAT1R is sodium water test facility located at Oarai, Ibaraki prefecture, see, "Cooperation on impingement wastage experiment of Mod. 9Cr-1Mo steel using SWAT-1R sodium-water reaction test facility," FR13 International Conference Paris, France March 4-7 2013 F. Beauchamp, M.Nishimura, R. Umedab, A. Alloua, CEA (French Alternative Energies and Atomic Energy Commission), Nuclear Energy Directorate, Cadarache center, France and JAEA (Japan Atomic Energy Agency), Oarai R&D center, Narira, Oarai, Ibaraki, Japan, <https://www.iaea.org/NuclearPower/Downloadable/Meetings/2013/2013-03-04-03-07-CF-NP-TD/T2.5/T2.5.beauchamp.pdf>

⁴⁵ "Deliberation Of Post-3.11 Fast Reactor R&D Strategy In Japan" S. Kondo, Japan Atomic Energy Commission, Tokyo, Japan, in Fast Reactors and Related Fuel Cycles: Safe Technologies and

Sustainable Scenarios FR13 Proceedings of an International Conference Paris, France, 4–7 March 2013 Vol. 1, see

<http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1665Vol1Web-68441300.pdf>

⁴⁶ "Statement of Protest Against Recommencement of Monju Test Operation", Hideyuki Ban, Co-Director Citizens' Nuclear Information Center (CNIC), April 6, 2010, see

<http://www.cnic.jp/english/topics/cycle/fbr/restartstate6may10.html>

⁴⁷ "Japanese Reactor Is Said to Stand on a Fault Line", Hiroko Tabuchi, May 15 2013, see

http://www.nytimes.com/2013/05/16/world/asia/japanese-reactor-is-said-to-sit-above-fault-line.html?_r=0

⁴⁸ On 7th October 2015, a panel of the NRA concluded that a seismic fault line beneath the Monju prototype fast-breeder reactor is likely inactive, after finding the fault line would not move in tandem with an active geological fault 500 meters away. A full report will be prepared for NRA Commissioners. "Fault beneath Monju nuclear reactor likely inactive", Masanobu Higashiyama, October 8 2015, see http://ajw.asahi.com/article/behind_news/social_affairs/AJ201510080072

⁴⁹ Safety design criteria for the next generation Sodium-cooled fast reactors based on lessons learned from the Fukushima NPS accident, Takaaki SAKAI Safety Evaluation Group Advanced Nuclear System Research & Development Directorate Japan Atomic Energy Agency (JAEA), IAEA Technical Meeting, Dresden, Germany, 19-23 March 2012, see

https://www.iaea.org/NuclearPower/Downloadable/Meetings/2012/2012-03-19-03-23-TM-NP-TD/18_TM-Safety-Dresden_Japan_Sakai.pdf

⁵⁰ "Energy Research and Development Database" (International Energy Agency), as cited in "Plutonium Separation in Nuclear Power Programs Status, Problems, and Prospects of Civilian Reprocessing Around the World", International Panel on Fissile Materials, 2015.

⁵¹ "JSFR Safety design based on the Safety Design Criteria of GEN IV SFR", S. Kubo, Japan Atomic Energy Agency, Oarai, Japan Y. Shimakawa: Mitsubishi FBR Systems, Inc., Tokyo, Japan, presented at the 4th Joint IAEA-GIF Technical Meeting/Workshop on Safety of SFR, 10–11 June 2014, IAEA, Vienna see

<https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2014-06-10-06-11-TM-NP-TD/21.kubo.pdf>

⁵² "Current status of fast reactor cycle technology development (FaCT) project in Japan", Ryodai Nakai, Advanced Nuclear System Research and Development Directorate Japan Atomic Energy

Agency (JAEA), November 13, 2007

⁵³ "Mitsubishi Activities for Advanced Reactor Development - Sodium-cooled Fast Reactor", Takaya Ito, Shigeru Kunishima, Shigeki Kobayashi, Haruo Mochida, Mitsubishi Heavy Industries Technical Review Vol. 46 No. 4 (Dec. 2009), see <https://www.mhi.co.jp/technology/review/pdf/e464/e464042.pdf>

⁵⁴ "Experience on Reprocessing in Japan", Naoto Ichii Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Japan, 2010, see, https://www.iaea.org/INPRO/2nd_Dialogue_Forum/Experience_on_Reprocessing_in_Japan.pdf, Technical Cooperation Project INT/4/142: "Promoting Technology Development and Application of Future Nuclear Energy Systems in Developing Countries" INPRO Dialogue Forum on Nuclear Energy Innovations: Multilateral Approaches to Sustainable Nuclear Energy Deployment - Institutional Challenges 4–7 October 2010, IAEA, Vienna, Austria, see https://www.iaea.org/INPRO/2nd_Dialogue_Forum/

⁵⁵ "Sellafield's ageing THORP plant flunks major foreign fuel reprocessing target", Martin Forwood, International Panel on Fissile Materials (IPFM), November 6 2015, see http://fissilematerials.org/blog/2015/11/_sellafields_ageing_thorp.html

⁵⁶ "Spent Nuclear Fuel Reprocessing in France.", Mycle Schneider and Yves Marignac, International Panel on Fissile Materials (IPFM), April 2008, see <http://fissilematerials.org/library/rr04.pdf>

⁵⁷ President Carter Library, National Security Affairs, Brzezinski Materials, Country File (Tab 6), "Japan 8/77", Box 40, August 1977, declassified August 1999, Presidential Library, National Archives and Records Administration, as provided to Professor Frank von Hippel, January 18 2011.

⁵⁸ President Carter Library, National Security Affairs, Brzezinski Materials, Country File (Tab 6), "Japan 8/77", Box 40, August 1977, declassified August 1999, Presidential Library, National Archives and Records Administration, as provided to Professor Frank von Hippel, January 18 2011.

⁵⁹ "Options Paper on Japanese Nuclear Reprocessing Facility", Cyrus Vance to President Carter, July 31 1977, President Carter Library, National Security Affairs, Brzezinski Materials, Country File (Tab 6), "Japan 8/77", Box 40, August 1977, declassified August 1999, Presidential Library, National Archives and Records Administration, as provided to Professor Frank von Hippel,

January 18 2011.

