

Recapturing U.S. Leadership in Uranium Enrichment

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George David Banks
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A Report of the CSIS Nuclear Energy Program

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Contents

Setting the Scene	1	
Promoting an Integrated Approach to Uranium Enrichment Policymaking		5
Tracking the Uranium Enrichment Programs of U.S. Competitors		13
European Union	14	
Russia	15	
Japan	15	
China	15	
Policy Recommendations	16	
About the Authors	18	

Recapturing U.S. Leadership in Uranium Enrichment¹

George David Banks and Michael Wallace

The United States is at risk of finding its nuclear weapons capabilities weakened by the absence of an available capability to produce low-enriched uranium (LEU) for tritium production—a key component in maintaining our nuclear arsenal. With the closure of the 60-year-old Paducah plant earlier this year, the United States has no domestic facility that uses U.S.-origin technology to enrich uranium. Treaty obligations prohibit the United States from using, for military purposes, foreign-produced enriched uranium or uranium enriched here in this country by foreign-source technology. Moreover, existing stockpiles of LEU and tritium produced by U.S.-origin technology are limited, placing the United States on borrowed time. Efforts to deploy a next-generation American enrichment technology must succeed so that our nation has the ability to address the forthcoming shortage of this strategic material. This national security requirement could be met with little cost to taxpayers if the federal government implemented policies that ensure a strong U.S. enrichment industry.

Setting the Scene

The U.S. civil nuclear fleet runs on fuel produced from uranium, but only a small percentage of natural uranium—the U^{235} isotope—can be easily split to generate energy. Comprising less than 1 percent by weight of natural uranium, the concentration of U^{235} must be increased to 3 to 5 percent before being made into a fuel for power reactors. This process is called “enrichment,” which is the key step in the nuclear fuel cycle—for both peaceful and military purposes, though weapons-grade uranium must be enriched to a much higher level of U^{235} .²

During the Cold War, uranium enrichment was viewed broadly by U.S. policymakers as a strategic process that was vital to national interests. Unfortunately, over the past few decades, the strategic value of uranium enrichment has diminished in the eyes of many American policymakers—a development that has helped hasten the decline of the domestic enrichment industry, thus threatening some key U.S. military capabilities.

In most cases, stovepiping of the nation’s nuclear energy policy in commercial and national security channels has produced this result. Many energy analysts

¹ This paper provides further detail on the link between the health of the U.S. civil nuclear program and national security interests, following up on an earlier report, CSIS Commission on Nuclear Energy Policy in the United States, *Restoring U.S. Leadership in Nuclear Energy: A National Security Imperative* (Washington, DC: CSIS, June 2013), http://csis.org/files/publication/130719_Wallace_RestoringUSLeadershipNuclearEnergy_WEB.pdf.

² Weapons-grade uranium typically contains a concentration of approximately 90 percent or more U^{235} .

erroneously view enriched uranium as simply another feedstock for the production of electricity—comparable to coal or natural gas—regardless of its impact on defense needs. For their part, domestic advocates for nuclear disarmament link the goal of diminishing the nation’s uranium enrichment capabilities to reducing the size of our nuclear arsenal. Even some fiscally conservative groups have turned negative on U.S. uranium enrichment policy, joining antinuclear groups in letters to Congress that would reduce funding from Washington.³ However, this is misguided since it is debatable whether the federal government should have moved forward in the first place with privatization of the development and use of our enrichment technologies.

Federal policy has certainly evolved since the days of the Cold War. For decades, U.S. technology dominated the market for enrichment and technology. By the early 1990s, however, a heavily subsidized European enrichment industry and the introduction of Russia as a major supplier brought cost pressures on the federal program. Fearful that the United States could not compete in the marketplace, Congress moved forward to privatize enrichment. The Energy Policy Act of 1992 resulted in the creation of a government corporation, the United States Enrichment Corporation (USEC), that was then fully privatized in 1998.

The privatization of USEC has certainly been troubled by a number of factors—primarily by competition from foreign-subsidized uranium enrichment that has undercut the company’s prices and diminished its domestic market share. State-owned competitors in Western Europe enjoy assured home markets that limit imports of enriched uranium, while benefiting from open access to the U.S. civil nuclear fleet—the largest in the world. Another major competitor, Russia, gained access indirectly under a key nonproliferation program, Megatons to Megawatts (M2M), which allowed Moscow to sell through USEC a large quantity of enriched uranium derived from nuclear weapons.⁴ The large amount of Russian enriched uranium imported under the program, combined with expanding European imports, resulted in the closure in 2001 of one of the two U.S. enrichment plants then in operation—the Piketon, Ohio, facility. With its closure, the United States no longer had the capacity to produce enriched uranium to meet all of its needs, which started a trend toward dependence on foreign-supplied enriched uranium that continues to this day.

