



# Towards a Fissile Zero Future

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## Biography

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## BEHIND THE FISSILE ZERO FUTURES PROJECT

This report describes the results of a two-year project focused on ways in which the United States and other countries with significant stockpiles of weapons-usable fissile material in their military and/or civilian sectors could help reduce risks from that material (highly enriched uranium and separated plutonium).<sup>1</sup> The project started with the idea of a “fissile zero future” – that is, a future in which weapons-usable fissile material would no longer pose risks of proliferation (vertical or horizontal) or of nuclear terrorism. Along the way, we contemplated the specific problems posed by military fissile material, civilian plutonium and naval nuclear fuel.

A Fissile Zero Future does not mean a nuclear-free future, or even zero fissile material stocks. Instead, it was an attempt to find a nuclear equivalent to “Coke Zero” – all the taste and none of the risks.<sup>2</sup> Of course, Coke drinkers can balance their risks (calories or sugar) and rewards (taste) among Coke, Diet Coke, Coke

Zero and now Coca Cola Zero Sugar. It is not so easy in the nuclear world.

However, by better identifying risks it may be possible to build agreement about the level of risk and thereby lead to a reassessment of the costs and benefits of reducing those risks posed by fissile material. The four nuclear security summits from 2010 to 2016 successfully brought high-level attention to the nuclear security risks of keeping weapons-usable material around. They were most successful in reducing risks from highly enriched uranium (HEU) in the civilian sector and probably succeeded in changing the cost/benefit calculation for many states to swap out low-enriched uranium for their HEU. The summits, however, did little to reduce risks from military fissile material, civilian plutonium or naval nuclear fuel. In each of these areas, a new calculation of and balance between risks and rewards is needed.

<sup>1</sup>There is no widely accepted definition of “weapons-usable” fissile material, but it is a larger category of material than encompassed by “weapons-grade,” which is typically defined as uranium enriched to above 90% in U-235 and separated plutonium with a Pu-239 content of 93%. According to the US Department of Energy, fuel-grade plutonium has a Pu-239 content of between 80 and 93% and reactor-grade plutonium has less than 80% Pu-239. DoE says all of it can be used to make nuclear weapons. See Department of Energy, “Nonproliferation and Arms Control Assessment of weapons-usable fissile material storage and excess plutonium disposition options,” January 1997, available at <https://www.osti.gov/servlets/purl/425259>. The International Atomic Energy Agency uses the term “special fissionable material,” defined as plutonium-239; uranium-233; uranium enriched in the isotopes 235 or

233; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine; but the term “special fissionable material” does not include source material. The category of special fissionable material would include low-enriched uranium (< 20%) that is typically not considered weapons-usable. Often, definitions of material are paired with quantities, since the concern is whether the quantity and composition of the material is close to the amount needed for a single weapon.

<sup>2</sup> Obviously, risks can’t be eliminated completely. A consumer could switch to drinking tap water, which can carry other risks in America Alex Daniel, “The 25 U.S. Cities With the Worst Drinking Water,” *BestLife*, October 6, 2017. <https://bestlifeonline.com/worst-drinking-water/>

The formula for Coca Cola is famously secret and some of that secrecy has carried over to its new products. It's hard to tell by looking at labels how Diet Coke, Coke Zero and Coca Cola Zero Sugar differ. It's fair to say that transparency does not take center stage in Coca Cola Company's marketing strategy for its new products, but that is less important for carbonated beverages than for fissile material.

In fact, transparency has to be a key component of any future that involves reducing risks from fissile material. It is not a substitute for eliminating these risks but an enabling mechanism. One of the objectives of the Fissile Zero Futures project was to develop ideas for information exchange that could pave the way for later progress. In the areas of military fissile material stocks, civil plutonium and naval nuclear fuel, the policy recommendations of this project focused on developing and promoting norms rather than legally binding standards, for the simple reason that the prospects for legally binding limits in these areas are quite remote.

## Project Activities

The project, which began life as a grant from the MacArthur Foundation to the Center for Strategic & International Studies' Proliferation Prevention Program and then transferred to the International Institute for Science & Technology Policy at the Elliott School of International Affairs at George Washington University.

In 2017, the Fissile Zero Futures project hosted a small international experts' workshop to

identify mechanisms for enhancing transparency and separation of facilities and materials (e.g., declarations of excess military material, expanded declarations and/or safeguards on civilian facilities). We shared recommendations with U.S. government and other foreign government officials through the Nuclear Nonproliferation Treaty (NPT) review process, including at Preparatory Committee meetings.

In 2018, analysts worked on the issue of naval nuclear fuels – a gray zone for safeguards under the NPT that could complicate verification of a future treaty to stop production of fissile material for weapons.<sup>3</sup> More importantly, plans by Brazil and potentially Iran and the Republic of Korea to deploy nuclear submarines in the next decades make the loophole in comprehensive safeguards agreements no longer an academic exercise. Analysts considered whether it would be possible to provide a pathway for states with nuclear navies to wean themselves gradually from fuel enriched above commercial reactor-grade levels (~ 6%) and whether it was feasible to build support for a global cap on uranium enrichment levels. The project commissioned essays from experts on elements of new norms, published as the first set of [IISTP Occasional Papers](#), and hosted a meeting to elicit feedback. Members of the expert workshop agreed to continue collaboration, including through Track 2 meetings with Brazilian naval officials, and through efforts to educate government officials within the NPT Review Conference process.

<sup>3</sup> A treaty that ends fissile material production for weapons is sometimes called a fissile material treaty (by those who want it to include existing stocks) and sometimes called a fissile material production cutoff

treaty (by those who want a narrow treaty limited to future production). There is no universal way to refer to the treaty, so I will use the impartial acronym FM(C)T.

Between 2017 and 2018, the Fissile Zero Future project, in collaboration with the Maureen and Mike Mansfield Foundation, hosted a public session in Tokyo on minimization and transparency norms for civil plutonium, essentially expanding and improving upon the Japanese principle of no surplus plutonium. Private exchanges and another public session at the Sasakawa Peace Foundation in Tokyo, as well as a public meeting with Japanese Diet members, completed the exchanges in Tokyo in June 2018. In addition, American, Japanese and Korean experts wrote [essays](#) on the kinds of information sharing that would be useful in Asia on civil plutonium stockpiles and spent nuclear fuel.