⁶⁰ The PNC (Power Reactor and Nuclear Fuel Development Corporation) established in 1967, was the operator of the MONJU and Joyo FBR's, as well as the planned RETF and the existing Tokaimura reprocessing plant, and other facilities. In the years following the MONJU accident, PNC was renamed JNC - Japan Nuclear Cycle Development Institute. In 2005, JNC was merged with the JAERI (Japan Atomic Energy Research Institute) to form JAEA (Japan Atomic Energy Agency) – which operates under the JNC is a government-funded research and development organization under the supervision of Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI), see

<http://www.jaea.go.jp/jnc/jncweb/>

⁶¹ Legal opinion of Eldon V. C. Greenberg to Greenpeace International, "Memorandum: Analysis of the Lawfulness of the Transfer of Sensitive Nuclear Technology from the United States to Japan." Law Offices Garvey, Schubert & Barker Fifth Floor 1000 Potomac Street N.W.

Washington, D.C. 20007, as cited in "The Unlawful Plutonium Alliance Japan's Supergrade plutonium and the role of the United States", Shaun Burnie and Tom Clements, September, 1994, Greenpeace International, see

http://www.srswatch.org/uploads/2/7/5/8/27584045/retf_report_sept_1994.pdf

⁶² "U.S., Criticized for Helping Japan Over Plutonium, Will Stop", Matthew L. Wald, New York Times, September 9, 1994, New York Times, see

<http://www.nytimes.com/1994/09/09/world/us-criticized-for-helping-japan-over-plutonium-will-stop.html>

⁶³ "Current status of fast reactor cycle technology development (FaCT) project in Japan", Ryodai Nakai, Advanced Nuclear System Research and Development Directorate Japan Atomic Energy Agency (JAEA), November 13, 2007.

⁶⁴ "Regulator to call for new Monju reactor operator to enhance safety", Nikkei Asian Review, November 4 2015, see

<http://asia.nikkei.com/Politics-Economy/Policy-Politics/Regulator-to-call-for-new-Monju-reactor-operator-to-enhance-safety>

⁶⁵ "Nuclear regulator: Agency 'unfit' to operate Monju fast-breeder reactor", Masanobu Higashiyamaasahi Shimbun, November 3 2015, see

http://ajw.asahi.com/article/behind_news/social_affairs/AJ201511030054

- ⁶⁶ "Nuclear regulator: Agency 'unfit' to operate Monju fast-breeder reactor", Masanobu Higashiyamaasahi Shimbun, November 3 2015, see http://ajw.asahi.com/article/behind_news/social_affairs/AJ201511030054
- ⁶⁷ "Problems with prototype reactor threaten Japan's nuclear fuel recycling plan", Yoshio Takahashi, Kyodo, January 17 2016, see <http://www.japantimes.co.jp/news/2016/01/17/national/problems-prototype-reactor-threaten-japans-nuclear-fuel-recycling-plan/#.VqL2wCiyT6h>
- ⁶⁸ "Panel holds first meeting on finding new Monju reactor operator", Kyodo, December 28 2015, see <http://www.japantimes.co.jp/news/2015/12/28/national/panel-holds-first-meeting-finding-new-monju-reactor-operator/#.VoFB-igqT6h>
- ⁶⁹ "NRA targeted in second lawsuit against Monju reactor experiment", Japan Times, December 26 2015, see <http://www.japantimes.co.jp/news/2015/12/26/national/locals-others-seeking-monju-decommissioning-file-suit-nra/#.VpMdBSiyT6h>
- ⁷⁰ "Japan's Dangerous Nuclear Waste on the Cutting Board? Towards a Renewables Future", Andrew DeWit, Japan Focus, November 9, 2015, see <http://japanfocus.org/2015/13/44/Andrew-DeWit/4396.html>
- ⁷¹ "Japan may review spending on plutonium fuel cycle-minister", Aaron Sheldrick and Linda Sieg Reuters, December 10 2015, see <http://mobile.reuters.com/article/companyNews/idUSL3N13C2VD20151210>
- ⁷² "Editorial: Scrap Monju reactor project and use money to develop renewable energies", Asahi Shimbun, November 13, 2015, see <http://ajw.asahi.com/article/views/editorial/AJ201511130034>
- ⁷³ Administrative Reform Promotion Council, Friday, November 27, 2015, see http://japan.kantei.go.jp/97_abe/actions/201511/27article1.html
- ⁷⁴ "Cabinet approves record ¥96.7 trillion budget for fiscal 2016", December 24 2015, Japan Times, see <http://www.japantimes.co.jp/news/2015/12/24/national/politics-diplomacy/japans-cabinet-oks-record-¥96-7-trillion-fiscal-2016-budget-focused-welfare-fiscal-health/#.VpFyoSiyT6g>
- ⁷⁵ "Lower maintenance cost for Monju in 2016", Nikkei, December 24 2015, see http://www.nikkei.com/article/DGXLASGG24H0B_U5A221C1EAF000/

⁷⁶ "Nuclear Fuel Cycle Projects in Rokkasho", International Conference Atalante May 22 2008, Montpellier, Yuichiro Matsuo Japan Nuclear Fuel Limited,
<http://www.atalante2008.cea.fr/home/liblocal/docs/Atalante2008/PDF/MATSUO.pdf>

⁷⁷ "JNFL and COGEMA: a wide and innovative cooperation in the fields of spent fuel reprocessing and MOX fuel fabrication", M. Yoneda (JNFL) M. Ohtou (JNFL) M. Arslan (COGEMA) M. Gillet (COGEMA), 2004, see

https://www.ipen.br/biblioteca/cd/unepapers/2004/pdf/11_Session_G/IAEA-CN-114_G-6.pdf

⁷⁸ See analysis reported in "Japan's Nuclear Spent Fuel Management Challenges", March 7, 2013, Tatsujiro Suzuki, (then) Vice Chairman, Japan Atomic Energy Commission, citing the conclusions of the Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle, etc., Material No. 1-1, No. 1-2, No. 1-3, No. 1-4 , 16 May 2012, (Japanese),

<http://www.aec.go.jp/jicst/NC/tyoki/hatukaku/siryu/siryu15/index.htm>

⁷⁹ "Summary and Evaluation of Cost Calculation for Nuclear Power Generation by the "Cost Estimation and Review Committee", Yuji Matsuo, May 2012,