Washington has taken some steps to address the challenge posed by foreign competition. In the early 1990s, restrictions were imposed on imports of Russian uranium outside the scope of the Megatons to Megawatts program, although a statute passed in 2008 will allow imports of Russian commercial enriched uranium to meet up to 20 percent of U.S. needs after M2M expires at the end of this year. In 2001 and 2002, European government support to their own enrichment industry—in the form of grants, tax credits, and low-interest loans—was found by the U.S. government to have materially injured the domestic enrichment industry. Consequently, duties were imposed on imports of enriched uranium from Europe. Recently, the International Trade Commission (ITC) approved the continuation of duties on imports of French

³ “Nine Groups Support Amendment to Stop USEC Giveaways in Energy and Water Development Appropriations Bill,” PR Newswire, July 9, 2013, <http://www.prnewswire.com/news-releases/nine-groups-support-amendment-to-stop-usec-giveaways-in-energy-and-water-development-appropriations-bill-214805811.html>.

⁴ This ground-breaking program removed the equivalent of 20,000 nuclear weapons from Russia’s stockpile.

low-enriched uranium (LEU) to offset dumping—selling at less than fair value—in the U.S. market.⁵

Certainly, U.S. leadership in the technology has diminished substantially with the United States becoming increasingly dependent on foreign sources of enrichment. With the cessation of enrichment activities at the Paducah Gaseous Diffusion Plant last May, uranium is no longer enriched in the United States with U.S.-origin enrichment technology.⁶ The European-owned URENCO facility in New Mexico has production capacity of over 3 million separative work units (SWU),⁷ but that plant uses foreign-origin enrichment technology, which cannot be used for U.S. defense purposes.

- It is important to emphasize that aside from the antiquated gaseous diffusion plant in Kentucky and the state-of-the-art American Centrifuge, there is no other domestic enrichment technology available to meet national security needs. No other U.S. technology is under development or even on the drawing board to meet future defense requirements for low-enriched uranium (LEU). Thus, either the Paducah plant or American Centrifuge, or some combination of the two, are necessary to fulfill our national defense needs for enrichment services.

USEC is working to deploy the American Centrifuge Plant in Piketon, Ohio—a highly efficient U.S. centrifuge technology.⁸ USEC is demonstrating development of its centrifuge capability under a research, development, and demonstration (RD&D) agreement with the Department of Energy. The objective of the RD&D effort is to demonstrate the technology through construction and operation of a commercial plant configuration 120-centrifuge machine cascade. Although the RD&D program is on schedule for completion at the end of 2013, prospects for following through with construction of the commercial plant are far from certain, despite the \$2.5 billion of private capital USEC has invested in the project over the past decade. The lack of long-term financing for deployment could result in the termination of the project.

USEC's push for financing has been complicated by reduced demand and declining prices for enriched uranium, resulting in large part from the shutdown of nuclear reactors in Japan because of the Fukushima disaster.⁹ Additional shutdowns in the United States have also softened demand. With foreign enrichers guaranteed markets in their own countries, USEC also faces difficulty competing against foreign companies

⁵ “U.S. International Trade Commission Votes 3-1 for Continued Duties on Imported French Low Enriched Uranium,” Business Wire, November 13, 2003, <http://www.marketwatch.com/story/us-international-trade-commission-votes-3-1-for-continued-duties-on-imported-french-low-enriched-uranium-2013-11-13>.

⁶ The Paducah plant used an enrichment process called gaseous diffusion, which results in the forcing of uranium hexafluoride gas through a series of porous membranes with microscopic openings to separate out U²³⁸ isotopes from the fissile U²³⁵ isotopes. Using gaseous diffusion is much more energy intensive than enriching uranium with centrifuge technology and requires greater land usage.

⁷ The measure of how much work is required to enrich uranium is called a separative work unit or “SWU.” With an average price of \$141.36 per SWU last year, SWU services cost the U.S. civil nuclear sector about \$2.3 billion.