The world is a long way yet from a Fissile Zero Future. Critics might argue that an approach that builds norms and tweaks policies is wrong-headed because civilian and military uses of the atom cannot ever be truly separated. In the words of Ted Taylor, a former Los Alamos nuclear weapons designer, “The connections between nuclear technology for constructive use and for destructive use are so closely tied together that the benefits of one are not accessible without greatly increasing the hazards of the other.”<sup>4</sup> Simply re-branding a less dangerous version of the nuclear enterprise as risk-free does not resolve the underlying problems, in the same way that managing risk does not eliminate risk.

Countries have tended to be doggedly attached to their nuclear assets once acquired and resistant to innovative approaches to

restrict them. It seems that for the foreseeable future, we are stuck with both nuclear weapons and fissile material that will continue to pose risks. The trick will be to shift perspectives of fissile material, which was once thought of as the “reward” from military nuclear programs, as a risk not worth taking. Such a shift will become easier for the civilian sector as alternatives (e.g., renewable energies) without military risks become more attractive but the case is harder in the military sector, as long as nuclear weapons continue to hold sway as the most potent and prestigious armament. The best approach to peeling away the layers of prestige is to expose programs to public accountability through transparency.

<sup>4</sup>Theodore B. Taylor, *Nuclear Power and Nuclear Weapons*, (Santa Barbara, CA: Nuclear Age Peace Foundation, July 12, 1996), available from

[www.wagingpeace.org/nuclear-power-and-nuclear-weapons/](http://www.wagingpeace.org/nuclear-power-and-nuclear-weapons/)

## BACKGROUND

For over 70 years, nuclear weapons have been considered the most destructive weapons ever invented. Efforts to limit them began shortly after they were invented. Nonetheless, nuclear weapons stockpiles in the US and the Soviet Union rose to dizzying heights during the Cold War. Although nuclear warhead stockpiles have declined, there is a massive overhang of fissile material stocks, the key ingredient for nuclear weapons. One 2015 estimate suggests that while there were about 15,000 nuclear weapons worldwide in 2014, the amount of military fissile material stock could have fueled 80,000 weapons.<sup>5</sup> There are still no legal limits on producing or stockpiling fissile material, even if it is weapons-grade or weapons-usable. This is true for nuclear weapon states, half of which are adhering to a fissile material production moratorium (US, UK, China, Russia, France and Israel, but not North Korea, India or Pakistan), but it is also true for non-nuclear weapon state parties to the Nuclear Nonproliferation Treaty (NPT).<sup>6</sup>

Non-nuclear weapon state parties to the NPT have comprehensive inspections on all fissile material on their territory, and thus stockpiles

of weapons-usable material would be inspected, but the risks are quite substantial in a country that may intend to divert such material to nuclear weapons. Negotiators attempting to reduce risks from Iran's nuclear program were keenly aware of this and sought to address this fundamental gap through provisions in the Joint Comprehensive Plan of Action (JCPOA) for Iran that limited the production and stockpiling of material for the duration of the agreement. One of the key complaints about the agreement is that these limits for Iran won't last forever. In fact, some nonproliferation experts would like to see application of JCPOA-like limits for other countries but recognize that it will be nearly impossible to achieve wider, legally binding limits within the NPT.

On the territory of those countries that already have nuclear weapons, large stocks of weapons-usable fissile material pose other concerns. The first is the risk of nuclear terrorism. The second is the complications that such stocks will pose for an eventual verifiable and irreversible disarmament process. Transparency there will be crucial, yet nuclear weapon states have comingled civilian and military fissile material production for decades. A future fissile material treaty will likely require safeguards on uranium enrichment and spent

NPT out of fear that using that term for states outside the NPT with nuclear weapons such as India, Pakistan, Israel and North Korea would grant them legitimacy. This paper uses the term NPT nuclear weapon states to refer to the US, UK, Russia, China and France.

<sup>5</sup> David Albright and Serena Kelleher-Vergantini, "Military Highly Enriched Uranium and Plutonium Stocks in Acknowledged Nuclear Weapon States," November 3, 2015, available at [https://isis-online.org/uploads/isis-reports/documents/Military\\_HEU\\_and\\_Pu\\_Stocks\\_in\\_Acknowledged\\_NWS\\_November3\\_2015\\_Final.pdf](https://isis-online.org/uploads/isis-reports/documents/Military_HEU_and_Pu_Stocks_in_Acknowledged_NWS_November3_2015_Final.pdf)

<sup>6</sup> The Treaty on the Nonproliferation of Nuclear Weapons (NPT), came into effect in 1970. It created a legal definition of nuclear weapon states to include only those that exploded a nuclear device by January 1, 1967. These were the US, UK, China, France and the USSR. For many years, the term "nuclear weapon states" was used only to refer to those states within the

nuclear fuel reprocessing and possibly either civilian or excess military stocks.

The Nuclear Security Summits from 2010 to 2016 emphasized the risks from stocks over production, from HEU over plutonium, and from civil material as opposed to military material. One of the real successes of the summits was growing political will to minimize, and where possible, eliminate HEU in the civil sector. At the beginning of the summit process, there were more than 1500 tons of HEU in 55 countries. By 2016, more than 90 reactors that were fueled with HEU worldwide were shut down or converted to low-enriched uranium fuel. Twenty-nine countries (plus Taiwan) that had HEU no longer have any inventories of the material.

Unfortunately, the summits achieved less on the military side of the ledger with respect to HEU. Although the UK, US and Russia declared hundreds of tons of HEU as excess and downblended more than 600 tons in the last 15 years, there are significant stockpiles in all three, much of which has been assigned to naval nuclear fuel. The “hands-off” approach to naval nuclear fuel in terms of monitoring will continue to be a problem. As explained in detail in the [IISTP Occasional Papers](#) edition on naval nuclear fuel, the naval nuclear loophole in the NPT could complicate safeguards in countries like Brazil, provide a rationale for Iran to pursue “legitimate” highly enriched uranium (HEU) after the JCPOA ends, and detract from U.S. leadership to reduce the risks from HEU globally. Currently, naval platforms in the U.S., the U.K., Russia

and India use HEU fuel and Brazil will use slightly under 20% low-enriched uranium in its future submarines.

Of course, highly enriched uranium is only the tip of the iceberg. There is a lot less political will to address the roughly 500 tons of plutonium separated from spent fuel worldwide, about half of which is under military control. The nuclear security summits resulted in just two countries (Japan and Italy) consolidating, shipping and securing plutonium.<sup>7</sup> It has been difficult to address the growth of civilian plutonium stockpiles for many reasons and for many decades, largely because several countries have invested billions of dollars to reprocess spent nuclear fuel despite weak economic, technical and political rationales for such activity. This project focused on promoting transparency in Northeast Asia regarding civilian plutonium stockpiles. Essays written by U.S., Japanese and South Korean scholars can be found [here](#) and audio and video recordings of events can be found [here](#).

