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Proliferation Risks of Civilian Nuclear Power Programs

June 2012

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The risks of nuclear proliferation—the further spread of nuclear weapons and weapons-usable material, technology, and expertise—derive in part from the technical characteristics of the nuclear fuel cycle and the national and international management of fuel cycle activities. Civilian nuclear power plants themselves are not considered a high proliferation risk because it is difficult to make weapons-usable material from reactor fuel. The principal proliferation risk is that states can use the civilian nuclear fuel cycle as a source for the material, technology, and expertise needed to develop nuclear weapons. A state's intent to develop a nuclear weapons capability can be concealed if its activities otherwise appear compliant with its obligations under the Nuclear Non-Proliferation Treaty (NPT). Creating more effective barriers to the diversion of civilian nuclear programs to military purposes—as North Korea has done and as Iran appears to be doing—is central to current efforts to strengthen the global nuclear nonproliferation regime.

Nuclear Fuel Cycle

There are two proliferation pathways associated with the diversion of the nuclear fuel cycle: the enrichment of natural uranium to weapons-grade levels (over 90 percent of the fissile isotope U-235), and the chemical reprocessing of "spent" or irradiated nuclear fuel to separate out sufficient weapons-grade plutonium (typically about 93 percent Pu-239) to build a bomb.[1] These two processes and their associated technologies are commonly referred to as enrichment and reprocessing (ENR). At the *front end* of the fuel cycle—the process for preparing uranium fuel for reactor operation—most civilian power plants house light water reactors that run on low enriched uranium (LEU), which is uranium enriched to 3 to 5 percent U-235. The same techniques used to produce LEU can be used to produce both high enriched uranium (HEU), which is uranium enriched above 20 percent U-235, and weapons-grade uranium. The industrial effort and time required to convert LEU to HEU is considerably greater than that required to convert HEU to weapons-grade uranium. Thus, once a state is capable of producing HEU, it has mastered the most challenging aspects of the enrichment process; further enriching to weapons-grade requires less effort. The figure on page 2 illustrates this phenomenon.

Current concerns surrounding Iran focus on its growing stockpile of LEU, its further enrichment of

