



EXPANDING RUSSIAN HEU BLEND DOWN

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ABSTRACT

One of the most successful US-Russian cooperative nuclear projects has been the US-Russia Highly Enriched Uranium Purchase Agreement, which has eliminated over 300 metric tons worth of highly enriched uranium (HEU), representing the destruction of over 12,000 Russian nuclear weapons. Building on research presented in 2005 and 2007 on accelerating Russian blend down activities, this paper will introduce the findings of an optimization analysis to refine and evaluate options to blend down HEU beyond the current rate of 30 metric tons per year. It will consider the history of current HEU blend down efforts, and present the case for expanding the current blend down efforts both in quantity and pace. It will touch on the methodology of the joint US-Russian analysis, and describe the prospects of achieving the nonproliferation and nuclear energy benefits of going faster and farther in blending HEU.

1. Introduction

The research that forms the basis for this conceptual analysis was carried out jointly by Russian and U.S. specialists at the request of NTI, as well as by U.S. firms under contract to NTI. Its focus was an examination of the options for accelerating the downblending of Russian highly enriched uranium (HEU) no longer used for defense purposes (hereafter, excess HEU), to low enriched uranium (LEU) for use in nuclear power plants. The Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted From Nuclear Weapons of 1993 (hereafter, HEU Purchase Agreement), which is currently in force, envisages the processing of 500 metric tons of uranium (MTU) of Russian HEU into LEU by 2013 at the rate of 30 MTU of HEU annually.

Our Phase I analysis of options to accelerate 30 MTU/year annual blending rate, in support of disarmament and nonproliferation goals, was completed in 2005.¹ The options considered differed in the rate of additional downblending (from 5 to 30 MTU/year), whether and where the output would be stored prior to customer delivery, and the enrichment level of the LEU product (4.4%, 12%, and 19% ²³⁵U). This analysis considered the production capacities that were already available, the infrastructure requirements of accelerated HEU processing, the costs to install such upgrades, and the time required to complete the infrastructure upgrades. Phase I also evaluated

legal considerations and the influence of additional LEU on the uranium and enrichment markets. The research assumed the use of the same downblending process currently used to execute the HEU Purchase Agreement.

The Phase I analysis formed the basis for the following primary observations:

- Counterintuitively, the need for additional enrichment capacity associated with blend-stock production is by far the greatest driver for cost and schedule associated with the different downblending options. This is so even for the intermediate-enrichment (12% and 19% ^{235}U) options, where the capital cost of creating *de novo* processing capacity was more than offset by the savings associated with the significantly smaller additional enrichment needs.
- The long lead time required for the upgrades associated with the high-quantity options (up to 10 years) means that the HEU under the current agreement will have been mostly or completely blended before the new capacity is operable; this makes the possibility of “doubling” the rate under the HEU Purchase Agreement (that was considered in some options) unrealistic. Even in the lower-quantity options, upgrade lead times limit the value of acceleration unless additional HEU is made available for downblending.

In 2005, NTI and its Russian partners embarked on a Phase II analysis designed to optimize options for accelerating downblending of excess HEU. In contrast to the somewhat arbitrary quantities considered in Phase I, these new options were sized to be consistent with the capacities of standard Russian downblending process modules, and they focused all new upgrades on a single Russian facility at the Siberian Chemical Combine (SCC) close to Seversk, while taking advantage of existing capacity reserves at the three other downblending facilities (PA Mayak near Chelyabinsk, the Electrochemical Plant near Zelenogorsk, and the Urals Electrochemical Combine near Ekaterinburg). These options also addressed a variety of approaches to reducing the enrichment requirements associated with blend-stock production, including:

- higher enrichment of the final product (4.95% vs. 4.4% ^{235}U) reflecting current practices
- use of higher-assay U.S. uranium tails to produce blendstock
- use of natural uranium both directly as blendstock and for production of 1.5% ^{235}U blend-stock
- substitution of the 1996 version of the ASTM C996 specification for ^{234}U with the 2004 specification², which allows 10% more ^{234}U in the product
- two-stage downblending with first-stage downblending to 19% ^{235}U as an intermediate product. However, in contrast to the Phase I analysis, this analysis includes the estimated costs and schedules for second-stage downblending in Russia to 4.4% ^{235}U , as well as second-stage downblending in the U.S.

Our Phase II study was also designed to present information about the end-to-end costs and schedule issues; additional research was developed by U.S. firms for those portions of each option’s requirements that would take place outside Russia, such as transportation and U.S.-based downblending activities.