This final report ties together the three strands of work and summarizes key findings. For more detail, please see the Fissile Zero Futures [website](#).

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<sup>7</sup> For Japan, it was 500kg of HEU and Pu, which, in the context of its 47 tons of separated plutonium, is a small fraction of its plutonium stockpile.



## BUILDING A NORM FOR TRANSPARENCY IN STATES WITH NUCLEAR WEAPONS

Nuclear weapon states, whether inside or outside the NPT, have no legal obligation to provide information about their civilian nuclear programs, their civilian or military stockpiles of fissile material or their nuclear weapon programs.<sup>8</sup> Unless such states sign and ratify the 2017 Treaty on the Prohibition on Nuclear Weapons, there will continue to be no legally binding requirement to disclose much of that information.

However, some states have released information voluntarily over the years. This report and the project uses the term “transparency” to describe the voluntary release of information previously kept confidential. There has been progress in transparency on both nuclear weapons and fissile material in the last two decades, which suggests there is potential for building a norm of transparency absent legally binding obligations.

Certainly, expectations of transparency among states without nuclear weapons for states with nuclear weapons have grown. Those arguing for improved transparency believe that information builds trust, that better reporting by nuclear weapon states can strengthen accountability under the NPT and that nuclear security is strengthened by better accountability.

Transparency has also been identified as an essential building block of nuclear disarmament. Non-nuclear weapon state officials argue that almost fifty years after the NPT entered into force, nuclear weapon states to show a commitment to disarmament and an acknowledgement that accountability is necessary. In addition, they argue that transparency is a *sine qua non* for verification and irreversibility, two indispensable principles in nuclear disarmament.

It is tempting to conclude that transparency grows linearly – that the more information that is revealed, the easier it is to reveal additional information. Some argue that once information is in the public domain and there are no negative consequences, fears of disclosures lessen. There is scant evidence to support a linear progression, however. Although information is put in the public domain, future disclosures can be limited by government policies or laws.

<sup>8</sup>India, Pakistan, and Israel report on nuclear material and facilities under facility-specific IAEA safeguards as a result of supplier requirements. The 5 NPT NWS and India disclose some information through providing

lists of facilities eligible for the voluntary application of IAEA safeguards. In addition, the five NPT nuclear weapon states (and four other states) voluntarily report on some materials under INFCIRC/549.

Obviously, some argue against transparency for reasons of national security and nonproliferation. Sometimes greater transparency could lead to unintended consequences. And, there are also experts who argue that transparency may have run its course and should not be accepted in lieu of verified reductions in nuclear weapons or in fissile material stockpiles. In other words, while transparency is a prerequisite in the disarmament process, it should not be a “consolation prize” in the absence of real verification.

Clearly, the value of transparency measures depends a great deal upon what the measures are and what they accomplish. With respect to nuclear weapons, do they pertain to intentions (e.g., strategy, doctrine)? Historical production or stockpile numbers? Qualitative achievements? Can the information be confirmed or verified? While the release of information about past activities (production histories, stockpiles, etc.) is helpful, it is quite different from the release of information about current activities. Are the measures aimed more at building trust or improving accountability?

With respect to fissile material, there is a dual challenge because civilian fissile material is also largely outside the bounds of accountability for several of these states.

Pending a fissile material treaty, NPT nuclear weapon states may find it easier to provide more information or even place material and/or facilities under international monitoring, because they have stopped production for weapons purposes. India, Pakistan, and North Korea, however, are still producing fissile material for nuclear weapons, and in each case, there are significant obstacles to releasing information. On the civilian side, there have

been modest attempts at transparency (e.g., Plutonium Management Guidelines, or INFCIRC/549) that, frankly, pale in comparison to the information and access that non-nuclear weapon states parties to the NPT provide via IAEA safeguards to assure others they are not diverting material to nuclear weapons programs.

## Challenges and Opportunities for Transparency

One of the key criticisms of transparency measures is that they are by nature unverified. In the absence of verification measures, a critical function of civil society work in this area is to assess the credibility of government statements. This is more difficult in countries that do not have a culture of transparency, where there is generally less authoritative information available. In the case of the United States, scholars early on used environmental data on the concentration of Krypton-85 in the atmosphere to calculate plutonium production before the government released actual numbers. This analysis required assessing all the potential releases of Kr-85 over decades to extrapolate what U.S. and Soviet plutonium production might have contributed to such concentrations. Another approach is to cross-check numbers, using stockpile numbers to calculate fissile material production or vice versa.

Poor historical records can limit the credibility of government statements. For example, the lack of historical production records has hampered confirmation of fissile material holdings. In the process of making fissile material declarations, the United Kingdom, the United States, and South Africa all found inaccuracies in their purported holdings; the UK, specifically, lacks records to confirm the extent of shipments made to the United

States.<sup>9</sup> Further, drawdowns and processing losses can be difficult to accurately measure but can quickly amount to larger quantities of material in states with larger production capacities—a challenge for future verification of disarmament.

This raises an important question about the limitations of transparency measures in meeting their policy objectives. Transparency measures meant to improve accountability or function as an interim step toward verifiable limits could raise expectations for corroboration or verification, as opposed to those merely meant to build trust or confidence. However, the failure to meet those expectations might diminish the measures' ability to engender trust or confidence.

### Views of the Experts

In February 2017, the project hosted a workshop for top experts who have produced public estimates of nuclear weapons and fissile material stockpiles for decades to discuss some of the challenges and opportunities in developing those estimates with consumers of the analyses (see link to report below). The experts explored what we know, how we know it, and how to move forward to improve the estimates and laid the groundwork for clearer definitions and goals of transparency from governments, the benefits and risks of such transparency, and policy approaches to coax greater transparency from states that possess

nuclear weapons. Here are some of their conclusions:

#### ***On role of transparency:***

Transparency is a means to an end, such as strategic stability, regional security, or disarmament. Both civil society and governments must consider how releasing certain kinds of information affect attainment of potentially conflicting objectives. This calculation will clearly vary by country. Different attitudes about transparency, different motives for secrecy, and different international obligations exist in the countries with nuclear weapons.

#### ***On accountability:***

Accountability plays a role in reducing the risks of nuclear arms races, accidents, and the possibility of terrorists getting their hands on fissile material. Both government declarations and civil society estimates are both integral to building a norm of greater accountability. Where no government declarations are forthcoming, civil society estimates can create a basis for public discussion and generate pressure on national policies. Where governments have declared information, civil society estimates can help confirm, corroborate, or check official statements.

