EXPANDED AND ACCELERATED HEU DOWNBLENDING: DESIGNING OPTIONS TO SERVE THE INTERESTS OF ALL PARTIES

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ABSTRACT

Accelerating and expanding the downblending of highly enriched uranium (HEU) beyond the current 500-ton U.S.-Russian HEU Purchase Agreement would have significant security benefits. Russia will still have large quantities of HEU not needed for military purposes after 500 tons of HEU has been blended to low-enriched uranium (LEU). But no agreement to expand and accelerate the downblending of Russian or U.S. excess HEU will succeed unless it is structured in a way that serves the interests of all sides. Russia has made clear that it has no interest in extending the HEU Purchase Agreement on its current terms. This paper outlines key Russian, U.S., and industry interests relating to expanded and accelerated HEU downblending. It then explores a variety of approaches under which accelerating and expanding the downblending of HEU could serve Russia's strategic goals of expanded nuclear construction for domestic use and export, and expanded nuclear fuel market share, while providing billions of dollars in additional revenue. Some of these approaches could also be structured to protect U.S. interests in maintaining a robust domestic enrichment industry, and industry interests in maintaining predictable supplies at prices sufficient to maintain investment in long-term capacity for uranium mining and enrichment. Despite the recent U.S.-Russian accord on amending the suspension agreement, offering Russia extensive access to the U.S. market without any linkage to blending additional HEU, there are still some options for the U.S. government to increase Russia's incentives to blend down additional HEU.

INTRODUCTION[1]

Russia is likely to have hundreds of tons of highly enriched uranium (HEU) not needed for plausible military purposes after the current 500-ton HEU Purchase Agreement is completed in 2013. Accelerating and expanding the downblending of this excess HEU would have significant security benefits. Russia has made clear, however, that it will not extend the HEU Purchase Agreement on its current terms. What set of incentives might convince Russia that it was in its national interest to blend hundreds of tons of additional HEU to low-enriched uranium (LEU), while protecting the interests of other key stakeholders?

THE CURRENT DEAL AND THE PROJECTED MARKET

Currently, Russia produces 1.5% enriched blendstock for the HEU deal by stripping tails, using almost as many separative work units (SWU) each year as are contained in the LEU delivered to the United States. Since Russia must also carry out a number of other processes to transform HEU weapons components to deliverable LEU, it costs Russia more to make LEU by blending HEU using this approach than it would to produce new LEU from scratch. Moreover, with Russia limited to selling only through USEC (formerly the U.S. Enrichment Corporation), USEC succeeded in negotiating below-market prices, so Russia receives less revenue than it would for commercial sales as well. Hence Russia has no incentive to continue the existing deal beyond the 500 tons already agreed.

But the current deal provides nearly half of the LEU required in the U.S. market. To partly replace this supply when the HEU deal ends in 2013, Russia and the United States have agreed on an amendment to the U.S.-Russian suspension agreement that would, in effect, allow Russia to compete for 20% of the U.S. market from 2014 to 2020, with all restraints removed thereafter. This agreement is designed to provide adequate supply while making it possible for the firms planning investments in new enrichment plants in the United States – now including Louisiana Energy Services, USEC, Areva, and GE-Hitachi – to plan and raise funds. Recent U.S. court decisions that determined that enrichment is a service, not a good, and hence not

subject to U.S. anti-dumping laws, could open the U.S. market to unrestricted Russian exports, if not reversed by the U.S. Supreme Court or by further legislation.[2]

Clearly, the possibility of large additional supplies of LEU from HEU could have a major impact on uranium (U) and SWU markets. Unexpectedly releasing large quantities of LEU from HEU could crash prices and disrupt much-needed investments in uranium mining and enrichment capacity. But U mine output is still far below annual consumption and there are long time-lines to expand production to meet demand. Utilities would love to purchase more SWU than are currently available, to save on expensive uranium by driving down tails assays. In short, if handled appropriately, LEU from large additional quantities of HEU could play a key role in fueling nuclear growth while mining and enrichment capacity expand – without unduly competing with existing suppliers.

THE INTERESTS OF KEY PARTIES

No agreement to expand and accelerate the downblending of Russian or U.S. excess HEU will succeed unless it is structured in a way that serves the interests of all sides. What are the key interests that must be addressed?