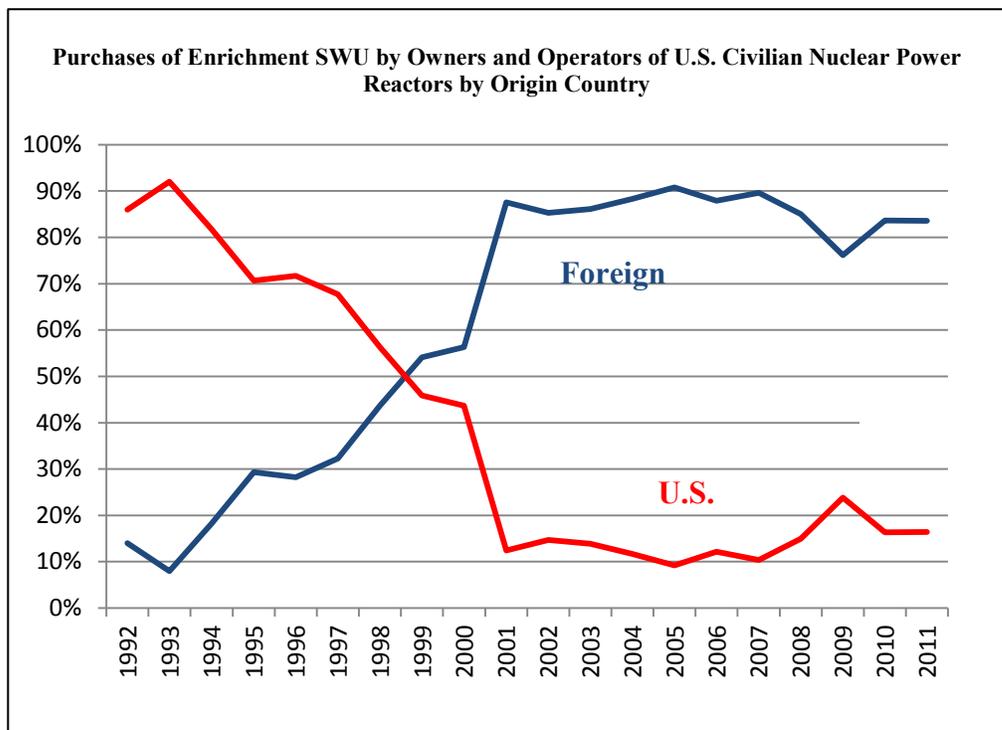
⁸ USEC has a construction and operating license issued by the U.S. Nuclear Regulatory Commission (NRC) and began construction of the American Centrifuge Plant in May 2007.

⁹ USEC's application for a DOE loan guarantee to complete its American Centrifuge Plant remains under consideration. In 2010, the department awarded French-owned Areva a conditional loan guarantee to build an enrichment facility in Idaho, but the company has deferred indefinitely its plans to build this plant, although it is expanding its capacity in France rapidly.

that are aggressively competing for the remaining fuel contracts in play. Moreover, those competitors have already moved to lower-cost centrifuge technology.

A setback in American Centrifuge would hasten the decline of the U.S. enrichment industry. In recent years, enriched uranium produced by foreign technologies has increased to about 85 percent with only 15 percent coming from U.S. enrichment technology production.¹⁰ About 40 percent of the foreign sourcing from 2001 through 2013 came from the import of Russian enriched uranium under the M2M program. SWU from Germany, the Netherlands, and the United Kingdom captured 33 percent of the market last year.

With the end of M2M, Russia is likely to maintain a significant U.S. market, given its quota of 20 percent of the U.S. market from 2014 through 2020—with unlimited access thereafter. URENCO (a British, Dutch, and German enrichment consortium that is two-thirds owned by the governments of the Netherlands and the United Kingdom) and the French government-owned enricher, Areva, will have the greatest growth. We expect these West European companies to increase their market share substantially now that USEC has ended enrichment activities in Paducah—at least until U.S. technology production capability is in place.¹¹



¹⁰ U.S. Energy Information Agency (EIA), “Uranium Marketing Annual Report: Table 16,” May 16, 2013, <http://www.eia.gov/uranium/marketing/html/table16.cfm>. The EIA table indicates that the share of U.S. production is roughly 21 percent. However, the 15 percent figure refers to the domestic production using U.S. enrichment technology. Roughly 6 percent of U.S. production came from European-source technology before the closure of the Paducah plant.

¹¹ Under a deal signed in 2011, USEC will continue to supply Russian enrichment within the framework of the 20 percent quota granted to Russia, though the quantities will be much smaller than under the Megatons to Megawatts program.

Promoting an Integrated Approach to Uranium Enrichment Policymaking

For decades, stovepiping of the different aspects of nuclear energy into civil and defense purposes has resulted in ineffective policy planning.¹² The ongoing debate surrounding uranium enrichment capabilities is perhaps one of the best current examples of how this bifurcation of policy negatively impacts national interests. The technology to enrich uranium is the same for defense and civil purposes. Consequently, U.S. leadership in the enrichment industry is indispensable to the country's competitiveness—both militarily and commercially.