#### ***On the role of technology:***

For those outside governments making estimates, computing and satellite technology, including the ability to share information on the

<sup>9</sup>In its June 2012 update to its history of U.S. plutonium production and holdings, the Department of Energy noted that “there remain uncertainties about how much plutonium was actually produced, processed, and discarded to waste, especially for the period from the

mid-1940s to 1970 before advances in nuclear material measurement systems and computer aided tools to assist in the analysis of nuclear material accounting data.” *The United States Plutonium Balance, 1944-2009*, p.3.

Internet, has vastly improved the quantity and quality of open-source information. The analysis, however, still needs to be done by, with, and for people.

***On what public estimates contribute:***

Consistent methodology over time is more important and attainable than precision in public (and perhaps in government) estimates. Public data can help show trends and changes over time. In particular, understanding the uncertainties in data can help target resources. The consistency of these public, unofficial estimates over time has helped defuse some of the worst-case scenarios that tend to flourish in the vacuum of secrecy. What is more, the interplay between official and unofficial estimates has, arguably, enhanced accountability of nuclear weapons programs in a few key states. The monopoly on information that governments traditionally have wielded has diminished in some cases.

***On improving transparency:***

Key tasks within civil society include: training the next generation of analysts, including tapping into other next-generation efforts in the nuclear area (e.g., in safeguards, security, and industry); making information freely available (i.e., not behind paywalls); collaborating to pool resources for analysis; and providing selected journalists with tools to report on these issues (e.g., two- to three-day training workshops).

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<sup>10</sup>The P-5 process is a multilateral government dialogue among the five permanent members of the UN Security Council, namely the US, UK, France, China and Russia, or NPT nuclear weapon states that was proposed by the UK in 2008 and began in 2009. These private meetings take stock of P-5 commitments under the NPT. See Cormac McGarry, “Backgrounder on the P-5 Conferences: London, Paris and the Future” for a

Key tasks for governments include: building on existing efforts, including new START and continuing the P-5 process, perhaps even enhancing the common glossary of terms<sup>10</sup>; identifying country-specific rationales to support transparency for national security reasons; and incorporating military voices in support of transparency, perhaps based on cost and efficiency.

The group of international experts also identified potential leverage points for further transparency by governments. They noted that classification is very expensive to maintain in a bureaucracy and that transparency by one’s competitor can help avoid needless spending or overreactions to capabilities that may not exist. (On the other hand, potential exaggeration by competitors of capabilities may help spur an arms race.) Transparency can thus be a cost-savings mechanism.

Second, transparency activities between United States and Russia could be cheaper than arms control and cheaper than a massive buildup.

Third, other governments, particularly if the convention to ban nuclear weapons fails substantially, may look to transparency as a “fallback” option. Regardless, government declarations will be necessary for any effort moving forward to reduce and eventually eliminate nuclear weapons.

summary of its origins.

[http://www.basicint.org/sites/default/files/p5-nuclearconferences\\_0.pdf](http://www.basicint.org/sites/default/files/p5-nuclearconferences_0.pdf) The glossary of common terms originated from a P-5 working group in 2011, led by China. The glossary can be found here: <https://2009-2017.state.gov/documents/organization/243293.pdf>

Fourth, some transparency measures can be accomplished quickly, like an agreement between the US and Russia to take warheads off high alert.

***Reports and Other Media:***

[“Not Separate and Not Equal: Co-Mingling Defense and Civilian Nuclear Activities,” Sharon Squassoni, October 2018.](#)

[“Transparency Workshop: Nuclear Weapons and Fissile Material Discussion Paper,” unpublished paper by Sharon Squassoni and Amelia Armitage, February 7, 2017](#)

[\*Transparency: Nuclear Weapons and Fissile Material; Report of a Workshop, April 2017\*](#)

[Podcasts](#)

## NORMS FOR CIVIL PLUTONIUM

Experts in nuclear security and proliferation have grappled for decades with the problem of providing enough assurances that the production, use and stockpiling of weapons-usable materials in civilian economies do not increase the risks of proliferation and nuclear terrorism. Whereas the series of nuclear security summits held from 2010 to 2016 helped entrench the notion that the use of HEU must be minimized and where possible, eliminated, there is no similarly entrenched notion about the dangers of civilian separated plutonium.<sup>11</sup>

Civilian plutonium has eluded restrictions for many reasons. Plutonium is generated in many research reactors and all power reactors, but in spent fuel, it is self-protecting and therefore not considered to be vulnerable. In addition, plutonium is thought of in some circles as the key to a perpetual fuel cycle – once harvested from irradiated nuclear fuel, it can be used as fuel in fast breeder reactors to generate even more plutonium. The fact that commercial reprocessing has never truly taken off has diminished the sense of urgency to put

in place measures to prevent widespread proliferation of plutonium separation capabilities. Under the Nuclear Non-Proliferation Treaty, however, there are few measures to diminish the nuclear security and proliferation risks of civilian plutonium separation, use and stockpiling. Even if countries eventually agree to a treaty to ban the production of fissile material for use in weapons, they are unlikely to be able to agree on restricting civilian plutonium use unless nuclear energy falls into disfavor. In the meantime, then, it could be useful to work towards establishing norms that would in fact diminish the risks of civilian plutonium. These norms could include policies and practices at facilities, by industries, by countries and across countries.

### Existing Norms

Nuclear weapon states are not required to safeguard stocks of plutonium in civilian use, whether separated or embedded in irradiated nuclear fuel. Twenty years ago, however, the nuclear weapon states and four non-nuclear

<sup>11</sup> As noted earlier, the U.S. Department of Energy has concluded that all grades of plutonium can be used in nuclear weapons. When plutonium is contained in irradiated fuel, the radioactivity of the spent fuel provides a barrier to its diversion. The National Academy of Sciences in 1994 called this the “spent fuel standard.” See Committee on International Security and Arms Control, National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium*,

Washington, DC: National Academy Press, 1994. Available at:

<https://www.nap.edu/catalog/2345/management-and-disposition-of-excess-weapons-plutonium> Separated plutonium is defined here as plutonium that has been separated from other constituents of spent fuel [or irradiated targets] to the extent that it becomes significantly more vulnerable to diversion or theft than the plutonium contained in light water-reactor spent fuel.

weapon states (Belgium, Japan, Germany and Switzerland) together established the Guidelines for Management of Plutonium, which were published by the International Atomic Energy Agency (IAEA) in an information circular (INFCIRC/549). Nine states publish information on an annual basis about their civil plutonium stocks under the agreed reporting mechanisms of INFCIRC/549. According to INFCIRC/549, however, governments agree to manage plutonium “in ways which are consistent with its national decisions on the nuclear fuel cycle and which will ensure the peaceful use or the safe and permanent disposal of plutonium.” Proliferation risks are taken into account, but so are the following factors: “protecting the environment, workers and the public, the resource value of the material, the costs and benefits involved and budgetary requirements; and the importance of balancing supply and demand, including demand for reasonable working stocks for nuclear operations.”<sup>12</sup> This is currently the only example of a multilateral norm on civilian plutonium.