The Russian nuclear industry today is growing and well-financed, not desperate for cash as it was in 1992 when the HEU Purchase Agreement was first agreed. Moreover, the amount of HEU remaining is smaller and U.S.-Russian strategic relations are worse than was the case in 1992. Today, Russia's top priorities related to considering options for expanded and accelerated downblending of HEU are: (a) maintaining sufficient stocks of HEU for remaining military needs; (b) ensuring sufficient fuel for Russia's strategic initiatives to expand nuclear reactor construction at home and abroad; (c) establishing a major international presence as a reactor and fuel vendor, including maximizing the international competitiveness of Russian nuclear reactor exports and fuel leasing services; (d) gaining equal footing in international fuel markets, including expanded and stable access to U.S., European, and Asian enrichment and uranium markets on profitable terms; (e) maximizing the potential value available from HEU; (f) building long-term U.S.-Russian partnership in nuclear energy development; (g) maintaining employment for key nuclear workers and facilities; and (h) avoiding domestic political confrontations over selling off "Russia's patrimony." Reducing the proliferation dangers and arms reduction obstacles posed by large HEU stockpiles, and the costs of storing these stockpiles, are presumably also objectives Russia shares, though they have not been strongly articulated in Russia's HEU policymaking. Of these interests, supporting Russia's major strategic initiatives in nuclear energy is likely to be more important to Russia's approach to HEU downblending than modest quantities of additional profit to be made.

Russia sees its HEU stockpile as a national patrimony, bought at the price of years of blood and toil. The default Russian view is likely to be to say "nyet" to large-scale additional HEU downblending beyond the 500 tons covered by the original HEU purchase agreement. The key, therefore, is to explore whether there exists a set of circumstances under which expanding and accelerating the downblending of HEU could be so strongly in Russia's national interests that the Russian political establishment is convinced that it should go this route. What set of incentives could turn "nyet" into "da"?

U.S. government interests related to expanding and accelerating the downblending of Russian HEU include:; (a) achieving the nonproliferation and arms reduction benefits of reducing HEU stockpiles as quickly as possible; (b) maintaining a viable domestic enrichment industry (an objective mandated by U.S. law); (c) ensuring an adequate and reliable fuel supply for a growing U.S. nuclear energy enterprise, including avoiding undue dependence on only one source and avoiding price crashes that would undermine needed investments; (d) minimizing cost to the U.S. government; and (e) to the extent consistent with the above objectives, reducing fuel costs to U.S. nuclear utilities. Of course, the United States, like Russia, seeks to maintain enough of its own HEU for both nuclear weapons and naval fuel.

U.S. industry interests are to some extent split between fuel consumers and producers, though all have a strong interest in stable, predictable markets. U.S. utilities want assured supplies of fuel in both the near term and the long term, at reasonable and stable prices. But with multi-billion dollar investments in nuclear reactors, making sure the fuel will be there is more important than its price. Release of additional

material blended from Russian HEU would be strongly in the interests of U.S. nuclear utilities – especially if handled in a way that avoided scaring off the investments needed to provide long-term uranium, enrichment, and conversion supply. U.S. uranium producers, enrichers, and converters want stable and high prices for their products and services, and predictable limits on the entry of additional foreign material into the U.S. market, which represents a threat to their market share and may drive down prices. Predictability – so that investors can make decisions with confidence on projects that may not pay off for a decade or more – is more important than absolute price, though perceptions of price trends (in particular, not creating perceptions that prices were likely to fall substantially) are important for maintaining the investment needed to bring annual production into balance with annual demand.

While there are many specific variations from one country to another, in general, the interests of European and Asian governments and their nuclear industries are similar to those for the U.S. government and industry, described above.

With appropriate mechanisms for making the release of LEU from HEU predictable and limiting any market damage it might otherwise cause, it should be possible to structure an approach that protects the interests of all parties. Approaches that could be considered include relying on existing economic incentives for Russia to make commercial use of its HEU; providing additional positive incentives for Russia to blend more HEU; threatening negative consequences (such as constraints on market access) if Russia does *not* blend more HEU; launching new partnership-based initiatives that include blending more HEU; and combinations of these approaches. Important criteria to consider for each option include: (a) probability of Russian acceptance; (b) degree to which U.S. and other industry interests are protected; (c) the scale and pace of HEU downblending that might be achieved; and (d) cost to the U.S. government or other governments of encouraging Russia to blend additional HEU to LEU.