2. Current context of LEU use and production

The LEU imported by the U.S. under the HEU Purchase Agreement represents roughly half of U.S. utilities’ requirements for LEU for nuclear power generation. The approaching endpoint of the

HEU Purchase Agreement in 2013 has engendered significant discussion among officials, experts, and industry actors as to how these LEU needs will be met, and whether and how additional Russian LEU might enter the U.S. market. The recent actions by U.S. and Russia to define the access conditions for newly produced Russian LEU (i.e., not blended from HEU) by amending the Russian Suspension Agreement in February 2008, the U.S. court decisions involving French LEU (the so-called “Eurodif” cases), and legislation introduced by Sen. Pete Domenici (R-N.M.) are all connected to resolving these uncertainties.

At the same time, prospects of the return to U.S.-Russian negotiations on nuclear arms reductions highlight the potential for additional Russian HEU that may be available for downblending. Experts have suggested that, even before any new agreements might come into effect, Russia may have up to 300 MTU of HEU that might be declared excess³, leaving conservative allowances for ongoing weapons maintenance, naval propulsion, and civil HEU uses. Should a renewed arms control process identify further warhead dismantlements, additional HEU might become available for downblending.

Furthermore, since our Phase 1 analysis was completed, significant changes have been seen in the domestic and international nuclear energy environment. Lack of investment in uranium production in the 1990s, ongoing limits on existing uranium producers, uranium market speculation, and the anticipated global increase in nuclear power worked together to produce record high prices for enriched uranium. This has led some to reconsider the wisdom of permanent disposal of U.S. uranium tails, especially those of comparatively high assay (0.3-0.4% ²³⁵U). During this same period, LES began construction on a new uranium enrichment facility in New Mexico, while USEC obtained a license for its American Centrifuge Plant. Areva also plans to construct an enrichment plant in Idaho, and General Electric has announced that it will construct a pilot plant using the Australian Separation of Isotopes by Laser Excitation (SILEX) enrichment process, which may offer significant savings over centrifuge-based enrichment processes.

The backdrop against which all of these actions are playing out is the much heralded “global nuclear renaissance” in which dozens of additional reactors are being planned and long-term fuel supplies are becoming a hot topic. The interactions of these current and future changes offer several points of relevance to expanded Russian HEU downblending:

- The global market for nuclear fuel remains balanced in the near term, but is likely to require additional LEU supplies in the future.
- The rise in LEU prices is sparking interest in non-traditional sources of both uranium and enrichment.
- In the U.S., on both the supply side (enrichers) and the demand side (utilities), there appears to be room for new LEU providers, but predictability will continue to be the primary concern.

3. General assessment of options for HEU accelerated downblending to LEU products

Capital costs and schedules of the 11 scenarios, as shown in Figure 1, are largely determined by the need to install additional separation capacities required to blend 4 or 12.5 additional metric tons of HEU annually. This analysis considered five techniques to reduce requirements for additional enrichment capacity.

Production of LEU with a higher enrichment – 4.95% rather than 4.4% ²³⁵U – lowers blendstock consumption and, thus, reduces the requirement for additional enrichment capacity. For example, downblending of 4 MT per year of HEU to 4.95% ²³⁵U requires 16.5% less enrichment than the same amount of HEU processed to 4.4% ²³⁵U product. Thus, capital costs are reduced, and the required capital investment schedule is shortened by more than 10%.