Within industry, AREVA has adopted the equivalent of a “just-in-time” inventory policy, attempting to avoid significant stockpiles of separated plutonium. And Japan, as a country, established a “no-surplus plutonium policy” as early as 1991. Japan, the only non-nuclear weapon state now with a domestic

reprocessing capability, has taken special steps to allay international concerns about its civilian plutonium stockpile. In 1991, the Japan Atomic Energy Commission (JAEC) specified that Japan would not separate plutonium for which it did not already identify a specific use.<sup>13</sup> Since 1994, Japan has shared information publicly on its separated plutonium and plutonium in spent nuclear fuel, and has reported to the Guidelines for Management of Plutonium (INFCIRC/549) since 1997.

For many years, the Japanese government has relied on the Japanese nuclear industry to specify plutonium consumption plans. Beginning in 2003, the Japan Atomic Energy Agency (then the Japan Nuclear Fuel Cycle Development Institute) participated also in formulating that plan.

Japan’s nuclear industry at this point in time, however, is unable to assess with accuracy when its fleet of nuclear power plants, and particularly the MOX-burning plants will be up and running. The original plan for consuming plutonium relied on at least 16 reactors burning MOX, but at present, the only reactors operating than can burn MOX are Ikata-3, Genkai-3, and Takahama-3 and -4.<sup>14</sup> The continuing disarray that plagues Japan’s nuclear industry as a result of the 2011 accident at Fukushima, new regulations and delays in completing and opening the

<sup>12</sup> Guidelines for the Management of Plutonium, published as Information Circular (INFCIRC) 549 on March 16, 1998, available at:

<https://www.iaea.org/sites/default/files/infirc549.pdf>

<sup>13</sup> <http://www.aec.go.jp/jicst/NC/about/ugoki/geppou/V36/N08/199103V36N08.html>

<sup>14</sup> Ikata-3 was under court injunction and should start October 27, 2018; operations see periodic updates from Japan Atomic Industrial Forum’s website, [https://www.jaif.or.jp/cms\\_admin/wp-content/uploads/2018/10/jp-npps-operation181002\\_en.pdf](https://www.jaif.or.jp/cms_admin/wp-content/uploads/2018/10/jp-npps-operation181002_en.pdf)

Rokkasho reprocessing plant, and decisions to close the Monju fast breeder reactor, raise questions about the credibility of Japan's plutonium consumption plan. With approximately 10 tons of separated plutonium at home and over 37 tons of separated plutonium at reprocessing plants in the UK and France, Japan's no-surplus plutonium policy looks hollow indeed.

In October 2017, the Japan Atomic Energy Commission released a statement on Plutonium Utilization in Japan. The statement underscored previous policies of not holding plutonium without specific purposes and also Japan's intention to keep a steady state of plutonium through consuming it in light water reactors. The statement reiterated that "It is the intention of the Japanese government (JAEC) to remain engaged to secure appropriate supply-demand balance of plutonium under the current framework of assessing future plutonium consumption by fully grasping the nuclear operators' demand for plutonium and their consumption and verifying its appropriateness."<sup>15</sup> In July 2018, the JAEC released a statement of "Basic Principles on Japan's Utilization of Plutonium." Remarkably, the statement declared that Japan would reduce its plutonium stocks. It then elaborated steps it would take to **maintain the balance at current levels**. It is worth quoting the operative paragraphs of the statement in full here:

1. Approve reprocessing plans under the Spent Nuclear Fuel Reprocessing Implementation Act

so that reprocessing is to be carried out only to an extent necessary for steady pluthermal power generation, reflecting the operational situation of the Rokkasho Reprocessing Plant (RRP), the MOX Fuel Fabrication Plant,\* and MOX-burning reactors; Instruct the operators and confirm that the produced MOX fuel is to be fully consumed in a timely manner;

2. Instruct the operators so as to secure a balance between demand and supply of plutonium, minimize the feedstock throughout the process between reprocessing and irradiation, and reduce the feedstock to a level necessary for proper operation of the RRP and other facilities;

3. Work on reducing Japan's plutonium stockpile stored overseas through measures including promoting collaboration and cooperation among the operators;

4. Examine all options such as use and disposal of plutonium that is associated with research and development purposes, if there is no concrete plan for its immediate use, while ensuring flexibility depending on the situations; and

<sup>15</sup> The October 2017 policy can be found at <http://www.aec.go.jp/jicst/NC/about/kettei/kettei171003e.pdf>



5. Steadily promote efforts toward expanding storage capacity for spent fuel.

In addition, in order to enhance transparency, electric utilities and Japan Atomic Energy Agency (JAEA) are expected to develop plutonium utilization plans anew, which describes owners, the amount of plutonium in possession and the purposes of plutonium utilization, and then release them every fiscal year.<sup>16</sup>

The document updated plans for operating the Rokkasho reprocessing plant (construction to be complete in FY 2021) and the MOX fuel fabrication plant (FY 2022).

Without further details, it is difficult to know whether these plans will show anything but slow progress in reducing Japan's plutonium stockpile. The Takahama-3 and -4 reactors were credited with consuming 1 ton of plutonium between 2016 and 2017 and presumably they will remain on-line to continue that steady burning. A significant question is what may occur as a result of the proposed collaboration among operators to reduce Japan's plutonium stockpile stored overseas.

Japan's neighbors, China and South Korea, watch these developments with interest. Although China's growth in nuclear power has slowed a little since 2011, its plans call for considerable expansion, including civilian reprocessing of spent nuclear fuel, as well as work on advanced nuclear reactors.<sup>17</sup> South Korea, under Moon Jae-In, currently has a

policy of phasing out nuclear power, but this policy is very likely only to survive Moon's one five-year term. Despite some safety scandals a few years ago, South Korea will probably return to a robust nuclear energy program that features exports and a strong push for pyroprocessing, a form of reprocessing for spent fuel.