<https://eneken.ieej.or.jp/data/4337.pdf>

⁸⁰ There are two methods of producing glass canisters. One method is to evaporate off the nitric acid by heating the HLW nitric acid solution, mixing HLW oxide powder produced at high temperature with glass, melting this mixture and sealing it in stainless steel canisters. This is the method used in France. The other method, used in Japan, is to mix HLW in liquid form with glass and then heat the mixture to melt the glass. Two year delay for Rokkasho Reprocessing Plant, Citizens Nuclear Information Center, CNIC, Tokyo, see

<http://www.cnic.jp/english/newsletter/nit138/nit138articles/rokkasho.html>; JNFL completed successful vitrification tests 2013, Rokkasho steps forward 30 May 2013, see

http://www.world-nuclear-news.org/WR_Rokkasho_steps_forward_3005131.html

⁸¹ "Rokkasho Update: Earthquake safety and criticality design flaws", Nuke Info Tokyo 118, May 11, 2007, Citizens Nuclear Information Center, CNIC, Tokyo, see

<http://www.cnic.jp/english/?p=1102>

⁸² "Rokkasho Active Tests - where are they up to and what problems have they encountered?", Citizens Nuclear Information Center, CNIC, Tokyo, see

<http://www.cnic.jp/english/topics/cycle/rokkasho/activetests.html>

⁸³ "Outline of the Draft New Regulatory Requirements for Nuclear Fuel Facilities, Research Reactors", and Nuclear Waste Storage/Disposal Facilities, July 2013, see <https://www.nsr.go.jp/data/000067274.pdf>

⁸⁴ Convention on Nuclear Safety National Report of Japan for the Second Extraordinary Meeting, July 2012, see Government of Japan, see http://www.meti.go.jp/english/press/2012/pdf/0705_01b.pdf

⁸⁵ 1991, STA/JAERI/PNC, OECD, see <https://www.oecd-nea.org/nsd/docs/1991/csni-r91-10.pdf>

⁸⁶ "Submission To The Inquiry Committee On Rokkasho Reprocessing Plant Comprehensive Inspection", [Rokkasho Saishori Shisetsu Soutenken Ni Kansuru Kentoukai] Rokkasho Reprocessing Plant, Yves Marignac and John Large, Greenpeace International, February 2004, see <http://www.greenpeace.org/international/Global/international/planet-2/report/2006/6/submission-to-the-inquiry-comm.pdf>; Rokkasho Reprocessing Plant Never Ending Vitrification Problems, Masako Sawai, CNIC, November/December 2008, <http://www.cnic.jp/english/newsletter/pdffiles/nit127.pdf>, NFL and COGEMA : a wide and innovative cooperation in the fields of spent fuel reprocessing and MOX fuel fabrication, M. Yoneda (JNFL) M. Ohtou (JNFL) M. Arslan (COGEMA) M. Gillet (COGEMA), IAEA 2004, IAEA-CN-114/G-6, see https://www.ipen.br/biblioteca/cd/unepapers/2004/pdf/11_Session_G/IAEA-CN-114_G-6.pdf

⁸⁷ "Active fault decision could affect all nuclear facilities in Aomori Prefecture", Asahi Shimbun, December 21, 2012, see http://ajw.asahi.com/article/behind_news/social_affairs/AJ201212210079

⁸⁸ Rokkasho Update: Earthquake safety and criticality design flaws, Nuke Info Tokyo No. 118 (May/June 2007), CNIC, see <http://www.cnic.jp/english/newsletter/nit118/nit118articles/nit118rokactive.html>

⁸⁹ 1991, STA/JAERI/PNC, OECD, see <https://www.oecd-nea.org/nsd/docs/1991/csni-r91-10.pdf>

⁹⁰ Response to the New Regulatory Requirements at the Rokkasho Nuclear Fuel Cycle Facilities, December 19, 2013, Japan Nuclear Fuel Limited, see <http://www.jnfl.co.jp/english/topics/131219-1.pdf>

⁹¹ In Japan when designing earthquake-resistant features for nuclear plants, buildings and equipment are categorized in four levels of importance, on the basis of the potential damage from a release of radiation into the environment. Until July 1981 there were only three classes: Class 'A' being the most important; Class 'B' being for buildings and equipment with less safety significance than Class 'A'; and Class 'C' being for buildings and equipment which have the same safety significance as general industrial facilities. Class 'A' buildings and equipment must be able to withstand the strongest predicted earthquake, known as the 'design-basis strongest earthquake'. The magnitude of this earthquake is assessed on the basis of past earthquakes and the likely effect of active faults. A higher classification, Class 'As', was introduced in July 1981. This includes buildings and equipment in Class 'A' which are deemed to be especially important. These buildings and equipment must be able to withstand what is called the 'design-basis upper limit earthquake'. See "Earthquake Zone Earthquakes and Nuclear Safety in Japan", Citizens Nuclear Information Center, November 2004, see

<http://www.cnic.jp/english/newsletter/nit103/nit103articles/earthquake2Nov04.html>

⁹² "Quake risk at Japan atomic recycling plant: experts", Kyoko Hasegawa, December 19, 2012, see <http://phys.org/news/2012-12-quake-japan-atomic-recycling-experts.html#jCp>

⁹³ Ishibashi Katsuhiko Professor at the Research Center for Urban Safety and Security of Kobe University, International Herald Tribune/Asahi Shinbun on August 11, 2007

⁹⁴ Extraordinary Press Conference Schedule Change of Completion of Rokkasho Reprocessing Plant and MOX Fuel Fabrication Plant, JNFL, November 16 2015, see <http://www.jnfl.co.jp/english/topics/151116-1.html>

⁹⁵ "Nuclear energy and its fuel cycle in Japan: Closing the circle", IAEA Bulletin, March 1991, <https://www.iaea.org/sites/default/files/35304893437.pdf>

⁹⁶ "Nuclear energy and its fuel cycle in Japan: Closing the circle", IAEA Bulletin, March 1991, <https://www.iaea.org/sites/default/files/35304893437.pdf>

⁹⁷ JAEC Subcommittee on Nuclear Power/Nuclear Fuel cycle technologies) <http://www.aec.go.jp/jicst/NC/iinkai/teirei/siryoy2012/siryoy22/siryoy1-1.pdf> (in Japanese)

⁹⁸ "Nuclear Energy and Nuclear Fuel Cycle Policy Options after the Fukushima Accident", East Asian Alternative Nuclear Weapons Future Conference & East Asian Alternative Energy Futures Conference Honolulu, Hawaii, February 26, 2014 Tatsujiro Suzuki, http://npolicy.org/article_file/Suzuki-Japan-energy-nuclear-policy.pdf

⁹⁹ "New evidence shows that plutonium fuel shipment could contain falsified data", September 29 1999, see

<http://www.greenpeace.org.uk/media/press-releases/new-evidence-shows-that-plutonium-fuel-shipment-could-contain-falsified-data>

¹⁰⁰ "Lawsuit Against the Use of MOX Fuel at Fukushima I-3", Chihiro Kamisawa, CNIC, January/February 2001, see

<http://www.cnic.jp/english/newsletter/nit81/articles/fukushima.html>; "MOX Production Standards And Quality Control At Belgonucleaire And The Implications For Reactor Safety In Fukushima-1-3" Submission to the Fukushima District Court, Fukushima City, Japan, Frank Barnaby and Shaun Burnie, Greenpeace International, December 26 2000.