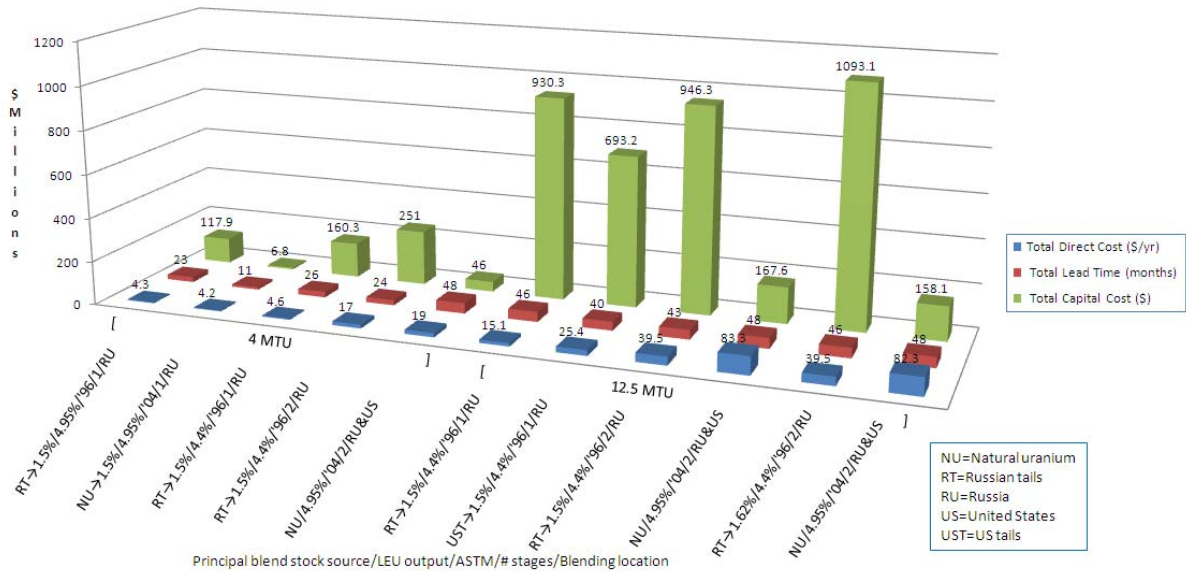


Figure 1. Total capital costs, schedule, and annual operating costs by scenario

Production of LEU in conformity with ASTM C996-04 allows using natural uranium as the source material for blendstock, which decreases enrichment requirements such that existing capacity reserves are sufficient for blending an additional 4 MTU annually. This reduces the capital costs to less than 5% of other options, and the schedule is half as long.

Using U.S. tails with a higher ²³⁵U assay for blendstock production also reduces enrichment requirements. For instance, comparison of similar options with a 12.5 MTU per year increment of HEU processing shows that enrichment requirements are 27% less, with commensurate savings in capital costs and an investment schedule that is also shorter – by 13%. The savings persist even when the cost of containers and shipping from the U.S. are included.

Switching from direct downblending to a two-stage process offers the potential to reduce the requirement for enrichment capacity. However, if all processing is performed at Russian enterprises, and both stages are accomplished in the same 12-month period, the cost of the two-stage process is greater than that of the direct downblending process of HEU to LEU. This is primarily because the cost of new facilities for producing and storing 19% ²³⁵U and

its subsequent dilution more than offsets the savings in enrichment. If the time frame of the second-stage downblending were extended beyond the completion of all first-stage blending, it would be possible to achieve a small savings in enrichment requirements, though the cost savings would be less than the cost of the needed 19% ²³⁵U facilities and interim storage. However, two-stage downblending makes it possible to manage the requirement for capital investment, allowing a much earlier start with disposition. In addition it makes possible other options that could result in larger savings in cost and timescale through the use of U.S. facilities for the second-stage blending.

Use of natural uranium blendstock for the first stage of a two-stage process allows the investment in enrichment capacity to be deferred, but eventually would slightly increase the requirement for enrichment capacity as compared with using the standard 1.5% ²³⁵U blendstock if C966-96 specification is used for the final LEU. This is because, when using natural uranium blendstock for the first stage, the second stage requires blendstock enriched to 1.62% ²³⁵U in order to meet the ASTM C966-96 specification for ²³⁴U.

Each of the scenarios assumed that the additional blending activity was occurring in concert with on-going downblending of 30 MTU of HEU based on the current Russian blending approach. Were any of the first three techniques noted above to be applied, separately or in combination, to that baseline downblending activity, these findings suggest that significant increases in throughput could be achieved at minimal cost.

4. Secondary downblending in the U.S.

Certain scenarios were also considered in which the intermediate LEU product was shipped to the U.S. as 19% UF₆ for further downblending. Since no U.S. facilities are currently configured to downblend 19% ²³⁵U, new facilities to store and process this LEU would be required. Using the U.S. downblending technology, the Russian 19% ²³⁵U can be downblended to meet the 2004 ASTM specification using either natural or depleted uranium. Therefore, there are no enrichment requirements associated with the U.S.-based downblending scenarios.

As seen in Figure 1, this avoidance of enrichment requirements results in significant savings in capital costs required for the scenarios involving U.S. downblending. This is true even when the purchase of large quantities of new containers and packages for overseas transport of 19% ²³⁵U is included. On the other hand, the operational costs for U.S. facilities are significantly higher by comparison with the direct-blending scenarios. These higher operational costs will begin to offset the savings in capital costs after eight or nine years of operations.

Another important consideration is the licensing uncertainty associated with constructing and operating a new U.S. downblending facility. Whereas all the Russian facilities that would be involved in any of the scenarios already participate in the types of operations they would perform, the U.S. facility would be the first of a kind. Moreover, it would rely on a process that requires regular handling of large quantities of liquid UF₆, which is a significant safety hazard. While mitigation strategies and experience exist, a successful license application for a new facility capable of handling 19% ²³⁵U is not assured.