The Fissile Zero Futures project tasked experts from Japan, the United States and South Korea to contemplate what kinds of additional transparency or restrictions could strengthen the norm against plutonium stockpiling in Northeast Asia. Could Japan do more regarding its no-surplus plutonium policy? Specific questions included:

- What kinds of information would be useful to improve confidence in intentions about the management of civilian plutonium, either separated or in irradiated fuel?
- How much and what kinds of information is shared publicly about spent nuclear fuel and separated civilian plutonium in your country? Has this shifted over time? Are there domestic economic, technical or political hurdles to sharing information?
- In your view, are there domestic, regional or international incentives exist for sharing more information? What potential new best practices or

<sup>16</sup>The July 31 2018 policy can be found at <http://www.aec.go.jp/jicst/NC/iinkai/teirei/3-3set.pdf>

<sup>17</sup>See Mark Hibbs, "The Future of Nuclear Power in China," Washington, DC: Carnegie Endowment for

International Peace, May 2018, available online at: <https://carnegieendowment.org/2018/05/14/future-of-nuclear-power-in-china-pub-76311>

approaches would you like to see in place in other states in the region?

- What barriers exist that might prevent more information-sharing? Do trade/regulatory relationships work for or against greater information-sharing?
- Are there ways in which industry can strengthen confidence? What information can industry share and with whom?
- What constitutes a reasonable level of working stocks for specific reprocessing facilities (based on throughput)? How is that level calculated?

In the compilation of essays produced, several themes emerged. ***One was that Japan had an opportunity to play a leadership role in strengthening norms against plutonium stockpiling.*** In his essay, “Proliferation Risks of Plutonium Production,” former Assistant Secretary of State for International Security Tom Countryman suggested that Japan should invest more in medium-term storage (in dry casks) of spent nuclear fuel, and in research on safe and economical methods of permanently storing excess plutonium (with researchers in the US and UK). Making significant progress on identifying a permanent depository for long-term storage of nuclear waste could be helpful in the region.

Countryman proposed that Japan make good on the Joint Atomic Energy Commission’s July 31, 2018 pledge to reduce holdings of plutonium by committing “to limiting production when the Rokkasho facility eventually opens to an annual limit matching the realistic consumption capacity of currently existing Japanese reactors.” A more far-reaching step

would be for Japan to propose a regional moratorium on reprocessing, making a virtue of necessity. In Countryman’s view, a moratorium would serve as a confidence-building measure among economic and security rivals, even if it were initially proposed for a limited period, e.g., five years. It could potentially allow the four East Asian states – Japan, China, North Korea and South Korea – to share information on capabilities and risks, and to work together on methods of handling and permanently storing spent nuclear fuel, and of further reducing the cost of LEU for reactor input.

Tatsujiro Sukuki, former JAEC commissioner and director of the Research Center for Nuclear Weapons Abolition, Nagasaki University (RECNA), suggested four actions that could support efforts to reduce plutonium stockpiles. He recommended first that each country’s declaration under the Guidelines for the Management of Plutonium should specify “demand” (consumption/disposition) for the next 3 years, restrain “supply” (reprocessing) up to the amount specified by the demand, including the current stockpile, and define what is “excess” stockpile (beyond the quantity defined above). Suzuki recommended that numbers should be in kg rather than tons (per Japan’s example), that the report should specify sites where separated plutonium is stored (per Japan’s example), include HEU stockpile, if any, and review the country’s national nuclear fuel cycle policy (cost, rationale, environmental impacts, safety etc.).

Another theme was ***the need for international collaboration to reduce risks from***

## **Reports and Other Media:**

### **Essays**

[Jor-shan Choi, "Reasonable Working Stocks for MOX Fuel Fabrication," July 2018](#)

[Thomas Countryman, "Proliferation Risks of Plutonium Production," September 2018](#)

[Tatsujiro Suzuki, "Possible Options for International Management of Plutonium Stockpile," July 2018](#)

[Sungyeol Choi, "Responses to 'Norms for Civilian Plutonium' by Sharon Squassoni," July 24, 2018](#)

[Yongsoo Hwang, "The Norm of Managing Special Nuclear Materials in Spent Nuclear Fuel in the ROK," June 27, 2018](#)

### **Briefings**

[Jor-shan Choi, "Taking Stock: Plutonium in Northeast Asia," International House of Japan, Tokyo, June 28, 2018](#)

[Yongsoo Hwang, "Managing Special Nuclear Materials in Commercial SNF in the ROK: The Era of Energy Transition," International House of Japan, Tokyo, June 28, 2018](#)

[Alan Kuperman, "Plutonium for Energy? A Study of MOX Fuel in 7 Countries," International House of Japan, Tokyo, June 28, 2018](#)

[Sharon Squassoni, "Reducing Plutonium Risks in Northeast Asia," International House of Japan, Tokyo, June 28, 2018](#)

**plutonium.** In his essay, Suzuki recommended that countries revisit the option of establishing an international plutonium storage concept, cooperate on plutonium disposition, including "swapping" ownership of plutonium to be able to consume it more quickly, and, ultimately, phase out reprocessing. Suzuki specifically proposed that the UK, France, Japan and Russia commit to a moratorium for the foreseeable future until plutonium stocks are substantially reduced.

Sungyeol Choi, a professor in the Nuclear Fuel Cycle Laboratory at the Korean Advanced Institute of Science and Technology, suggested that potential incentives for regional

cooperation might be lower national costs by sharing investment in research and development, shorter timelines for a fuel cycle program, increased public trust (peer review between cooperative countries) and enhanced regional transparency, non-proliferation and security. Regional collaboration could help promote economies of scale, widen the candidate sites for repositories and create multiple options for managing spent nuclear fuel, among other things. However, Choi also cited security concerns, cultural barriers, and economic barriers to sharing information between regional partners in these areas.

**On the question of reasonable working stocks for reprocessing plants,** Choi noted that inventory optimization is a very common problem in the process, chemical and manufacturing industries. He suggested a crude estimate of working stock as enough to operate reactors for 2-3 years, or roughly 2.5 tons of plutonium per 1 GWe reactor using a one-third core loading. JorShan Choi, in his essay, echoed the importance of working stocks in reprocessing plants for balancing the supply and demand of plutonium. He noted that industrial operation of fuel fabrication plants in Belgium and France suggested that reasonable working stocks may amount to 1 to 2 years of production throughput, and sufficient for contingencies associated with administrative procedures, transportation logistics and security requirements, etc.