¹⁰¹ "Comments by Fukushima Prefecture Governor Eisaku Sato Concerning Japan's Plutothermal (MOX fuel utilization) Program and the Nuclear Fuel Cycle." Green Actio, August 20 2002, see <http://greenaction-japan.org/jp/2002/08/63>

¹⁰² "Fukushima Daiichi Intended To Increase MOX Use In Unit 3", Simply Info, September 11th 2011, see <http://www.fukuleaks.org/web/?p=1734>

¹⁰³ "The Impact of the Use of Mixed-Oxide Fuel on The Potential for Severe Nuclear Plant Accidents in Japan", Edwin S. Lyman, PhD Scientific Director Nuclear Control Institute, October 1999, see <http://www.nci.org/>

¹⁰⁴ "Japanese village rejects recycled nuclear energy - Referendum is gauge of public opinion on plan", May 28 2001, Uli Schmetzer, Chicago Tribune, see http://articles.chicagotribune.com/2001-05-28/news/0105280169_1_nuclear-plants-kariwa-uncontrolled-nuclear-reaction

¹⁰⁵ "Kashiwazaki-Kariwa Earthquake - Japan's Nuclear Safety Shaken to the Roots", CNIC Report, July 23 2007, see

<http://www.cnic.jp/english/newsletter/nit119/nit119articles/kkearthquake.html>

¹⁰⁶ "Nuclear Shipments and Small Island Developing States (SIDS)" Duncan Currie, Greenpeace International, July 2004, see

<http://www.greenpeace.org/seasia/th/PageFiles/106895/greenpeace-briefing-nuclear-s.pdf>

¹⁰⁷ "Nations on Route of Japan's Plutonium Ship Voice Fears : Safety: Possible leaks or terrorist raids could create danger as the cargo is moved from France." Los Angeles Times, LESLIE HELM, October 7 1992, http://articles.latimes.com/1992-10-07/news/mn-449_1_container-ship;

"Nuclear Shipments and Small Island Developing States (SIDS)", Greenpeace Briefing, 2003, see <http://www.greenpeace.org/seasia/th/PageFiles/106895/greenpeace-briefing-nuclear-s.pdf>; "Japanese Shipment of Nuclear Fuel Raises Security Fears", Howard W. French, New York Times, July 5 2002, see <http://www.nytimes.com/2002/07/05/international/05JAPA.html>; Letters sent to countries potentially on the route of the MOX fuel shipment, Aileen Mioko Smith, Green Action, March 2013, see http://www.greenactionjapan.org/internal/130305_Letter_en_route_MOX.pdf

¹⁰⁸ This material is distinct in that the plutonium is weapons grade quality. As detailed by SRS Watch in December 2015, "Japan's Atomic Energy Commission has publicly revealed that 331 kilograms (730 pounds) of foreign-origin plutonium are now stored at Japan's Fast Critical Assembly (FCA) at Tokai Research and Development Center, on the Pacific Ocean north of Tokyo. Sources in Japan report that approximately 236 kilograms of the plutonium are of U.K.-origin, 93 kilograms are of U.S.-origin and 2 kilograms are of French-origin. The plutonium was taken to Japan primarily in the 1960s and 1970s, as part of problem-plagued research and development program to develop sodium-cooled plutonium "breeder" reactors. The FCA, which began operation in 1967, has been used in fuel development for the Joyo and Monju fast reactors. According to the Japan Atomic Energy Agency (JAEA), the Fast Critical Assembly "is the country's only critical assembly for the study of the neutronic characteristics of fast reactors" and "is designed for studying physics characteristics of fast breeder reactor cores. Experiments are carried out to provide integral data for core design of a fast reactor by building various simulating assemblies. The reactor assembly is divided into two halves...which are separated for fuel loading, then brought together for operation." see, "DOE'S South Carolina Plutonium Dilemma: Plutonium Keeps Secretly Coming In But No Viable Plan To Take It Out", Tom Clements, SRS Watch, December 21 2015, see http://www.srswatch.org/uploads/2/7/5/8/27584045/srs_watch_plutonium_import_report_december_21_2015.pdf

¹⁰⁹ "Reality Check: Energy Mix 2030 and Japan's Collapse in Nuclear Power Generation", April 2015 (updated June), Shaun Burnie, Kendra Ulrich, Jan Vande Putte, Hisayo Takada, Greenpeace Germany, 2015, see <http://www.greenpeace.org/japan/Global/japan/pdf/20150428-briefing-energy-mix.pdf>

¹¹⁰ "Economic and Energy Outlook of Japan for FY2014 Japan is reaching a crucial moment" The

414th Forum on Research Work, December 2013 - Yanagisawa Akira, T. Yoshioka, H. Suzuki, Choi J. W., R. Ikarii, S. Iwata, Y. Shibata, K. Ito, The Energy Data and Modeling Center, The Institute of Energy Economics, Japan, see http://eneken.ieej.or.jp/en/press/press_131220.pdf

¹¹¹ "Economic and Energy Outlook of Japan for FY2015 - Overview – What about benefit of oil price plunge for stagnating Japanese economy after VAT increase?," Yanagisawa Akira, R. Ikarii, S. Iwata, I.H. Hwang, K. Tomokawa, Y. Shibata and K. Ito, 19 December 2014 The 418th Forum on Research Work, see <http://eneken.ieej.or.jp/en/press/press141219.pdf>

¹¹² "Reality Check: Energy Mix 2030 and Japan's Collapse in Nuclear Power Generation", April 2015 (updated June), Shaun Burnie, Kendra Ulrich, Jan Vande Putte, Hisayo Takada, Greenpeace Germany, 2015,

<http://www.greenpeace.org/japan/Global/japan/pdf/20150428-briefing-energy-mix.pdf>

¹¹³ A GW or GigaWatt is a unit of electrical power equal to one thousand megawatts.