There are several crucial issues related to U.S. uranium enrichment policy that need to be addressed more comprehensively by our policymaking community, taking into account defense and civil needs:

- Legal restrictions that impact the ability of the United States to use foreign enriched uranium or enriched uranium produced by foreign technology for defense purposes;
- Adequacy of existing stockpiles of low-enriched uranium (LEU) and other related sensitive material;
- The link between the strength of the domestic uranium enrichment program and the ability of the United States to shape the global nonproliferation regime; and
- The impact of increased dependence on foreign LEU on U.S. energy security.

The rest of this section takes a brief look at each of these *key* issues.

1. Can the United States use, for military purposes, imports of enriched uranium or enriched uranium produced by firms using foreign technology located in the United States?

Some analysts point to the availability of imported enriched uranium, or investments by firms in the United States using foreign technology to produce enriched uranium, as justification for ending or reducing federal government support of U.S. enrichment technology. Although foreign-source enriched uranium could feasibly power the U.S. civil nuclear fleet, defense needs can be met *only* with enriched uranium produced by and procured from domestic sources using U.S. enrichment technology because of U.S. treaty obligations.¹³

¹² See CSIS, *Restoring U.S. Leadership in Nuclear Energy*, for a general discussion on the impact of bifurcation of commercial and defense policymaking on nuclear energy.

¹³ See Secretary Steven Chu's testimony, Senate Committee on Energy and Natural Resources, February 16, 2012, <http://pbadupws.nrc.gov/docs/ML1220/ML12205A396.pdf>, and Secretary Ernest Moniz's nomination hearing, Senate Committee on Energy and Natural Resources, April 9, 2013, <http://www.gpo.gov/fdsys/pkg/CHRG-113shrg80930/pdf/CHRG-113shrg80930.pdf>.

- From this perspective, it is important to understand that it does not matter who owns and operates the plant that is producing the technology and/or the enriched uranium. What matters is the source of the technology and what government controls it under international law.

Treaties with Australia, the European Union and certain European governments, and Russia, for instance, currently prohibit the United States from using enriched uranium or related technology from those suppliers for nonpeaceful purposes, including tritium production for warheads. Moreover, these treaty provisions govern foreign-source technology that is used in enrichment plants located in the United States, including URENCO's operating facility in New Mexico.

Key agreements include:

- The U.S.-Australia Agreement for Cooperation for the transfer of SILEX technology¹⁴ (SILEX Agreement), specifically:
 - Article 8—No explosive or military application
 - Sensitive nuclear facilities and major critical components subject to this Agreement and any material used in them or produced through their use, and Restricted Data and sensitive nuclear technology transferred pursuant to this Agreement, shall not be used for any nuclear explosive device, for research on or development of any nuclear explosive device, or for any military purpose.
- The U.S.-EURATOM Agreement for Nuclear Cooperation¹⁵ (EURATOM Agreement), specifically:
 - Article 7—Peaceful Use
 - Cooperation under this Agreement shall be carried out for peaceful purposes.

¹⁴ Australia–United States of America Agreement concerning peaceful uses of nuclear energy, with annex and agreed minute. Signed at Canberra July 5, 1979. Entered into force January 16, 1981. 32 UST 3227; TIAS 9893; 1217 UNTS 211. The original agreement was set to expire January 16, 2011. President Obama issued a memorandum approving the extension of the agreement on May 5, 2010. The House of Representatives passed H.R. 6411: “To provide for the approval of the Agreement Between the Government of the United States of America and the Government of Australia Concerning Peaceful Uses of Nuclear Energy” on November 30, 2010. The two countries brought the agreement into force December 22, 2010, for an initial period of 30 years. Also, the “Agreement For Cooperation Between Australia And The United States Of America Concerning Technology For The Separation Of Isotopes Of Uranium By Laser Excitation.” UN Treaty Series, vol. 2117, I-36840 (1999), p. 248, reaffirms the peaceful use commitment: “The Parties shall account for and control material used in or produced through the use of sensitive nuclear facilities and major critical components subject to this Agreement under the systems established and maintained pursuant to Article 9.4 of the Agreement between Australia and the United States of America concerning Peaceful Uses of Nuclear Energy, signed 5 July 1979 and entered into force 16 January 1981.”

¹⁵ European Atomic Energy Community (EURATOM)–United States of America. Agreement for cooperation in the peaceful uses of nuclear energy, with annexes, agreed minute, and declaration. Signed at Brussels November 7, 1995, and March 29, 1996. Entered into force April 12, 1996. See <http://ec.europa.eu/world/agreements/downloadFile.do?fullText=yes&treatyTransId=746>.