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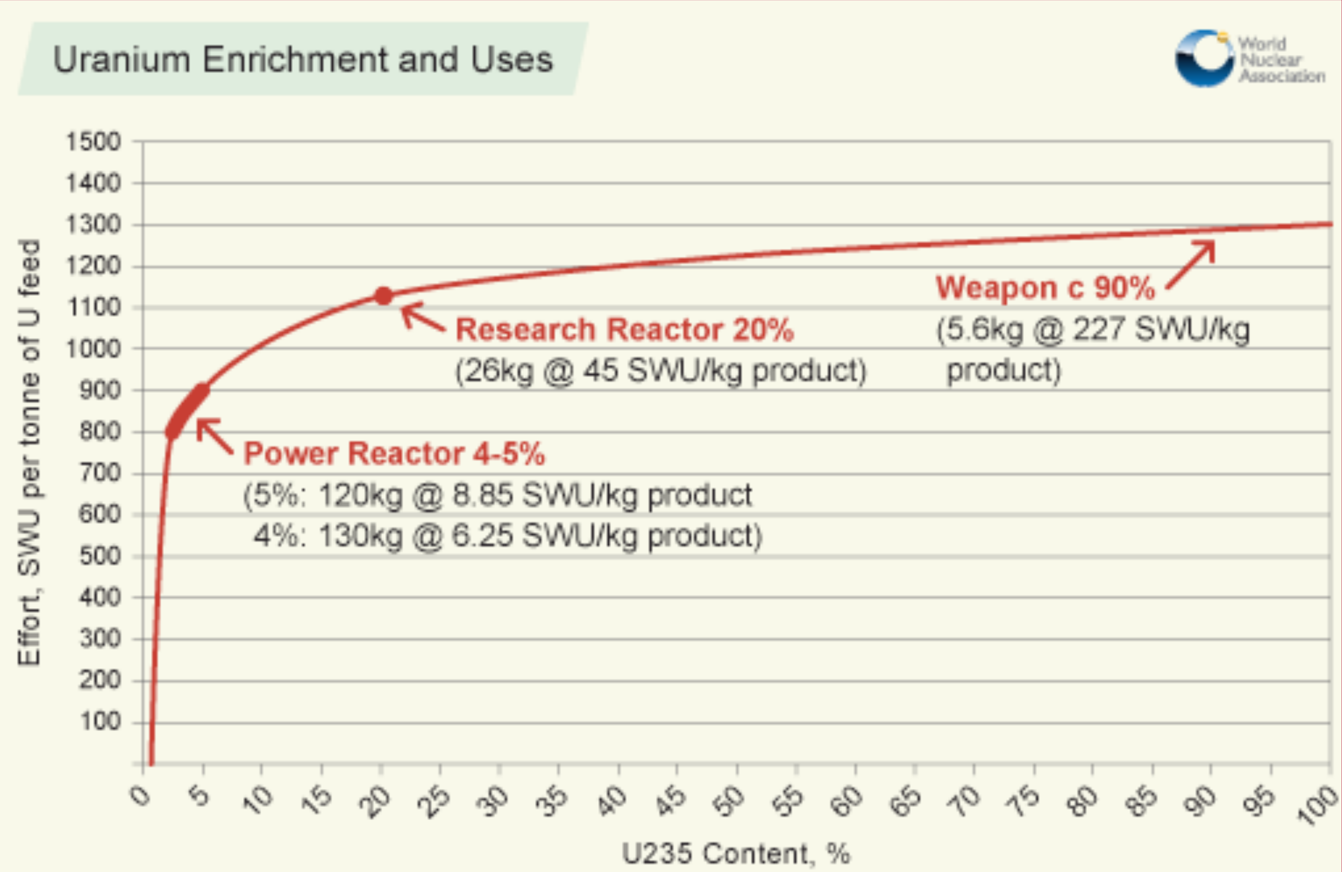
Moving from Reactor- to Weapons-grade Uranium



Note: In terms of the Separative Work Unit (SWU), a measure of energy used in the enrichment of U-235, the number of SWUs required per tonne of feed material (natural uranium) increases in relatively smaller increments as the desired level of enrichment rises.

uranium to 20 percent (ostensibly to fuel the Tehran Research Reactor for the production of medical isotopes), and its growing capacity to produce weapons-grade uranium should it decide to do so. When proliferation analysts speak of Iran's "breakout" potential, they are referring to the capacity to convert LEU to weapons-grade levels.

At the *back end* of the fuel cycle—relating to storage, reprocessing, and disposal—spent nuclear fuel is removed from the reactor and generally stored as waste. A small number of countries (for example, France and Japan) reprocess spent fuel to separate out plutonium for reuse in reactors. But plutonium can also be diverted directly to manufacture nuclear weapons. This is the pathway that North Korea pursued to produce the nuclear devices it is believed to possess. Syria appeared to be proceeding down this path as well; the nearly completed (but undeclared) nuclear reactor at al-Kibar, destroyed by Israeli air forces in September 2007, was closely modeled on North Korea's plutonium production reactor at Yongbyon.[2]

Nonproliferation Regime

The dual-use nature of the nuclear fuel cycle therefore poses an inherent proliferation risk and an ongoing challenge for global nonproliferation efforts. The proliferation risks of nuclear energy have been widely recognized since the nuclear age began nearly 70 years ago. Early efforts to stem nuclear weapons proliferation culminated in the 1968 NPT, which enshrines a set of basic bargains. Nonnuclear weapon states permanently forswear the pursuit of nuclear weapons and are assured the "inalienable right" to access nuclear energy for peaceful purposes. Nuclear weapon states, in turn, agree to work "in good faith" toward eliminating their nuclear weapons and may not transfer or in any way assist nonnuclear weapon states in developing such weapons.