EXISTING INCENTIVES – WITH A DIFFERENT APPROACH

From the point of view of international security, once HEU has been blended to LEU, it does not matter if that LEU is shipped to the United States or elsewhere, used in Russia, or simply stored. If, rather than shipping the LEU blended from HEU for sale and fabrication in the United States, Russia fabricated fuel from this LEU at its own fabrication facilities to fuel Russian reactors or Russian-exported reactors, it would not have to meet ASTM specifications, and it could blend the HEU with natural uranium or even with tails – saving over 5 million SWU for every 30 tons of HEU blended.

If blended with 0.2% ^{235}U tails, a ton of 90% enriched HEU would produce 21 tons of 4.5% enriched LEU. Blending 300 tons of HEU in this manner would be the equivalent of both a virtual uranium mine producing 6,400 tons per year for 10 years and a virtual enrichment plant producing 3.9 million SWU per year for 10 years.[3] Of course, there is no requirement that the blending to LEU and commercial release on the market have to occur at the same rates: it might well turn out to serve Russia's interests better to meter the material onto the market more slowly, even if the blending occurred rapidly. (And it might serve U.S. and international interests to give Russia incentives to blend the HEU to LEU rapidly, but to carefully regulate the release of the blended LEU onto the commercial market.)

This amount of material would be enough to provide key support for Russia's strategic initiatives for growing domestic nuclear construction and nuclear exports. Russia is clearly concerned over getting sufficient uranium supplies to fuel its plans, and has been actively negotiating uranium deals not only with former Soviet countries but with major suppliers such as Australia and Canada as well. LEU blended from HEU could take the pressure off; combined with new production, there would be enough material to ensure that there were no uranium or SWU constraints on Russian nuclear energy growth or nuclear export growth for decades to come. (Indeed, as discussed below, there may be an opportunity for a joint U.S.-Russian initiative on nuclear energy and disarmament, focused on providing LEU from HEU for the initial cores of all U.S.-built or Russian-built reactors.)

Moreover, Russia could generate immense revenues from this material. Every ton of LEU blended from HEU used to fuel Russian-designed reactors would free up an additional ton of new-production LEU for export. If that freed-up LEU were sold at current long-term market prices of around $230 per kilogram of

uranium and $150 per SWU, the LEU made from each ton of HEU would be worth over $72 million. Blending 300 tons of HEU in this way would produce LEU worth some $22 billion.[4] The only thing Russia would need from other countries is enough market access to sell this uranium and SWU at market prices; this will require careful planning and market mitigation measures to avoid undermining the predictable prices necessary for investments in sustainable production capacity. But reactor operators will certainly be eager to buy such additional amounts of U and SWU in the 2013-2030 timeframe, and it should be possible to work out arrangements that make this possible without undermining the commercial prospects of Western producers.

LEU blended from HEU could support Russia's strategic objectives as a nuclear reactor and fuel exporter in other ways as well. In seeking export sales of reactors, Russia could offer a guarantee of lifetime fuel supply, with the assurance made especially credible by being backed up by a large LEU reserve made from blended HEU. This increased fuel assurance, plus the disarmament aspect of using up HEU, could make these reactors more attractive in relation to their competitors. Making LEU from HEU might be a particularly attractive approach for reactors that use LEU fuel with enrichment in the 8-19% range, where making material from HEU would greatly reduce enrichment costs; these include South Africa's planned pebble-bed reactors, future Russian floating reactors, the gas-turbine modular helium reactor (GT-MHR) being jointly developed by the United States and Russia, future small "nuclear battery" reactors, and others. LEU from HEU could supplement the fuel reserve at the Angarsk International Enrichment Center and could make participation in the Center more attractive for some countries, because of the link to disarmament; offering LEU from HEU could have a similar effect for Russia's hoped-for fuel leasing business.