- Non-nuclear material, nuclear material and equipment transferred pursuant to this Agreement and special fissionable material used in or produced through the use of such items shall not be used for any nuclear explosive device, for research on or development of any nuclear explosive device or for any military purpose.
- The Agreement¹⁶ between the Government of the United States of America and the Four Governments of the French Republic, the United Kingdom of Great Britain and Northern Ireland, the Kingdom of the Netherlands, and the Federal Republic of Germany Regarding the Establishment, Construction and Operation of Uranium Enrichment Installations Using Centrifuge Technology in the United States of America, specifically:
 - Article III—Peaceful Use¹⁷
 - Any ETC Centrifuge Technology, Operations Technology, equipment and components transferred into the United States subject to this Agreement, each Installation, any Nuclear material in an Installation, any special nuclear material¹⁸ produced through the use of such technology, any special nuclear material produced through the use of such special nuclear material, and any data generated at an Installation that is designated Restricted Data while such data is under the jurisdiction of the United States Government or any of the Four Governments shall only be used for peaceful, non-explosive purposes.
- The U.S.-Russia Agreement for Cooperation in the Field of Peaceful Uses of Nuclear Energy,¹⁹ specifically:
 - Article 12
 - Nuclear material, moderator material, equipment and components transferred pursuant to this Agreement and nuclear material used in or produced through the use of any nuclear material, moderator material, equipment or components transferred shall not be used for any nuclear explosive devices,

¹⁶ Paris, February 24, 2011. Entered into force January 31, 2012. See <http://www.official-documents.gov.uk/document/cm83/8396/8396.pdf>.

¹⁷ The 1992 agreement regarding the transfer of technology for the New Mexico plant contains identical language in Article III. Agreement between the Three Governments of the United Kingdom of Great Britain and Northern Ireland, the Federal Republic of Germany and the Kingdom of the Netherlands and the Government of the United States of America regarding the Establishment, Construction and Operation of a Uranium Enrichment Installation in the United States. Treaty Series No. 133 (2000). Washington, July 24, 1992 [the Agreement entered into force on February 1, 1995] Cm 5009. The agreement was previously published as United States No. 2 (1994) Cm 2456.

¹⁸ “Special nuclear material” includes low-enriched uranium, and the use of nuclear fuel fabricated from low-enriched uranium to produce tritium for nuclear weapons would be a use of the LEU for a nonpeaceful or military purpose. See, for example, 10 C.F.R. §40.42 (defining “military purposes” to include “the production of tritium for use in nuclear explosive devices”).

¹⁹ Available at <http://nnsa.energy.gov/sites/default/files/nnsa/05-13-inlinefiles/2013-05-24%20Russia%20123%20Agreement.pdf>.

for research on or development of any nuclear explosive devices, or for any military purpose.

Ironically, these treaty provisions—which reflect U.S. nonproliferation policies designed to prevent foreign governments from using U.S. nuclear-related technology and materials for military purposes and were agreed to as mutual obligations in order to secure foreign government agreement—could actually place limits on the U.S. nuclear weapons program.

If the United States were to abandon production of uranium enriched by U.S. technology, Washington would need to build its own enrichment capacity at the cost of billions of dollars or revise or suspend treaties in order to use those materials and technologies to be used legally for military purposes. We find the latter scenario unlikely, given the severe negative impact on U.S. nonproliferation objectives, bilateral relations, broader foreign policy goals, and the likelihood that U.S. treaty partners would demand reciprocal rights to use U.S. nuclear material in their military applications, which the United States is unlikely to grant.

2. Do existing stockpiles of low-enriched uranium (LEU) and tritium provide long-term security for the United States?

Critics of continued federal government support of enrichment programs often argue that the United States has sufficient stockpiles of material that could meet defense needs for the foreseeable future. We agree with that assessment as it pertains to high-enriched uranium (HEU), which is used to make nuclear weapons and a source of fuel supply for naval nuclear propulsion systems, and depleted uranium, which is a key component in the production of defensive armor plating and armor-piercing projectiles.

However, we are concerned about stockpiles of LEU and tritium, which are far more limited.²⁰ In particular, the special circumstances associated with tritium, including its short half-life of just more than 12 years and its decay rate are often overlooked.²¹ Tritium, a radioactive isotope of hydrogen, is an essential component of several military applications:

- Boosting the fission primary explosion of a thermonuclear weapon multistage hydrogen and fission bombs;
- External neutron initiators, which are like switches or triggers to detonate a nuclear device (initiate a nuclear chain reaction); and
- Other minor uses such as self-powered lighting used in sighting setups on small firearms.