¹¹⁴ The MONJU reactor is currently loaded with 5.9 tons of plutonium and uranium MOX fuel. Some of this fuel is the original fuel loaded in 1994, some manufactured in the mid-1990's but never loaded, and some was fresh fuel loaded in 2009. It has a uranium breeder blanket of 17.5 tons.

¹¹⁵ JNFL, Reprocessing Business Application, November 2015, see

<http://www.jnfl.co.jp/press/pressj2015/20151116-1besshi1.pdf> (in Japanese).

¹¹⁶ Due to the decay of the plutonium isotope 241 to Americium 241, which is undesirable in fresh MOX fuel. Unless more recent separated plutonium is exchanged for this older stock, it will become unusable.

¹¹⁷ The Pacific Heron and Pacific Egret, two lightly armed British flagged nuclear transport vessels, from Barrow, England, are likely to be the transport ships.

¹¹⁸ "Japan: Mox Pluthermal Program Is Passing A New Milestone, Areva", January 24 2011, see <http://www.areva.com/EN/news-8661/japan-mox-pluthermal-program-is-passing-a-new-milestone.html>

¹¹⁹ "Nuclear Power: Selective Separation And Recycling", AREVA Forward Looking Energy, accessed December 8 2015, see

<http://www.areva.com/EN/operations-1370/nuclear-waste-recycling-and-treatment.html>

¹²⁰ "Sellafield MOX Plant (SMP) axed by Fukushima fallout – says NDA"

(<http://www.corecumbria.co.uk/newsapp/pressreleases/pressmain.asp?StrNewsID=291>),

Martin Forwood, CORE, August 8 2011.

¹²¹ The UK Nuclear Installation Inspectorate (NII) were warned prior to its licensing that the SMP had fundamental design deficiencies and would not operate as planned (see, *Fundamental Deficiencies In The Quality Control Of Mixed-Oxide Nuclear Fuel* (http://www.greenpeace.fr/stop-plutonium/dossiers/MOX_quality_annexe4.pdf), Dr Frank Barnaby/Shاون Burnie, Greenpeace International, Fukushima City, Japan, March 27 2000, and submission to US NRC, Chief, Rules and Directives Branch (<http://pbadupws.nrc.gov/docs/ML0037/ML003709986.pdf>) U.S. Nuclear Regulatory Commission, March 27 2000. The evidence was ignored the SMP was contaminated with plutonium and ten years later it was finally scrapped costing the UK taxpayer billions 2.1 billion sterling, and unknown decommissioning costs of at least 800 million sterling, "Revealed: £2bn cost of failed Sellafield plant" (<http://www.independent.co.uk/news/uk/politics/revealed-2bn-cost-of-failed-sellafield-plant-8650779.html>), The Independent, June 2013.

¹²² The other major failure of recent decades at Sellafield, THORP, should give pause for thought before commercial operation of Rokkasho-mura, "Sellafield's ageing THORP plant flunks major foreign fuel reprocessing target" (http://fissilematerials.org/blog/2015/11/_sellafields_ageing_thorp.html), Martin Forwood, IPFM, November 6 2015.

¹²³ "Special Features -Five Key Approaches to Achieving New Growth-Approaching the Construction of the Ohma Nuclear Power Plant" (<http://www.jppower.co.jp/english/ir/pdf/2007-06.pdf>), June 2007.

¹²⁴ "J-Power Given Permit For Ohma ABWR Full-MOX Unit" (<http://www.nucnet.org/all-the-news/2008/04/30/j-power-given-permit-for-ohma-abwr-full-mox-unit>) NucNet, April 30 2008.

¹²⁵ "Final Report of the International MOX Assessment, Comprehensive Social Impact Assessment Of Mox Use In Light Water Reactors" (http://www.cnic.jp/english/publications/pdf/ima_fin_e.pdf); J. Takagi, M. Schneider, F. Barnaby, I. Hokimoto, K. Hosokawa, C. Kamisawa, B. Nishio, A. Rossnagel, M. Sailer, November, 1997, IMA Project Citizens' Nuclear Information Center.

¹²⁶ The FUGEN ATR, was intended to be the intermediary technology for a smooth transition

from conventional uranium fuelled light water reactors, through to full scale fast reactor plutonium reactor operation. For a potted history industry view of the success of FUGEN see, "25 years of Fugen ATR" (<http://www.neimagazine.com/features/feature25-years-of-fugen-atr/>), October 1 2003.

¹²⁷ "Japan's Civilian Nuclear Fuel Cycle And Nuclear Spent Fuel Management Issue" (http://nautilus.org/wp-content/uploads/2012/01/copy_of_IPFMFact200606b13.pdf), Tadahiro Katsuta and Tatsujiro Suzuki, International Panel On Fissile Material, June 2006.

¹²⁸ "Summary Of Fugen Project" (<http://www.jaea.go.jp/04/fugen/compilation/pamphlet/English/P44.html>).

¹²⁹ "MOX Supply Deal Signed For Japan's Ohma N-Plant" (<http://www.nucnet.org/all-the-news/2009/04/03/mox-supply-deal-signed-for-japan-s-ohma-n-plant>), NucNet, April 3 2009.

¹³⁰ "Court hears first arguments in Ohma nuclear plant lawsuit" (<http://ajw.asahi.com/article/0311disaster/fukushima/AJ201407040041>), Kozue Isozaki, Asahi Shimbun, July 4 2014. Areas administered by the Hakodate city government fall within the designated Urgent Protective Action Planning Zone (UPZ), which covers a 30-km radius from a nuclear plant. In the UPZ, local governments are required to establish emergency measures, such as evacuation plans. "If a serious accident takes place at the Oma plant, it would be impossible to quickly evacuate the entire city of more than 270,000 residents," Hakodate city claimed in the lawsuit. "The whole city could possibly be destroyed."

¹³¹ JNFL, Reprocessing Business Application (<http://www.jnfl.co.jp/press/pressj2015/20151116-1besshi1.pdf>), November 2015 (in Japanese), cited in "Another delay for the Rokkasho reprocessing plant" (http://fissilematerials.org/blog/2015/11/another_delay_for_the_rok.html), IPFM, November 17 2015.