5. Impact of HEU Accelerated Downblending on Uranium and Enrichment Services Markets

The accelerated downblending scenarios have the potential to significantly impact the uranium and enrichment markets, as well as cause possible overdependence of the U.S. or Europe upon foreign enrichment services. Although both the uranium and enrichment markets are presently stressed, with a perceived supply deficit, it is unlikely that any of the options can be executed quickly enough to offset the current short-term gap between uranium supply and demand. The perception of new large supplies from governmental inventories could negatively impact the recent, and potentially fragile, investment climate that is needed to support long-term expansion of nuclear fuel supplies.

At the same time, utilities are eager for clarity in the post-2013 fuel supply. Some predictability has been created by the February 2008 signature of the Russian Suspension Agreement, which will allow U.S. utilities to contract directly with Russia for newly-produced LEU in small quantities over the next five years, swelling to quantities representing roughly 20% of U.S. LEU requirements after 2013. These limits do not apply to initial cores for new reactors. This leaves roughly 80% of projected U.S. LEU needs after 2013 to be covered by some combination of existing and new USEC enrichment plants, LES's new plant in New Mexico, and AREVA's potential new plant in Idaho. The speculative character of some of these facilities may motivate both suppliers and consumers to welcome additional sources of LEU as a hedge against delays or difficulties in achieving the outputs expected from U.S.-based enrichment facilities.

Unconstrained sales of large amounts of uranium and enrichment services could distort the competitive structure of the nuclear fuel markets. Holding material off-market in an inventory would not, by itself, provide the required market protection because market participants will anticipate the release of material at the earliest feasible opportunity and adjust their buying patterns accordingly. Therefore, additional market protection mechanisms would be needed to avoid price instability. These include, for example, avoiding sales into volatile short-term markets and seeking instead long-term contracts, or extraordinary transactions such as fuel for the first cores of new reactors or enhancement of utility security of inventories. Integrating other objectives such as the desire to limit the spread of inherently dangerous fuel cycle technologies suggests additional mitigation options, such as fuel supplies for new nuclear nations, national strategic LEU reserves, or international "fuel banks" in support of supply assurances. In any case, clear communication of scope and intent of any downblending program will be necessary to avoid confusion and market damage.

6. Recommendations

These findings suggest several opportunities to expand downblending of Russian HEU.

- Downblending of an additional 4 MT HEU per year to 4.95% ²³⁵U, using natural uranium as the source material for a blendstock, and based on the 2004 ASTM specification for ²³⁴U, can be achieved right away with minimum investment. The resulting 102.6 MTU of LEU can be readily absorbed in the current market without undue disruption, assuming transparency of decisionmaking. This scenario should be pursued as soon as possible, either between the U.S. and Russia, or by other potential consumers.

- Russia should seriously consider adjusting its downblending operations under the current agreement in ways suggested by this analysis to reduce the enrichment requirements for blending 30 MTU of HEU annually and make that capacity available either for additional downblending activities or for commercial sale.
- An approach that provides high-assay U.S. uranium tails to Russia for blendstock production shows promise for additional downblending of 12.5 MTU HEU, especially if the output is 4.95% ²³⁵U and the 2004 ASTM specification is used.
- Two-stage downblending adds complexity and saves little over comparable options when both stages are carried out within one to two years. Looking forward, certain applications, such as research reactors and floating power plants, can be expected to require fuel based on 19% ²³⁵U. Should these requirements become significant in the future, the analysis of the first stage of the two-stage scenarios reveals comparatively low capital and operational costs that could make them attractive for these specialized fuel requirements.
- These scenarios do not consider the potential for cost savings associated with lowering the burden of maintaining large HEU stocks. Security, safety, and other management expenses can contribute considerable savings if stockpile reductions allow for closure of current storage sites or facilities. Given that the security burden can be expected to continue increasing, a decision to eliminate additional HEU can have important financial benefits down the road.
- The benefits to global security associated with reduced HEU stockpiles are impossible to quantify, but as long as terrorists and others seek the raw material for nuclear weapons, those who are responsible for those materials are morally bound to minimize the risk that it may be stolen or diverted. There is no better way to reduce that risk than to eliminate the material itself.

References

¹ Joint Conceptual Analysis and Cost Evaluation of the Possibility of Accelerated Disposition of Highly Enriched Uranium No Longer Needed for Defense Purposes. Final Report. FSUE TSNIATOMINFORM, Moscow, 2005

² Standard Specification for Uranium Hexafluoride Enriched to Less than 5% ²³⁵U, Designation C996-04, ASTM International, 2004.

³ Global Fissile Material Report 2006. International Panel on Fissile Materials, Princeton, NJ, 2006, page 19.