The International Atomic Energy Agency (IAEA) establishes and administers a system of safeguards and inspections to verify that nonnuclear weapon states do not divert nuclear material to the manufacture of nuclear weapons. Additionally, the Nuclear Suppliers Group (NSG), established in 1975—a year after India exploded its first nuclear device—encourages restraint in the transfer of ENR technologies through a series of voluntary guidelines that govern nuclear exports. These guidelines are intended to ensure that states not part of the nonproliferation regime, or not fully compliant with their NPT obligations, do not engage in nuclear commerce that could advance a weapons program.

The vast majority of states that are party to the NPT are fully compliant with their obligations. However, the last two decades have revealed serious weaknesses and gaps in the nonproliferation regime that have allowed illicit nuclear programs to advance, facilitated the spread of material, technology, and expertise used in nuclear weapons, and eroded confidence in the NPT. The cases of North Korea and Iran, and the revelations surrounding the global nuclear black market created by the Pakistani metallurgist A.Q. Khan, exemplify this challenge and have led to a variety of efforts to strengthen the nonproliferation regime. Continued efforts to control, limit, or even end the further spread of ENR technologies thus remain critical to ensuring that future nuclear aspirants cannot use the guise of a legitimate civilian nuclear program to pursue a weapons capability. In essence, the goal is to prevent the "next Iran."

Nuclear Renaissance?

Lending added urgency to nonproliferation efforts is the possibility that nuclear power will expand significantly across the world as more governments seek to address increasing energy demands, rising oil and natural gas prices, and growing pressure to reduce greenhouse gas emissions. Some observers have called for a civilian nuclear "renaissance" to create new or wider markets, particularly in Asia and the Middle East. According to the World Nuclear Association, nuclear power is under serious consideration in more than 45 countries that do not currently possess it.[3] If these states follow through with their plans, nuclear energy capacity could double or triple by 2030.[4]

Experts debate two issues: whether this renaissance will actually occur on a significant scale, and the degree of proliferation risk it would pose. Although the use of the term renaissance almost certainly overstates what is likely to occur in the next couple of decades, there is no doubt that nuclear power will expand worldwide. Nuclear power is expected to expand significantly in some states, such as China and India, more modestly in other countries with established nuclear power programs, and it is likely that at least a few additional states will embark on new programs. Despite the significant interest expressed by many governments in expanding or adopting nuclear power, it is difficult to predict how many will actually proceed down this path. Civilian nuclear power infrastructures entail complex, large-scale projects shaped by political and other factors.[5] Economic and financial constraints, as well as new concerns about safety and public confidence following the Fukushima crisis in Japan, could limit the extent of a nuclear energy revival. In the aftermath of Fukushima, some governments, particularly in regions that are seismically active and prone to tsunamis, have cancelled their plans to pursue nuclear power. Some countries are deferring their plans, while others have vowed to stay on track.[6]

What are the proliferation risks if nuclear power expands significantly, including expansion to many new states? Some experts argue that it makes more sense for proliferators to pursue dedicated nuclear weapons programs than to divert material, technology, and expertise from a civilian program. In this view, the risks posed by the revival of nuclear energy are limited, at least in the near term. Over time, however, this judgment could change if nuclear power expansion leads to the emergence of a new group of states capable of providing fuel services and equipment. Only a small number of advanced countries provide such services today.

Other experts are less sanguine, arguing that it will be difficult, if not impossible, to prevent ENR technologies from spreading if nuclear power expands. In this view, despite the risks and costs, many governments opting for nuclear power will choose to construct indigenous ENR infrastructures, if only for reasons of independence and prestige. While most states that do so are likely to use these capabilities responsibly and strictly for peaceful purposes, some states may also view these capabilities as providing a security hedge. Should one or more of these governments make a strategic decision to pursue a nuclear weapons capability, key building blocks will be in place. The IAEA is working to transform its safeguards system to meet the challenges of proliferation and growth in nuclear power, but the agency is limited in its ability to detect undeclared nuclear activities in a timely way, particulary since there is not yet universal adherence by NPT member states to the IAEA Additional Protocol, which grants the agency expanded inspection rights.