¹³² "Japan postpones plans to use MOX fuel", Nucleonics Week November 26 2015.

¹³³ As cited in Nuclear Energy and Nuclear Fuel Cycle Policy Options (http://npolicy.org/article_file/Suzuki-Japan-energy-nuclear-policy.pdf) after the Fukushima Accident East Asian Alternative Nuclear Weapons Future Conference & East Asian Alternative Energy Futures Conference Honolulu, Hawaii, February 26, 2014 Tatsujiro Suzuki Vice Chairman, Japan Atomic Energy Commission, quoting figures from: Technical Subcommittee on

Nuclear Power, Nuclear Fuel Cycle, etc.

(<http://www.aec.go.jp/jicst/NC/tyoki/hatukaku/siryu/siryu15/index.htm>), Material No. 1-1, No. 1-2, No. 1-3, No. 1-4 (Japanese), 16 May 2012.

¹³⁴ "Panel seeks new body to expand government role in nuclear fuel reprocessing"

(<http://www.japantimes.co.jp/news/2015/11/30/national/panel-seeks-new-body-to-expand-government-role-in-nuclear-fuel-reprocessing/#.VoBXgCgqT6h>), Kyodo, November 30 2015.

¹³⁵ "Boost nation's N-fuel cycle project steadily with govt involvement,"

(<http://the-japan-news.com/news/article/0002617205>) Yomiuri, December 11 2015.

¹³⁶ As cited in, "Research Report No. 12 International Panel on Fissile Materials, Ending reprocessing in Japan: An alternative approach to managing Japan's spent nuclear fuel and separated plutonium", Masafumi Takubo and Frank von Hippel, November 2013, see www.fissilematerials.org see also "Nuclear Fuel Cycle Policy Options" (http://www.aec.go.jp/jicst/NC/about/kettei/kettei120718_e.pdf) Japan Atomic Energy Commission, June 21, 2012.

¹³⁷ "National Report of Japan, for the Fifth Review Meeting Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management,"

(<http://www.nsr.go.jp/data/000110078.pdf>) October, 2014.

¹³⁸ "Declaration of 1 August 2013 by Gordon R. Thompson: Comments on the US Nuclear Regulatory Commission's Draft Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a US Mark I Boiling Water Reactor"

(<http://www.nrc.gov/reading-rm/doc-collections/commission/slides/2014/20140106a/thompson-08-01-2013-declaration.pdf>).

¹³⁹ "Scenario and Contingency Planning of Fukushima Daiichi Nuclear Power Plant," Shunsuke Kondo March 25, 2011. Released by Japanese Cabinet Office, January 30 2012, Greenpeace English language translation.

¹⁴⁰ "Japan Weighed Evacuating Tokyo in Nuclear Crisis"

(http://www.nytimes.com/2012/02/28/world/asia/japan-considered-tokyo-evacuation-during-the-nuclear-crisis-report-says.html?ref=topics&_r=0), Martin Fackler, New York Times, February 27 2012.

¹⁴¹ High density storage of spent fuel in pools increases the amount of fuel stored approaching levels of density of reactor cores. This lowers the safety margin in the event of a loss of cooling

function. In particular, spent fuel recently discharged from a reactor core (such as those at Fukushima Daiichi unit 4) will heat up relatively rapidly to a temperature where the zircaloy cladding would catch fire and the radioactive volatile fission products including Cesium 137 would be released. The consequences could be significantly worse than the 1986 Chernobyl accident. See, "Reducing the hazards from stored spent power reactor fuel in the United States" (https://www.princeton.edu/sgs/publications/articles/fvhippel_spentfuel/rAlvarez_reducing_hazards.pdf), Robert Alvarez, Jan Bayea, Klaus Janberg, Jungmin, Kang, Edwin Lyman, Allison MacFarlane, Gordon Thompson, Frank von Hippel, Science and Global Security, 2003.

¹⁴² Reinforcement of Measures for Spent Nuclear Fuel Storage (Spent Fuel Action Plan) (https://www.fepec.or.jp/english/news/message/___icsFiles/afieldfile/2015/11/27/press_e_20151120.pdf), November 20, 2015 Federation of Electric Power Companies (FEPC).

¹⁴³ This is in response to the governments, "Action Plan on Measures for the Disposal of Spent Nuclear Fuel" and a request for utilities to draw up a Spent Fuel Action Promotion Plan." (https://www.fepec.or.jp/english/news/message/___icsFiles/afieldfile/2015/11/27/press_e_20151120.pdf) see Reinforcement of Measures for Spent Nuclear Fuel Storage (Spent Fuel Action Plan), November 20, 2015 Federation of Electric Power Companies (FEPC).

¹⁴⁴ The only two not planning re-racking are Tohoku and Hokkaido Electric – the two utilities with the smallest tonnage of spent fuel.

¹⁴⁵ See, "Electric Power Companies' Policies for Spent Fuel" (https://www.fepec.or.jp/english/news/message/___icsFiles/afieldfile/2015/11/27/press_e_20151120.pdf), Reinforcement of Measures for Spent Nuclear Fuel Storage (Spent Fuel Action Plan), November 20, 2015 Federation of Electric Power Companies (FEPCO).

¹⁴⁶ "Demonstration Test Program for Long-term Dry Storage of PWR Spent Fuel" (<http://www-pub.iaea.org/iaeameetings/cn226p/Session4/ID79Kishimoto.pdf>), S. Fukuda, The Japan Atomic Power Company N. Irie, The Kansai Electric Power Co., Inc. Y.Kawano, Kyusyu Electric Power Co., Inc. K. Nishi, J. Kishimoto, Mitsubishi Heavy Industries, Ltd. June 17 2015.

¹⁴⁷ As cited in, "Research Report No. 12 International Panel on Fissile Materials, Ending reprocessing in Japan: An alternative approach to managing Japan's spent nuclear fuel and separated plutonium", Masafumi Takubo and Frank von Hippel, November 2013, see www.fissilematerials.org see also "Nuclear Fuel Cycle Policy Options"

(http://www.aec.go.jp/jicst/NC/about/kettei/kettei120718_e.pdf) Japan Atomic Energy

Commission, June 21, 2012.

¹⁴⁸ In 2012, JNFL paid ¥16 billion (~\$160 million) in spent fuel taxes to Aomori.