²⁰ See NNSA under secretary Thomas D'Agostino's testimony, Hearing of the Energy and Water Development Subcommittee of the House Appropriations Committee, March 6, 2012, <http://pbadupws.nrc.gov/docs/ML1217/ML12171A675.pdf>; and Department of Energy FY 2013 Congressional Budget Request, Volume 1—NNSA Domestic Uranium Enrichment RD&D Overview, <http://energy.gov/sites/prod/files/FY13Volume1.pdf>.

²¹ The National Institute of Standards and Technology estimates the half-life of tritium at 12.32 years and its decay rate at 5.5 percent per year.

Naturally produced tritium is extremely rare, a quality that requires human fabrication for defense needs. Because of its decay rate, the production of tritium necessitates an ongoing replenishment of supply. Besides tritium taken from decommissioned warheads,²² tritium can be produced from commercial light reactors, using low-enriched uranium (LEU) fuel from either newly enriched uranium or from U.S. stockpiles of high-enriched uranium (HEU), which can be downblended to LEU for use in producing fuel. Currently, tritium production is conducted at the Tennessee Valley Authority (TVA) Watts Bar Unit 1 reactor,²³ using fuel fabricated from commercial LEU from the Paducah plant, and tritium production may be expanded at a second TVA commercial reactor.

The United States has roughly a decade of stockpiles of qualifying LEU to produce tritium. The extent of the availability of HEU stockpiles for downblending to LEU is unknown and certainly limited, given the fact that the nation no longer has any capacity to produce HEU to replace consumed material.²⁴ Current stocks of HEU are reserved primarily for defense program strategic reserves and for production of fuel for the U.S. Navy.²⁵ Accordingly, we hold significant concerns that remaining HEU stocks will not be available for LEU downblending and tritium production on a consistent basis over the next three decades. With the ceasing of enrichment at Paducah, there is no facility today in the United States that legally could produce enriched uranium for tritium fabrication without treaty modification or suspension.

Commercial deployment of the American Centrifuge project is therefore critical to U.S. plans to produce tritium economically in sufficient quantities for preservation of defense capabilities—particularly given the development, permitting, and construction time required to deploy a new qualifying enrichment facility. We suspect that an understanding of the constraints associated with U.S. dependence on tritium helps inform the position of advocates for U.S. nuclear weapons disarmament, who view the two issues as inherently linked—ending uranium enrichment with domestic technology (and therefore tritium production) in the United States would have a negative impact on U.S. nuclear weapons capabilities.

If the American Centrifuge project is terminated and once stockpiles of LEU and tritium diminish, we would expect the federal government to restart a public program for uranium enrichment that uses U.S. technology—at least for defense purposes. This initiative, without the benefit of sharing costs and risks with the private sector, would certainly cost the taxpayer billions of dollars.²⁶

²² In 1993, the U.S. Government Accountability Office (GAO) forecast that warhead needs for tritium could be met by decommissioned nuclear weapons until 2012.

²³ See Norman Augustine, “Iran’s Uranium Enrichment Expands, America’s Withers,” *Washington Times*, December 22, 2011, <http://www.washingtontimes.com/news/2011/dec/22/irans-uranium-enrichment-expands-americas-withers/>.

²⁴ “U.S. Trims Nuclear Material Stockpile,” December 2005, http://www.armscontrol.org/act/2005_12/DEC-NukeMat.

²⁵ Department of Energy, “Fiscal Year 2014, Stockpile Stewardship and Management Plan, Report to Congress, June 2013,” p. 65, http://nnsa.energy.gov/sites/default/files/nnsa/06-13-inlinefiles/FY14SSMP_2.pdf.

²⁶ USEC is currently engaged in a \$350 million cooperative research, development, and demonstration (RD&D) program with DOE. Further, title to all centrifuges and other equipment built for this program are transferred to the government and, as a provision of the RD&D agreement, USEC granted to DOE in

The total cost to the federal government of restarting a program is an open question—much of which would depend on the availability of required manufacturing infrastructure and technical skills. At the time USEC resumed its centrifuge program, it was able to secure agreement with DOE to use facilities, equipment, and technology that the U.S. government had developed in the 1970s and 1980s at the cost of several billion dollars but then abandoned. Still, USEC had to spend another *\$2.5 billion of its own money* to upgrade the technology, modernize facilities in Ohio and Tennessee, and retool facilities in other states, as well as locate and rehire individuals from the DOE program and train new ones.

3. To what extent would U.S. influence over global nonproliferation policy be impacted by the collapse of the U.S. uranium enrichment industry?

Enrichment facilities are considered at greater risk for proliferation than nuclear power plants because they can more easily be converted to produce weapons-grade uranium.²⁷ Consequently, the United States has a significant stake in preventing the proliferation of enrichment technology.