Some states have pledged to accept ENR services from others and forsworn indigenous acquisition of such technologies (for example, the United Arab Emirates). Other governments (for example, Egypt, Turkey, Saudi Arabia, and Brazil) have refused to make such a pledge, insisting instead on keeping open all their fuel cycle options as part of their rights under Article IV of the NPT. While welcome, voluntary restraints can be reversed and thus seem unlikely to provide more than a token degree of risk mitigation as nuclear power expands. As a result, a number of proposals have emerged to help limit the further spread of these capabilities as a more decisive way to manage future proliferation risks.

Managing the Nuclear Fuel Cycle

In 2004, President George W. Bush called on members of the NSG to deny the sale of ENR technologies to states that do not already possess them, including nonnuclear weapon state parties to the NPT.[7] President Bush asked these states, in turn, to renounce ENR technologies in exchange for reliable, assured access to nuclear fuel at a reasonable price. These proposals were controversial and widely opposed by nonnuclear weapon states that argued they were being asked to limit or forfeit a basic NPT right when nuclear weapon states had not made sufficient progress in meeting their own NPT obligation to work toward disarmament. Some nonnuclear weapon states argued that these proposals would therefore deepen the divide between nuclear haves and have-nots. Many nonnuclear weapon states also questioned the reliability of any mechanisms established to provide fuel services. The Bush proposal was a nonstarter in the NSG, but after several years of deliberation, the NSG agreed in July 2011 to tighten the rules governing the transfer of ENR technologies, establishing a number of specific conditions and criteria that recipients must meet to obtain ENR items.[8]

A number of other proposals have offered more specific and concrete approaches to the third party provision of fuel services. These proposals focus on establishing international or multilateral mechanisms to guarantee the supply of fuel, provide enrichment services, and establish fuel reserves. Some of the more prominent proposals over the past decade include the following:[9]

ElBaradei Proposal. In 2003, then-IAEA Director General Mohamed ElBaradei, noting that "the margin of security under the current non-proliferation regime is becoming too slim for comfort," proposed to restrict ENR technologies exclusively to facilities under multinational control, and to develop multinational approaches to manage and dispose of spent fuel and radioactive waste.[10] A 2005 Experts Group commissioned by ElBaradei to explore this concept proposed reinforcing existing market mechanisms by providing additional guarantees by nuclear suppliers or through an IAEA fuel bank, converting existing facilities to multinational facilities, and creating co-managed, jointly-owned facilities.[11]

Global Nuclear Power Infrastructure. In January 2006, Russian President Vladimir Putin proposed the creation of a "Global Nuclear Power Infrastructure" comprising international centers for enriching uranium, reprocessing and storing spent fuel, training personnel, and researching more proliferation-resistant nuclear technologies.[12] In 2007, Russia further proposed the establishment of an International Uranium Enrichment Center (IUEC) and a LEU fuel reserve at Angarsk under IAEA auspices. In November 2009, the IAEA Board of Governors approved the

Russian proposal to establish the Angarsk fuel reserve. The guaranteed LEU reserve has been available for use by IAEA member states since February 2011.

Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel (Six-Country Concept). In June 2006, France, Germany, the Netherlands, Russia, the United Kingdom, and the United States proposed a "Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel."[13] The so-called "Six-Country Concept" would allow the IAEA to facilitate the provision of alternative sources of LEU to states when a commercial supply relationship is interrupted. Only states not possessing ENR technologies would be eligible, and these states would have to meet a number of criteria regarding their nonproliferation obligations and their safety and physical protection standards.

Multilateral Enrichment Sanctuary Project. In May 2007, Germany proposed the construction of a new enrichment facility at an "extraterritorial" location, to be owned by the IAEA and managed by an independent board.[14] The plant would operate on a commercial basis but the IAEA would decide whether to supply LEU to recipients based on nonproliferation criteria. This concept, known as the "Multilateral Enrichment Sanctuary Project," is being considered by the IAEA Board of Governors.

International Framework for Nuclear Energy Cooperation. The International Framework for Nuclear Energy Cooperation (IFNEC), established by the U.S. Department of Energy in 2010, has its roots in the earlier Global Nuclear Energy Partnership (GNEP), which was created in 2006 to explore advanced fuel cycle concepts that would allow for commercial reprocessing of spent nuclear fuel with reduced proliferation risks. The IFNEC program continues the international forum established by GNEP that facilitates exploration among partner countries of alternative fuel cycle concepts.