Overall, there appear already to be significant incentives for Russia to blend down additional HEU. If Russia came to perceive additional downblending of HEU as an important means to support its strategic objective in nuclear energy, it might well choose to pursue such expanded blending. Approaches focused on using this material for initial cores of new reactors and metering it into existing long-term contracts at a predictable pace could reduce undesirable market impacts and protect the interests of foreign nuclear industries. Since Russia has not yet indicated any intention to blend down large additional quantities of HEU to LEU, additional incentives may be necessary to achieve such large-scale downblending – especially if the security objectives of downblending are to be achieved at a pace faster than Russia might require the material for its commercial purposes.

PROVIDING NEW INCENTIVES FOR EXPANDED DOWNBLENDING

A wide variety of options for the United States or other governments to offer additional incentives to help convince Russia to blend additional HEU to LEU. Incentives that could be offered include: additional market access; payments of cash premiums for purchases of LEU made from HEU; paying Russia's costs to blend HEU to a 19% intermediate level, as a security investment; offering to transfer rich tails to Russia that it could strip to produce additional LEU (or to reduce the blendstock costs of blending HEU for export to the United States); and agreeing to engage in new joint nuclear energy initiatives with Russia. Existing HEU transparency arrangements could be used to confirm that Russia had done whatever additional blending was agreed to.

Expanded market access. The recently amended Suspension Agreement effectively allows Russia to compete for 20% of the U.S. LEU market from 2014-2020 and 100% thereafter, without any linkage to additional blending of HEU. Russia is likely to resist any effort that would reduce the market access already agreed, reducing the options related to market access that are now available. Nevertheless, plausible market-access options include:

- **Access beyond the suspension agreement.** Congress could consider passing legislation that would offer Russia expanded access to the U.S. market if Russia agreed to blend additional HEU. Senator Pete Domenici, for example, has proposed legislation (discussed in more detail below) that would allow Russia to compete for 25%, rather than 20%, of the U.S. market if Russia continued to blend 30 tons a year of HEU after the existing HEU Purchase Agreement was complete (and would allow the LEU to be used in Russia rather than shipped to the United States, opening the opportunities for support for Russian

strategic initiatives and large revenues discussed above). At this writing (June 2008), this legislation has been attached to the Senate version of the supplemental appropriations bill. Discussions surrounding the Domenici legislation, however, suggest that those investing in new enrichment plants in the United States will strongly resist offering Russia the opportunity to compete for more than 25% of the U.S. market.

- **Access for SWU used to go to lower tails assays.** The United States could allow Russia to sell additional SWU in the U.S. market, linked to additional downblending of HEU, if those SWU were used to produce the same amount of LEU with lower tails assays. (Going from 0.3% tails to 0.2% tails can increase SWU requirements by 23%, potentially adding more than two million SWU per year to U.S. market demand.) This would not injure other SWU suppliers, and would modestly improve the uranium shortage situation.
- **Access for additional SWU sold to the firms establishing U.S. enrichment plants.** The firms establishing new enrichment plants in the United States may suffer delays in building these facilities (as many past plants have); having access to SWU under their control that could allow them to limit their financial risk by fulfilling their enrichment contracts even if the plants do not begin operating on time could serve their financial interests. The United States could agree to allow Russia to sell SWU going beyond the levels in the suspension agreement if Russia blended additional HEU to LEU and if the additional SWU coming into the United States were sold to any of these firms, allowing them to build up reserve stocks. Since there are several such companies (USEC, LES, Areva, and GE-Hitachi), they would compete with each other for whatever SWU Russia wanted to sell and they wanted to buy, helping to ensure that Russia would get a fair price.

European and Asian governments could also consider linking expanded access to their markets to Russian agreement to expand HEU downblending – such as by counting LEU blended from HEU as a separate supply that did not count against the limit on supply from any one supplier.

A premium on SWU purchases. Another approach would be for the U.S. government (or another government) to simply pay Russia a premium over the market SWU price for additional downblending, saying, in effect, "for every SWU that you can demonstrate comes from HEU or is matched by a SWU in LEU that comes from HEU, we will pay you an additional $10 on top of the commercial price." At a blending rate of 30 tons per year, that would bring Russia $40-$50 million/year (depending on blending strategy), which would increase proportionally at a 42.5 tons/year blending rate. An obvious problem with this approach is that payments big enough to be a substantial incentive to Russia may be big enough to be difficult to get governments to appropriate.