¹⁴⁹ In the early 2000's METI increased its subsidy (kofu-kin) to local governments that accepted MOX fuel use, with one billion yen per year for five years. Press Release of Kyushu Electric Power Company (http://www1.kyuden.co.jp/press_r_20040428_20040428_100001_1003), April 28, 2006.

¹⁵⁰ "Editorial: Kansai Electric out of step with vision of reduced dependence on nuclear power" (<http://ajw.asahi.com/article/views/editorial/AJ201502100039>), Asahi Shimbun, February 10, 2015.

¹⁵¹ "In Japan, Provocative Case for Staying Nuclear Some Say Bombs' Potential as Deterrent Argues for Keeping Power Plants Online" (<http://www.wsj.com/articles/SB10001424052970203658804576638392537430156>), Wall St Journal, October 28 2011.

¹⁵² "Japan eyes greater government role in nuclear fuel recycling" (<http://www.japantimes.co.jp/news/2015/11/28/national/japan-eyes-greater-government-role-in-nuclear-fuel-recycling/#.VoBXLsgqT6h>), Kyodo, November 28 2015.

¹⁵³ "The Nuclear Non-Proliferation Treaty: Origins and Implementation, 1959-1979" (<http://www.nonproliferation.org/the-nuclear-non-proliferation-treaty-origins-and-implementation-1959-1979/>), Mohamed Shaker, Oceana Publications.

¹⁵⁴ The Text Of The Agreement Of 4 March 1977 Between Japan And The International Atomic Energy Agency In Implementation Of Article Iii.1 And 4 Of The Treaty On The Non-Proliferation Of Nuclear Weapons (<http://www.jnmcc.or.jp/agree/pdf/infcirc255.pdf>), INFCIRC/255 March 1978.

¹⁵⁵ "Safeguards in action: IAEA at Rokkasho, Japan", Olli J. Heinonen, DDG-SG, IAEA, June 2010.

¹⁵⁶ As the IAEA itself admitted two decades ago in reference to Rokkasho-mura, *"the major challenge facing the IAEA in the next years is to prepare for and implement effective safeguards at a large commercial reprocessing facility."* in "Activities of the international Atomic Energy Agency Relevant to Article III of the Treaty on the Non-Proliferation of Nuclear Weapons", NPT/CONF/1995/PC.III/7, Document presented to the Third Session, Geneva, September 12-16, 1994.

¹⁵⁷ "Limiting the Spread of Weapons-Usable Fissile Materials", National Defense Research

Institute, Rand Corporation, November 1993, p. xiii.

¹⁵⁸ In one of the most significant documents of the nuclear age, the Acheson- Lilienthal report, released in March 1946, reported that: *"We have concluded unanimously that there is no prospect of security against atomic warfare in a system of international agreements to outlaw such weapons controlled only by a system which relies on inspection and similar police-like methods"*.

¹⁵⁹ Perhaps the most important public critique in recent decades has been that of Marvin Miller at MIT, Miller, M. M., "Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?" (<http://www.nci.org/k-m/mmsgdrds.htm>) Nuclear Control Institute, Washington, DC., August 1990; "Planning For Failure – International Nuclear Safeguards And The Rokkasho-Mura Reprocessing Plant" (<http://www.greenpeace.org/international/Global/international/planet-2/report/2002/11/planning-for-failure-internat.pdf>), Dr Frank Barnaby, Oxford Research Group; Shaun Burnie, Greenpeace International, November 2002.

¹⁶⁰ Shigeru is the current Defense Minister in the Abe Government, and was speaking while an opposition LDP member, as quoted in Sapio magazine and reported at, "In Japan, Provocative Case for Staying Nuclear Some Say Bombs' Potential as Deterrent Argues for Keeping Power Plants Online" (<http://www.wsj.com/articles/SB10001424052970203658804576638392537430156>), Wall St Journal, October 28 2011.

¹⁶¹ "In Japan, Provocative Case for Staying Nuclear Some Say Bombs' Potential as Deterrent Argues for Keeping Power Plants Online" (<http://www.wsj.com/articles/SB10001424052970203658804576638392537430156>), Wall St Journal, October 28 2011.

¹⁶² "Chinese ambassador: Japan has serious nuclear security and proliferation risks" (http://english.chinamil.com.cn/news-channels/pla-daily-commentary/2015-10/21/content_6733345.htm), China Military OnLine, October 21 2015.

¹⁶³ "A Report to the President, ~ Secret, The Committee on Nuclear Proliferation" (http://nsarchive.gwu.edu/NSAEBB/NSAEBB1/nhch7_1.html), January 21st 1965, declassified three decades later.

¹⁶⁴ "A Call on Japan to Strengthen the Non-Proliferation Treaty by Indefinitely Postponing Operation of the Rokkasho Spent Fuel Reprocessing Plant"

(https://web.archive.org/web/20080115203308/http://www.ucsusa.org/global_security/nuclear_terrorism/japan-strengthen-the-nonproliferation-treaty.html) May 5 2005.

¹⁶⁵ "Obama adviser raises concerns about Japan's plutonium stockpile"

(http://ajw.asahi.com/article/behind_news/politics/AJ201510130012), Asahi Shimbun, October 23 2015.

¹⁶⁶ "United States grants advance consents rights to Korea for overseas reprocessing"

(http://fissilematerials.org/blog/2015/06/united_states_grants_adv.html), Shaun Burnie and Mycle Schneider, International Panel on Fissile Materials, IPFM, June 25 2015.

¹⁶⁷ "Nuclear Watch: The true intentions of Prime Minister Sato"

(<http://mainichi.jp/english/articles/20151104/p2a/00m/0na/003000c>), November 4 2015.

¹⁶⁸ "Nobel Lecture, The Pursuit of Peace and Japan in the Nuclear Age"

(http://www.nobelprize.org/nobel_prizes/peace/laureates/1974/sato-lecture.html), December 11, 1974.

¹⁶⁹ "In Defense of Japan. From The Market To The Military In Space Policy", Saadia M. Pekkanen and Paul Kallender- Umezumi, Stanford University Press, Stanford, California, 2010.

¹⁷⁰ "In Defense of Japan. From The Market To The Military In Space Policy", Saadia M. Pekkanen and Paul Kallender- Umezumi, Stanford University Press, Stanford, California, 2010.

¹⁷¹ "In Japan, Provocative Case for Staying Nuclear Some Say Bombs' Potential as Deterrent Argues for Keeping Power Plants Online"

(<http://www.wsj.com/articles/SB10001424052970203658804576638392537430156>), Wall St Journal, October 28 2011.