IAEA LEU Fuel Bank. In December 2010, the IAEA Board of Governors approved the establishment of an IAEA-owned and -managed LEU fuel bank, using as seed money a $50 million pledge by the U.S.-based Nuclear Threat Initiative. Countries requesting access to LEU from the bank must meet eligibility criteria consistent with the IAEA Statute and approved in advance by the IAEA Board. In 2009, Kazakhstan informed the IAEA that it would be willing to host the fuel bank on its territory, but an agreement has yet to be finalized.

These and other concepts for multilateralizing the nuclear fuel cycle differ considerably in their objectives, scope, and timeframe required for implementation, but all recognize the need to implement any multilateral mechanism incrementally and without interrupting the international market for fuel cycle services.[15] They tend, as well, to focus on the front end of the fuel cycle. Currently, responsibility for spent fuel disposal and storage lies solely with the state concerned. More than 50 countries store their spent reactor fuel in onsite storage pools and some reprocess spent fuel rods into mixed oxide fuel for further electricity generation.[16] Viable multilateral concepts to manage spent fuel disposal services and interim storage could help limit the further spread of reprocessing technologies, but significant political, technical, and financial hurdles exist, including but not limited to achieving agreement to establish a shared multinational repository for radioactive waste.

While there have been no proposals for multilateral reprocessing facilities, there are a number of concepts for developing new reactor technologies that are claimed to be "proliferation resistant." Experts differ on just how proliferation-resistant technologies are likely to be and when in the future they might become available on a commercially viable basis. By almost all accounts, this will not occur anytime soon. Should proliferation-resistant technologies emerge over time as credible alternatives to current fuel cycle technologies, this could provide a way to reduce proliferation risks without limiting the access of nonnuclear weapon states to nuclear power technology.

In the Action Plan adopted at the 2010 NPT Review Conference, the NPT state parties agreed to:

> *Continue to discuss further, in a non-discriminatory and transparent manner under the auspices of IAEA or regional forums, the development of multilateral approaches to the nuclear fuel cycle, including the possibilities of creating mechanisms for assurance of nuclear fuel supply, as well as possible schemes dealing with*

the back-end of the fuel cycle without affecting rights under the Treaty and without prejudice to national fuel cycle policies, while tackling the technical, legal and economic complexities surrounding these issues, including, in this regard, the requirement of IAEA full scope safeguards.[17]

To date, proposals to multilateralize the fuel cycle have originated from states that already possess ENR technologies and that see further limitations on the availability of these technologies as key to managing proliferation risks moving forward. This is precisely why current multilateral proposals tend to be viewed as discriminatory by states not in possession of sensitive nuclear technologies. The challenge is to make fuel cycle alternatives both economically attractive and politically palatable.

Notes

[1] Although sophisticated weapon designs require weapons-grade uranium or plutonium, a crude or improvised nuclear device can be constructed using high enriched uranium or reactor-grade plutonium. See Charles D. Ferguson and William C. Potter, *Improvised Nuclear Devices and Nuclear Terrorism*, No. 2 (Stockholm, Sweden: The Weapons of Mass Destruction Commission, n.d.), available at <www.un.org/disarmament/education/wmd-commission/files/No2.pdf>.

[2] The Syrian reactor under construction was undeclared; that is, it was never reported to the International Atomic Energy Agency (IAEA).

[3] World Nuclear Association, "Emerging Nuclear Energy Countries," February 2012, available at <www.world-nuclear.org/info/inf102.html>.

[4] Currently, 30 countries operate more than 440 commercial nuclear power plants that supply about 14 percent of the world's electricity.