Payment for blending to 19%. Another option would be for the United States (or another government) to pay Russia a fee for blending an agreed amount of HEU to an intermediate level of 19% enriched LEU, which could then be stored until market conditions were right for Russia to use it (the timing and rate of commercial release possibly being limited by an agreement). Once HEU had been blended to 19%, Russia could draw on this stock for further blending to commercial levels as needed to meet its LEU contracts, thereby producing each kilogram of LEU with far fewer SWU and less U than would be required to produce it by enriching natural uranium. Indeed, the initial blending to 19% could be done with natural uranium (at the cost of needing 1.62% enriched blendstock for the final blending, if the LEU was to be sold in a way that required meeting 1996 ASTM specifications); this would eliminate the need for enrichment for the initial blending, by far the most expensive and time-consuming element of the accelerated downblending scenarios.[5] The size of the payment would, of course, be a matter for negotiation; it might well cover the full cost of blending to 19%, plus some profit for Russia (though, with the initial processing paid for, Russia would in any case make more profit from each kilogram of commercial LEU produced than it would if it had to cover the full cost of processing and blending, as it would in the existing incentives options above). Alternatively, once the material had been blended to 19%, it could be shipped to the United States for final blending and sale.

Providing rich tails for blending or stripping. The United States could agree to send a small portion of its comparatively "rich" depleted uranium tails to Russia if Russia agreed to blend down a

specified additional amount of HEU. As discussed in other papers at this session, making blendstock for deliveries that must meet ASTM specifications by stripping tails with 0.3% ^{235}U would require far fewer SWU than producing blendstock from 0.18% ^{235}U tails. While many parties would like access to the uranium contained in these tails for direct enrichment to LEU, allocating some portion of the rich U.S. tails specifically to HEU downblending would provide an additional nonproliferation benefit. Blending the 150 remaining tons under the existing HEU Purchase Agreement in this way would require less than 39,000 tons of the roughly 500,000 tons of tails in the U.S. stockpile (of which approximately one-third has a ^{235}U content of 0.3% or higher), and would free up more than a $1 billion worth of SWU, a higher value-added use for the material than any available in the United States (even without considering the national security benefits of blending additional HEU).[6]

NEW U.S.-RUSSIAN INITIATIVES INCLUDING EXPANDED HEU DOWNBLENDING

Several options are available which would make expanded HEU downblending one part of new joint U.S.-Russian initiatives on nuclear energy and nuclear arms reductions.

Linking to an expanded U.S.-Russian nuclear energy partnership. The United States and Russia are pursuing a range of cooperation on civilian nuclear energy. But there are a number of more ambitious types of U.S.-Russian nuclear energy partnership that could be pursued. The United States could seek to tie certain aspects of such a partnership to Russian agreement to blend substantial additional amounts of HEU.

In the early 1990s, in fact, then-Minister of Atomic Energy Victor Mikhailov proposed that the way HEU downblending should be managed was with a U.S.-Russian joint venture that would market the resulting LEU and share in the profit. Such an arrangement may be less attractive to Russia today, now that Russia's nuclear infrastructure is on a sound economic footing and already has access to world markets without U.S. help. But there are a variety of potential advantages that might be gained from a broader partnership in which U.S. and Russian firms would jointly develop and market reactors, fuel, or both. For example, Rosatom and U.S.-based firms might agree to approaches that would blend the best U.S. technologies (such as advanced reactor control systems) and the best Russian technologies into next-generation reactors for export. Such reactors might be fueled with fuel blended from HEU, under fuel-leasing arrangements in which portions of the fuel would be made in the United States and portions in Russia, and the spent fuel shipped to Russia (if the United States proved politically unable to accept spent fuel returns). The United States and Russia might agree to use LEU blended from HEU to fuel advanced reactor types that the two sides might jointly develop (such as the GT-MHR, under joint development now, and small encapsulated reactors, as discussed above). As in purely Russian systems, use of blended HEU could make such systems more attractive to potential purchasers.

A new U.S.-Russian nuclear energy-disarmament initiative. A major possible step would be a new U.S.-Russian joint initiative on nuclear energy and disarmament. Under this initiative, the United States and Russia would each pledge that they would make available LEU blended from HEU (beyond the 500 tons and 174 tons the two countries declared excess in the 1990s) to fuel the initial cores and the first reloads of each new reactor built in either of their countries, or that either of their companies exported, for a specified period (possibly the next two decades), or up to a particular number of reactors.