Finally, **the role of civil society in promoting transparency about civil plutonium is weak in some countries.** For example, in South Korea, as Yongsoo Hwang points out in his

essay, there are only limited universities dedicated to education about the nuclear fuel cycle, nuclear non-proliferation, and public and stakeholder engagement. Although some schools have begun to establish courses on nuclear non-proliferation, it will take some time to see real impact from this educational endeavor.

## REDUCING RISKS FROM HEU FOR NAVAL NUCLEAR FUEL

The use of nuclear fuel to power naval vessels has provided distinct advantages to countries able to master the technology, especially when it comes to enhancing the stealth and range of submarines. Those countries with the resources and impetus to proceed down this path have leveraged their nuclear-weapon programs. Japan and Germany were exceptions to this rule, and they limited their experimentation to nuclear-powered ships for civilian purposes. Canada contemplated nuclear submarines in the 1980s but ultimately abandoned its plan.<sup>18</sup>

Financial and technical hurdles make the naval nuclear club exclusive, but no legal barriers exist. In fact, parties to the Nuclear Nonproliferation Treaty (NPT) with or without nuclear weapons are free to develop nuclear fuel for non-proscribed military applications.<sup>19</sup> This “naval nuclear loophole” poses several dilemmas. The first is a well-known monitoring problem that arises because nuclear material for military reactors arguably passes in and out of the civilian and military sectors throughout its life cycle. The only inherently military segment of the naval nuclear fuel cycle involves the use of the fuel aboard the military

vessel, although some information associated with the composition of the fuel and its irradiation along the way might be sensitive.

The monitoring dilemma has lain dormant for several reasons. Nuclear-weapon states party to the NPT have thus far solved this problem by cordoning off their military programs from monitoring, as they are able to do under the terms of the treaty and their voluntary safeguards agreements. Non-nuclear-weapon states have never reached the point of needing to address the issue. According to the monitoring requirements of the standard comprehensive safeguards agreement (INFCIRC/153) that non-nuclear-weapon states sign with the International Atomic Energy Agency (IAEA), states would inform the agency when they intended to use material in a non-proscribed military activity and make arrangements for the non-application of safeguards for that period or set of circumstances (Paragraph 14 of INFCIRC/153).

No non-nuclear weapon state has yet challenged the naval nuclear loophole, but this may change. Brazil, a state that had a nuclear-weapon program but abandoned it more than

<sup>18</sup> Both domestic (e.g., cost) and foreign (particularly US) pressure helped cancel the program. A more recent proposal to resurrect nuclear submarines for Canada can be found in Dunlop (2017).

<sup>19</sup> For states without nuclear weapons, Article III of the treaty requires monitoring of nuclear material in all peaceful nuclear activities, while Article II specifically prohibits the diversion from peaceful activities to nuclear weapons or other nuclear explosive devices.

20 years ago, has been inching forward with a nuclear-powered-submarine program. South Korea, another state with a past nuclear-weapon program, declared a desire to counter future North Korean nuclear capabilities by developing its own nuclear-powered submarine. Those plans undoubtedly will be greatly influenced by what happens with North Korea's nuclear program and by US preferences. Iran in the last decade has also expressed interest in building nuclear-powered submarines and maritime transport, but the timing and scope of any activities are difficult to predict, particularly with the Joint Comprehensive Plan of Action for Iran in considerable jeopardy.

Plans for new nuclear-submarine programs are not the end of the challenges posed by naval nuclear fuel, however. A treaty to limit fissile material production for use in nuclear weapons—a so-called Fissile Material Treaty, or Fissile Material Cutoff Treaty—would likely require more stringent monitoring in nuclear-weapon states and would be unlikely to perpetuate the existing loophole for naval fuel.<sup>20</sup> There is little impetus at the moment to pursue a fissile-material treaty, but this also could change in the aftermath of what will likely be a contentious review conference for the NPT in 2020, the 50th anniversary of the treaty's entry into force.

Another dilemma arises from the fact that some nuclear naval programs—those of the

United States, the United Kingdom, Russia, and India—use highly enriched uranium (HEU) in their fuel. Proponents of HEU naval fuel see few reasons to abandon HEU, citing operational requirements, especially for submarines. For non-nuclear-weapon-state parties to the NPT, a naval nuclear program provides a credible rationale for indigenous uranium enrichment with no limits on the level of enrichment. As such, a naval nuclear fuel program could provide an opportunity for potential proliferators to hide activities or hide materials that could be diverted to a nuclear-weapon program. Moving away from HEU in all naval nuclear reactors would substantially reduce proliferation and nuclear-security risks. Doing so would parallel the growing norm in the civilian sector to minimize and, where possible, eliminate HEU for civilian applications, as well as simplify some elements of future negotiations on a fissile material treaty.

For bureaucratic, political, and economic reasons, steps that could mitigate the risks that naval nuclear fuel pose for proliferation and nuclear security have been unpopular. The four nuclear-security summits held between 2010 and 2016 successfully challenged the status quo regarding HEU in the civilian nuclear sector but left HEU in the military sector untouched. Legal routes to further restrictions, such as amending the NPT, completing a fissile-material treaty, or bringing the nuclear-weapons ban into effect, are long,

mandate ever (briefly) agreed upon, the Shannon mandate of 1995, left the question of scope open for negotiators to determine. Besides meetings of governmental experts, no negotiating progress has occurred at the Conference on Disarmament in Geneva on this topic.

<sup>20</sup> An agreement to end production of fissile material for nuclear weapons has been on the nuclear-disarmament agenda for decades and is considered, along with a Comprehensive Test Ban Treaty, to be a critical step on the path toward disarmament. Debate has raged over whether the treaty should ban just future production or also include existing stocks. The only negotiating

arduous, and possibly not worth the effort. In the interim, therefore, it makes sense to explore whether countries with naval nuclear programs can take actions individually or together that would support norms to reduce the proliferation and security risks associated with existing and future programs.

The Fissile Zero Futures project commissioned essays that explored whether norms such as greater transparency in the form of new monitoring approaches, restraint in the use of HEU stocks, and a global cap on uranium enrichment levels might be feasible or achievable. International experts met to discuss the trends and status of programs in established nuclear navies, particularly specific developments in newcomer nuclear navy states (Brazil and potentially South Korea and Iran), gaps in the nonproliferation regime and potential ways to close those gaps. Some key points of the discussion are summarized below.

1. The US and Russia have the largest HEU stockpiles, the most experience with nuclear-powered vessels, and both use HEU fuel but any cooperation in this area (unless limited to technical safeguards issues) is likely to be crowded out by other, higher priorities on the bilateral agenda. It will be important to watch what happens in Asia – Russia, China, India, and Pakistan are the drivers in terms of acquiring platforms. France and Russia have important supplier roles, but so could China with respect to Pakistan.