[5] Sharon Squassoni, *Nuclear Energy: Rebirth or Resuscitation?* (Washington, DC: Carnegie Endowment for International Peace, March 2009). For additional perspectives on the prospects for nuclear energy growth, see Charles D. Ferguson, "Potential Strategic Consequences of the Nuclear Energy Revival," Proliferation Papers, No. 35, Summer 2010; IAEA, "International Status and Prospects of Nuclear Power: Report by the Director General," September 2, 2010; and Mary Beth Nikitin et al., *Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear Power*, RL34234 (Washington, DC: Congressional Research Service, March 2, 2011).

[6] See James M. Acton et al., "After Fukushima: Early Implications for Nuclear Industry and Policy Makers," A Statement from the Carnegie Nuclear Policy Program, Carnegie Endowment for International Peace, March 15, 2011; Mark Hibbs, "After the Shock—Implications of the Japanese Nuclear Crisis," *Jane's Intelligence Review*, May 9, 2011; and Sharon Squassoni, "Nuclear Governance After Fukushima," in *Global Forecast 2011: International Security in a Time of Uncertainty*, ed. Craig Cohen and Josiane Gabel (Washington, DC: Center for Strategic and International Studies, 2011).

[7] "President Announces New Measures to Counter the Threat of WMD," Remarks by the President on Weapons of Mass Destruction Proliferation, Fort Lesley J. McNair, National Defense University, Washington, DC, February 11, 2004, available at <http://georgewbush-whitehouse.archives.gov/news/releases/2004/02/20040211-4.html>.

[8] IAEA, "Communication Received from the Permanent Mission of the Netherlands Regarding Certain Member States' Guidelines for the Export of Nuclear Material, Equipment and Technology," Information Circular/254/Rev.10/Part 1a, July 26, 2011, available at <www.iaea.org/Publications/Documents/Infcircs/2011/infcirc254r10p1.pdf>.

[9] For a more detailed discussion of multilateral proposals, see Yury Yudin, *Multilateralization of the Nuclear Fuel Cycle: Assessing the Existing Proposals* (Geneva, Switzerland: United Nations Institute for Disarmament Research, 2009); Tariq Rauf and Zoryana Vovchok, "Fuel for Thought," *IAEA Bulletin* 49, no. 2 (March 2008); Nikitin, et al.; and Fred McGoldrick et al., *Limiting Transfers of Enrichment and Reprocessing Technology: Issues, Constraints, Options* (Cambridge, MA: Belfer Center for Science and International Affairs, Harvard Kennedy School, May 2011).

[10] Mohamed ElBaradei, "Towards a Safer World," *The Economist*, October 16, 2003, available at <www.economist.com/node/2137602>.

[11] *Multinational Approaches to the Nuclear Fuel Cycle: Expert Group Report to the Director General of the IAEA* (Washington, DC: IAEA, February 22, 2005), available at <www-pub.iaea.org/MTCD/publications/PDF/mna-2005_web.pdf>.

[12] IAEA, "Communication Received from the Resident Representative of the Russian Federation to the IAEA on the Establishment, Structure and Operation of the International Uranium Enrichment Centre," Information Circular/708, June 8, 2007, available at <www.iaea.org/Publications/Documents/Infcircs/2007/infcirc708.pdf>.

[13] IAEA, "Communication Dated 31 May 2006 Received from the Permanent Missions of France, Germany, the Netherlands, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland and the United States of America," GOV/INF/2006/10, June 1, 2006, available at <www.state.gov/documents/organization/98987.pdf>.

[14] IAEA, "Communication Received from the Resident Representative of Germany to the IAEA with Regard to the German Proposal on the Multilateralization of the Nuclear Fuel Cycle," Information Circular/704, May 4, 2007, available at <www.iaea.org/Publications/Documents/Infcircs/2007/infcirc704.pdf>, and expanded upon in Information Circular/727 and Information Circular/735.

[15] Yudin, 51.

[16] The United States has not adopted mixed oxide fuel for commercial purposes, but is constructing a facility to produce this fuel as a way to dispose of excess weapons-usable plutonium.

[17] United Nations, *2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Final Document,* Volume I, NPT/CONF.2010/50 (Vol I.) (New York: United Nations, 2010), available at <www.un.org/ga/search/view_doc.asp?symbol=NPT/CONF.2010/50 (VOL.I)>.

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