Such an initiative would provide assured initial fuel supply for all reactors purchased from the United States or Russia; would link growth of nuclear energy to continuing nuclear disarmament (with each reactor built representing the destruction of something like 100 nuclear bombs); would avoid adding the demand "spike" from startup of each of these new reactors to a nuclear fuel market struggling to meet demand; and would not take away existing markets from existing suppliers.

Making LEU for the initial core for each 1000-GWe plant would require roughly 1.5-2.5 tons of 90% enriched HEU, depending on how the material was blended (and larger quantities if the HEU was less enriched). Fueling each such reactor would then require roughly 0.75-1 tons of HEU per year after that (again depending on the details of blending). Hence, if (a) Russia and the United States each committed to following this approach for all reactors they built domestically or exported for the next 15 years; (b) Russia succeeded in building 40 reactors during that time (more or less in line with current plans); and (c) Russia

committed to provide both the initial core and the first three years of fuel for each of these facilities from blended HEU, that would result in blending an additional 180-270 tons of HEU. U.S. reactor construction rates are likely to be somewhat lower, at least at the beginning of the period, but this approach would also result in a substantial amount of additional blending of U.S. HEU.

NEGATIVE INCENTIVES IF RUSSIA DOES NOT BLEND ADDITIONAL HEU

Another class of approaches would focus on threatening to take some particular negative action unless Russia agreed to blend down specified quantities of HEU at a specified pace. The most commonly discussed approaches involve restricting or cutting off access to the U.S. or other nuclear fuel markets.

For example, early in 2008, some proposals considered in Congress (greatly modified later) called for limiting imports from Russia to 5% of the U.S. enrichment market (a 75% reduction from the level permitted in the suspension agreement amendment) unless Russia agreed to blend large amounts of additional HEU to LEU.

In the current political and market environment, such approaches may not work very well. Russia's government today is self-confident and flush with oil revenue, strategic relations with the United States have gotten worse, and in today's tight uranium and SWU markets, Russia's nuclear industry is likely to be confident that it can find markets for its products. Russia would likely see legislative imposition of drastic cuts in already negotiated market access unless Russia met new U.S. demands on HEU downblending as bad faith on the U.S. part. The political fallout could be substantial. If Russia could negotiate adequate market access, it might well choose to sell its SWU in Europe and Asia instead. If that occurred, the market damage could be substantial (including skyrocketing U.S. fuel prices, at least for a period), though arrangements could eventually be made to export the displaced SWU to the United States.

COMBINATIONS OF APPROACHES

Of course, policymakers could combine multiple approaches incentives from the menu presented above. Senator Pete Domenici (R-NM), for example, has proposed legislation that would combine positive and negative incentives to try to convince Russia to blend an additional 300 tons of HEU. In the version passed by the Senate in its version of the supplemental appropriations bill, Russia would have been limited to 17% of the U.S. fuel market (as opposed to 20% specified in the amended suspension agreement) unless it agreed to continue blending HEU beyond the 500 tons covered by the existing agreement; the fraction of the market Russia could compete for would increase as Russia blended more HEU, up to a cap of 25% of the U.S. market at a blending rate of 30 tons per year. While the 20% limit in the amended suspension agreement would expire in 2020, under the Senate bill, the cap would not expire until an additional 300 tons of HEU had been blended. This provision was heavily criticized by Rosatom chief Sergei Kirienko as unilaterally rewriting a trade deal already agreed to, and was not included in the final appropriations act. Sen. Domenici has since floated a revised version that would give Russia access to 20% of the U.S. market, and would expire in 2020, as with the suspension agreement, but would allow Russia to compete for up to 25% of the U.S. market if it blends additional HEU. Domenici has made the point that this additional 5% of the U.S. market would mean as much as $1 billion in additional sales for Russia during the period between expiration of the current HEU deal and 2020.[7] Whether some provision of this kind will be passed into law this year remains uncertain.