¹⁷² New Nuclear Notebook: Chinese Nuclear Force Modernization, Hans M. Kristensen, November 13 2013, see <https://fas.org/blogs/security/2013/11/chinanukes2013/>, see also U.S. Department of Defense "Annual Report To Congress Military and Security Developments Involving the People's Republic of China 2015"

(http://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf).

¹⁷³ USPACOM Strategy (<http://www.pacom.mil/AboutUSPACOM/USPACOMStrategy.aspx>), which declares that is "*first and foremost a war fighting command, committed to maintaining superiority across the range of military operations in all domains...deters aggression; and is prepared to respond if deterrence efforts fail*".

¹⁷⁴ The eminent Japan and Asian scholar Chalmers Johnson, eloquently detailed the consequences of current U.S. military policy, in his four volume series *American Empire: Blowback*, see his work at The Japan Policy Research Institute (<http://jpri.org/>); "Chalmers Johnson Dies at 79; New York Times, November 24 2010, Criticized U.S. Role in World" (http://www.nytimes.com/2010/11/24/world/24johnson.html?_r=0).

¹⁷⁵ Following the August 1998 DPRK test-fired Taepo Dong-1 ballistic missile that flew over northern Honshu, Japan stepped up its cooperation with the U.S. "Japan-U.S. Cooperation on Ballistic Missile Defense: Issues and Prospects" (<http://www.iwar.org.uk/news-archive/crs/9186.pdf>), Richard P. Cronin Specialist in Asian Affairs Foreign Affairs, Defense, and Trade Division, CRS Report for Congress, Congressional Research Service March 19, 2002.

¹⁷⁶ "Pentagon Report: China Deploys MIRV Missile" (<https://fas.org/blogs/security/2015/05/china-mirv/>), Hans M. Kristensen, Federation of American Scientists, May 2015.

¹⁷⁷ "In addition to cooperating with the United States on development of technologies for the SM-3 Block IIA missile, Japan is modifying all six of its Aegis destroyers with Aegis BMD system, and in November 2013 announced plans to procure two additional Aegis destroyers and equip them as well with the Aegis BMD system, which will produce an eventual Japanese force of eight BMD-capable Aegis destroyers. Japanese BMD-capable Aegis ships have conducted four flight tests of the Aegis BMD system using the SM-3 interceptor, achieving three successful exo-atmospheric intercepts." see "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress" (<https://www.fas.org/sgp/crs/weapons/RL33745.pdf>), Ronald O'Rourke Specialist in Naval Affairs, Congressional Research Service, December 11, 2015.

¹⁷⁸ "Annual Report To Congress: Military and Security Developments Involving the People's Republic of China 2015" (http://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf), Office of the Secretary of Defense, April 2015.

¹⁷⁹ "Japanese Strategic Weapons Programs And Strategies: Future Scenarios And Alternative Approaches", Ian Easton, in "If Japan and South Korea Go Nuclear: Two Military-Technical Scenarios" (http://npolicy.org/books/East_Asia/Ch7_Easton.pdf), Non Proliferation Policy Education Center.

¹⁸⁰ The "United States would be highly unlikely to use its nuclear arms to defend Japan unless American forces in Japan were exposed to extreme danger." Kumao Kaneko, former director of the Nuclear Energy Division of the Foreign Ministry, argues in "Japan needs no Nuclear Umbrella," *The Bulletin of the Atomic Scientists* (March/April, 1996), cited in Morton H. Halperin, *The Nuclear Dimension of the U.S.-Japan Alliance* (<http://oldsite.nautilus.org/archives/library/security/papers/US-Japan-5.html>); see also "Nonproliferation Norms Why States Choose Nuclear Restraint" Maria Rost Rublee 2009

¹⁸¹ The 2015 U.S. Strategic Command Deterrence Symposium (<http://datab.us/vhQ57dGsjFs#Adm%20Haney%20Welcoming%20Remarks%20-%202015%20Deterrence%20Symposium>) was held in Omaha, Nebraska on July 29 – 30, 2015.

¹⁸² "The Enigma of Japanese Power – People and Politics in a Stateless Nation", Karel van Wolferen, ISBN 0-333-52947-2, Macmillan 1989

¹⁸³ "Japan's Bid to Become a World Leader in Renewable Energy" (<http://www.japanfocus.org/-Andrew-DeWit/4385/article.html>), Professor Andrew DeWit, *The Asia Pacific Journal - Japan Focus*, September 28 2015.

¹⁸⁴ "Study on Japan's Nuclear Materials" (<http://fissilematerials.org/library/cacda15.pdf>), China Arms Control and Disarmament Association China Institute of Nuclear Information and Economics September 2015.

¹⁸⁵ "Chinese ambassador: Japan has serious nuclear security and proliferation risks" (http://english.chinamil.com.cn/news-channels/pla-daily-commentary/2015-10/21/content_6733345.htm), China Military Online, October 21 2015.

¹⁸⁶ Press Conference by the Chief Cabinet Secretary (http://japan.kantei.go.jp/tyoukanpress/201510/21_a.html), October 21 2015.

¹⁸⁷ . "UK Flagged Ships Set To Transport Plutonium from Japan to the U.S. Located In Panama Canal" (http://www.srswatch.org/uploads/2/7/5/8/27584045/srsw_news_on_plutonium_ships_in_canal_feb_6_2016.pdf), Tom Clements, Savannah River Site Watch, February 6 2016, and Martin Forwood, CORE (<http://www.corecumbria.co.uk>); "DOE'S South Carolina Plutonium Dilemma: Plutonium Keeps Secretly Coming In But No Viable Plan To Take It Out" (http://www.srswatch.org/uploads/2/7/5/8/27584045/srs_watch_plutonium_import_report_december_21_2015.pdf), Tom Clements, SRS Watch, December 21 2015.

¹⁸⁸ Section 123 of the U.S. Atomic Energy Act requires the conclusion of a specific agreement for significant transfers of nuclear material, equipment, or components from the United States to another nation. "Agreement For Cooperation Between The Government Of The United States Of America And The Government Of Japan Concerning Peaceful Uses Of Nuclear Energy" (http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/Japan_123.pdf), November 1987.

¹⁸⁹ "Time to Stop Reprocessing in Japan" (<http://www.armscontrol.org/print/5640>), Masako Toki and Miles Pomper Arms Control Today, January 2013.