2. The Brazilian naval nuclear program is moving forward, despite recent scandals. The navy appears committed to transparency and in the view of some experts, may be open to Track 2-level consultations on international

monitoring. However, Brazil's transparency has not yet been tested by having to subject a reactor with a classified design to monitoring.

3. A new committee will start framing the terms of debate for safeguards, possibly as early as 2019 with a new president. Ultimately such efforts will likely involve ABACC (the bilateral material control and accounting agency with Argentina); it is not clear whether a wider multilateral forum would be welcomed.

4. South Korea's decisions regarding nuclear submarines, as in other key defense issues, are shaped by the tension between independence and alliance cohesion. If its decisions about fighter aircraft or extended missile ranges are any guide, South Korea may indeed choose to move forward on a nuclear submarine program. (Its previous plans were abandoned after discovery in 2004 as a result of South Korea making declarations for its IAEA Additional Protocol). South Korea has more experience than Brazil in building reactors, but other high-tech priorities like drones and missile defenses will compete for defense funds.

5. Iran announced to the IAEA in January 2018 that it would pursue nuclear fuel for maritime transport within the restrictions of the JCPOA. As such, the vessel could only use 3.6% enriched uranium fuel and could not have a military mission. If the JCPOA collapses, Iran would pursue a program bound by INFCIRC/153, which allows for military nuclear fuel of any enrichment level.

6. India's program, which began with the lease of a nuclear submarine (and crew) from

Russia, is highly secretive. At present, there are few incentives for India to lower the enrichment level of its fuel.

There are two major proliferation and security risks associated with naval nuclear programs – the diversion of HEU from the naval fuel cycle and the justification of new national enrichment programs. These are exacerbated by the monitoring loophole in the NPT for naval fuel.

### **HEU versus LEU**

1. Trying to restrict non-nuclear weapon states from using HEU fuel while a few nuclear weapon states continue to use HEU fuel (US, Russia, UK) may be seen as further proof of the inherent discriminatory nature of the NPT. Some participants regarded efforts to convert from HEU to LEU fuel as the only issue, suggesting that monitoring would be relatively easy; others suggested the loophole presented by Paragraph 14 of INFCIRC/153 was so enormous that a better approach would be to dissuade naval nuclear newcomers from acquiring nuclear-powered submarines at all.
2. There are several impediments within the nonproliferation regime for states that must purchase foreign uranium or purchase enrichment services or fuel for their submarines but few impediments for those with full fuel cycles, beyond cost and matching technologies to missions. Several participants agreed that most missions can be accomplished better and more cheaply with diesel submarines.
3. The broadest options could include banning HEU fuel for naval vessels, putting all enrichment plants (including in nuclear weapon

states) under IAEA safeguards, or making all enrichment plants multinational.

4. Those states continuing to use HEU are dealing with major defense budget challenges as they modernize aging fleets of nuclear-powered naval vessels as well as other branches of their militaries. This intense budget completion leaves little or no funding for national programs to develop and deploy replacement LEU-fueled naval vessels absent elevated national priorities to do so.

### **Monitoring Issues**

1. Since IAEA has never “non-applied” safeguards per Paragraph 14 of INFCIRC/153, there are no current standards for access and no rules for drawing boundaries around what is militarily sensitive and what is not. Navies may seek to cordon off large portions of the fuel cycle based on their desire to protect sensitive information, even though the only inherently military element of the naval fuel cycle is when the fuel is in service aboard a vessel. It will be important first to discuss/negotiate what information could be public knowledge versus what needs to remain secret.
2. States could explore containment and surveillance techniques along with managed access for more sensitive sites and facilities. An approach to track items rather than material may be helpful here. Other elements that could help plug some of the overall gaps in the regime might include commitments not to export naval nuclear fuel or to cap the sizes of naval fuel “stockpiles” to provide some predictability under a future fissile material treaty. A test-bed for approaches to deal with



sensitive information could be useful. Brazil is an obvious choice because it may be the first non-nuclear weapon state within the NPT to develop a nuclear-powered submarine, but France, as a nuclear weapon state with LEU-fueled submarines, might consider approaches to demonstrating that its fuel is not HEU.

### **Alternate Approaches**

A direct approach would be to admit that Paragraph 14 of INFCIRC/153 is a bad idea. Trying to get newcomer naval nuclear states just to use LEU without having all the nuclear weapon states convert is perpetuating discrimination. At the same time, it would be useful for navy officials to extoll the virtues of conventionally powered submarines – apart from deep-ocean missions, diesel subs are quieter and superior to nuclear-powered subs.

Indirect approaches could include widening the no-military-uses supply policies to all uranium suppliers, or to all enrichment service providers or to all equipment, material, technology supplied under peaceful nuclear cooperation agreements (Note that this would be more restrictive than the NPT). Another indirect approach would be to implement submarine export restrictions or incentives for conventionally powered submarines. For example, the Wassenaar Arrangement covers only diesel-powered submarines. Is it time for a Nuclear Submarines Supplier Group? Such a group could adopt a code of conduct, for example, only supplying a nuclear-powered submarine if its reactor is designed for LEU fuel. Finally, countries could ban port visits for nuclear-powered ships (of the sort implemented by New Zealand).

### **Targets For Discussion**

In some cases, the lack of information among the general public and high-ranking officials about the implications of having nuclear submarines points to the value of broader educational missions. It will be important to clear up what these machines can and cannot do, as well as analyze the systems effects of acquisition (that is, the reactions from other countries). Decisions about nuclear submarines should not be restricted to just nuclear or military officials, but also finance ministry officials.

***Reports and Other Media:***

[Institute for International Science & Technology Policy Occasional Papers Volume I,](#)

**BRIEFING SLIDES**

[Togzhan Kassenova, "New Naval Nuclear Programs: Brazil, South Korea, Iran," Naval Nuclear Fuel Workshop at IISTP, August 27, 2018](#)

[Sebastien Philippe, "The Naval Nuclear Fuel Cycle: Challenges and Opportunities for Governance," Naval Nuclear Fuel Workshop at IISTP, August 27, 2018](#)

[Sharon Squassoni, "Mitigating Risks of Naval Nuclear Fuel," Naval Nuclear Fuel Workshop at IISTP, August 27, 2018](#)

[Frank von Hippel, "Mitigating Security and Proliferation Risks from Naval Nuclear Fuel," Naval Nuclear Fuel Workshop at IISTP, August 27, 2018](#)