In compliance with Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons, countries can develop enrichment capabilities under the guise of “peaceful purposes,” but subsequently eliminate International Atomic Energy Agency (IAEA) safeguards. To avoid this, Washington encourages countries seeking to develop commercial nuclear power to rely upon international nuclear fuel supplies, rather than develop indigenous uranium enrichment capabilities. For the United States, the most effective means of implementing that policy is to have a vibrant private sector that produces fuel with U.S. technology, which is then under U.S. control—and available for supply to foreign countries on the condition that these countries use the material for only peaceful purposes.²⁸

Supplying nuclear fuel to countries that do not have weapons-use capabilities allows the United States to use market power to strengthen its nonproliferation efforts. Increasingly, the United States is losing much of the market leverage it once enjoyed to support its nonproliferation policies. According to the Government Accountability Office (GAO), the U.S. share of global exports of sensitive nuclear material, nuclear reactors, major components, and equipment has decreased dramatically.²⁹

Reversing this trend is crucial to preserving U.S. influence in shaping global nonproliferation policy. With the cessation of enrichment at the Paducah plant, deploying the American Centrifuge project is even more critical to giving the federal

perpetuity a no-cost license to use the \$665 million in intellectual property improvements of the technology for national security purposes.

²⁷ Sarah Case, *Proliferation Risk in Nuclear Fuel Cycles* (Washington, DC: National Academies Press, 2011), p. 6.

²⁸ As noted above, material that is under foreign obligations, such as enriched uranium produced in third countries or in the United States using foreign technology, is subject to the control of the government of the country that enriched the uranium or that provided the technology with which the enriched uranium was produced. In this scenario, a foreign government would determine whether the United States could supply the material to a third party and it would be that foreign government and not the United States that the third party would engage for supply assurances.

²⁹ U.S. Government Accountability Office (GAO), *Nuclear Commerce: Government-wide Strategy Could Help Increase Commercial Benefits from U.S. Nuclear Cooperation Agreements with Other Countries*, GAO-11-36 (Washington, DC: GAO, November 2010).

government a bargaining chip in negotiations—for example, the ability to provide U.S. low-enriched uranium to a foreign user over the long term. Absent the ability to back up its policy objectives with a means to achieve them, Washington would depend on other governments—such as Paris or Moscow—to lead in negotiations with countries seeking to develop enrichment capabilities. Certainly, some foreign users would view the U.S. negotiating position as weak and unsustainable without a strong U.S. enrichment industry.

4. When EPA regulation of greenhouse gases tightens over time and demand for U.S. civil nuclear power grows accordingly, how would dependence on foreign sources of enriched uranium impact our energy security?

We expect a significant expansion of global nuclear power between now and 2050, despite the political aftermath of the Fukushima disaster.³⁰ Seventy nuclear reactors are under construction in 13 countries today, according to the World Nuclear Association (WNA).³¹ By 2020, some 50 commercial reactors could help power the Chinese economy, compared with only three in 2000. Ten reactors are currently under construction in Russia, and India is building seven new reactors. These trends are expected to accelerate out to 2030, by which time China, India, and Russia could account for nearly 40 percent of the world’s fleet. In addition, up to 15 new nations could have nuclear-generating capacity by 2030.

The WNA forecasts that the expansion of the global civil nuclear market will result in a substantial increase in demand for uranium—48 percent by 2023³²—as well as for separative work units (SWU). U.S. owners and operators of nuclear power plants will certainly face greater fuel costs as they compete with new entrants and plants. Roughly one dozen countries supply the United States with over 80 percent of its natural uranium needs—with the vast majority of U.S. imports coming from Australia, Canada, Kazakhstan, Russia, and Uzbekistan, according to the EIA.³³

In the case of low-enriched uranium (LEU), however, only a handful of countries produce it for export, which generates concerns about competition and the risk of the development of monopolies and cartels that could then be used to leverage political outcomes at the expense of the United States. The United States should work diligently to avoid monopolization of LEU production and to encourage competition as much as possible, while confirming strong nonproliferation safeguards. The most effective way to achieve those multiple objectives is for the U.S. private sector to recapture its global leadership role in enrichment, and as a matter of public policy, the federal government should encourage that development.³⁴

³⁰ According to the International Energy Agency’s 2012 *World Energy Outlook*, global nuclear production will grow from 2,756 terrawatt hours (TWh) in 2010 to about 4,370 TWh in 2035, an increase of almost 60 percent.

³¹ See World Nuclear Association, “World Nuclear Power Reactors & Uranium Requirements,” October 1, 2013, http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/#.UIWVK77D_IU.