U.S. RECIPROCITY

In the original negotiation of the HEU Purchase Agreement, reciprocity, in the sense of the United States also blending large stockpiles of HEU to LEU, was only a minor issue. At that time, with its nuclear industry in desperate financial condition, Russia was primarily interested in the revenue from the LEU to be produced; Russian officials may have seen U.S. blending as introducing more material in the market that would compete with their own.

In today's context, however, for Russian officials to make the case domestically for blending large additional quantities of HEU may require the United States taking similar action. Because the two sides have

HEU stockpiles of quite different size (and probably somewhat different HEU requirements for weapons and naval fuel), exact equality – a kilogram of U.S. HEU blended for every kilogram of Russian HEU blended – is not likely to be a sensible goal. Rather, the two countries should consider, as they agree on lower numbers of nuclear weapons, agreeing to reduce their HEU stockpiles in parallel to the minimum required to support those remaining warhead stockpiles (plus a modest additional stock for naval fuel).[8]

CONCLUSIONS AND RECOMMENDATIONS

Blending hundreds of tons of HEU beyond the 500 tons covered by the existing HEU Purchase Agreement to LEU, and accelerating the pace of downblending, could contribute substantially to U.S. and international security. Technology is available that could make it possible to accelerate the downblending. Russia has made it clear that it does not plan to continue the existing arrangements beyond the 500 tons already agreed. But a variety of other arrangements could be designed under which Russia would have far greater economic and strategic incentives to expand and accelerate the downblending of its HEU.

- Drawing on the menu of options provided in this paper, the United States should begin negotiations with Russia with the goal of gaining agreement on an expanded and accelerated HEU downblending approach, going well beyond the 500 tons covered in the existing HEU Purchase Agreement.
- Other interested governments should also seek to give Russia incentives to blend down additional HEU, including offering additional market access for LEU blended from HEU, or matched by LEU blended from HEU.
- The United States should be prepared to agree to expand and accelerate its own down-blending of excess HEU.

The United States and Russia should agree to reduce their nuclear weapon stockpiles to low levels, and to reduce their HEU stockpiles to the minimum required to support those low levels of nuclear weapons plus a modest additional stock for naval fuel.

REFERENCES

[1] This work was financed by the Nuclear Threat Initiative, as part of their project on accelerated downblending of HEU. Any errors, omissions, and misjudgments are solely the responsibility of the author.

[2] Most Russian SWU are sold as enriched uranium product, which contains uranium that would still be subject to anti-dumping laws and agreements, but this could change over the longer term.

[3] This assumes 0.3% ^{235}U tails. At 0.2% ^{235}U tails, closer to the economic optimum at high U prices, the equivalent would be closer to 5,000 tons of U and 4.8 million SWU per year.

[4] Estimates of long-term contract prices provided by International Nuclear Enterprise Group. This is a gross revenue figure, not a profit figure. The other analyses of blending costs sponsored by the Nuclear Threat Initiative, however, suggest that the cost of blending this HEU to LEU would be a small fraction of the $22 billion in revenue, leaving room for many billions of dollars in profit to Russia.

[5] This would be true if the concentrations of undesirable isotopes in the material to be blended were similar to those in the material blended so far. If material beyond the 500 tons covered by the existing HEU Purchase Agreement had higher concentrations of undesirable isotopes, different blending approaches might be required.

[6] It would take approximately 8.5 million fewer SWU (valued here at $150/SWU) to produce the needed 4,275 tons of 1.5% enriched blendstock by stripping 0.3% ^{235}U tails to 0.15% than by stripping 0.18% ^{235}U to 0.15%. For a discussion of the value-added of other options for these tails, see U.S. Congress, Government Accountability Office, *Nuclear Material: DOE Has Several Potential Options for Dealing With Depleted Uranium Tails, Each of Which Could Benefit the Government* (Washington, DC: March 31, 2008).

[7] See "Politics on Supplemental Leave Domenici Amendment Behind," *UX Weekly*, 23 June 2008, and "Domenici Steps Up Promotion of Uranium Enrichment Plan in FY2009 Supplemental Spending Bill," press release, 11 June 2008.

[8] See discussion in Matthew Bunn and Anatoli Diakov, "Disposition of Excess Highly Enriched Uranium," in International Panel on Fissile Materials, *Global Fissile Materials Report 2007.*