³² *Ibid.*

³³ Energy Information Administration (EIA), “Uranium Marketing Annual Report: Uranium purchases and prices,” <http://www.eia.gov/uranium/marketing/>.

³⁴ Key economic philosophers who have been embraced by fiscal conservatives—including Friedrich Hayek, Ludwig von Mises, and Milton Friedman—all believed that government should aggressively

This energy security justification will grow in importance as EPA regulation of greenhouse gases (GHG) tightens over time and significantly changes the economics of civil nuclear power in the United States, resulting in an expansion of the country's fleet of reactors.³⁵ President Barack Obama has called for a reduction in U.S. GHG emissions by more than 80 percent by 2050, which if pursued will force a substantial amount of natural gas generation from the electricity grid. Currently, nuclear power is the only baseload source that can generate reliable, affordable zero-emissions electricity that can meet long-term greenhouse gas reduction targets.³⁶ Considering total lifecycle emissions, the average intensity from natural gas is estimated at 500 metric tons CO₂e/GWh, compared to 28 metric tons CO₂e/GWh for nuclear. This will be a lengthy, measured process, however, that must survive regulatory and litigation hurdles. Given EPA authority to regulate greenhouse gases and the agency's current model of rulemaking, we expect this scenario to unfold slowly over the next three decades.

In the mid-term, we expect an improvement in nuclear power's competitiveness as natural gas prices increase due to greater regulation of hydraulic fracturing, fuel switching from coal to natural gas, and the construction of new chemical plants and liquified natural gas (LNG) facilities.³⁷ We anticipate those developments to have a positive impact on decisions by public utility commissions in regulated markets. However, we are skeptical that an increase in the price of natural gas during this timeframe will provide the necessary incentive to utilities in merchant markets because of the substantial problems that exist in those power markets, which devalue baseload power, including nuclear.

With any significant expansion of the role of nuclear power in the U.S. electricity mix, we find it unlikely that the American public would support a heavy reliance on foreign supplies of enriched uranium, given the relative importance of energy security. Currently, the country's greatest energy security challenge flows from its dependence on petroleum imports and the monopoly from which petroleum fuels benefit within the U.S. transportation sector. On the other hand, the United States enjoys relative security in the electricity sector because of diversity of supply and heavy dependence on domestic resources, including coal.

protect the market. Hayek warned against the creation of monopolies and argued for government intervention to prevent their formation.

³⁵ The U.S. civil nuclear sector certainly faces challenges today in competitive electricity markets, particularly from cheap shale gas and subsidized renewables. We project that domestic nuclear capacity is likely to contract over the next two decades from about 100 gigawatts electrical (GWe) today to about 80 GWe—in sharp contrast to the much more optimistic EIA estimate that nuclear capacity will maintain its share of U.S. power generation. Most of the reduction will occur in competitive power markets, while we expect to see a slight expansion of nuclear power in the regulated markets of the South and parts of the Midwest.

³⁶ See Associated Press, "Top climate scientists ask environmentalists to support nuclear power in climate battle," *Washington Post*, November 3, 2013, http://www.washingtonpost.com/national/energy-environment/top-climate-scientists-ask-environmentalists-to-support-nuclear-power-in-climate-battle/2013/11/03/79a345b0-4473-11e3-95a9-3f15b5618ba8_story.html.

³⁷ There are currently 30 GWe, or 8 percent of the coal fleet, of announced coal plant retirements over the next five years, largely in response to EPA regulation of mercury and air toxics. Moreover, some analysts predict that an additional 100 GWe of coal could leave the grid within the next 20 years because of EPA greenhouse gas (GHG) rules.

With expected EPA regulation, nonetheless, we anticipate a lessening of diversity in our electricity generation, as the burning of coal, and increasingly natural gas, cannot comply with air-quality standards. Diminished diversity of electricity supply would therefore create an energy security imperative for the United States to recapture its leadership in the production of enriched uranium to reduce the existing and growing overreliance on foreign supplies and technology.

Internationally, moving forward with the American Centrifuge project would also help the United States continue to play an important role as a potential commercial nuclear fuel supplier to existing user countries. In the last three decades of the twentieth century, U.S. domestic enrichment production reliably supplied most of the low-enriched uranium used by the Western world as nuclear power fleets were deployed and expanded. Clearly, U.S. foreign policy would benefit substantially from a return to a robust domestic enrichment industry that could help ensure supplier diversity and increased competition. Possessing the ability to export enriched uranium—under control of the federal government—would help insulate the global economy, as well as those economies of our allies, from suppliers shutting off fuel exports for political and military reasons.

- For example, if Country X were to shut off LEU exports to Country Y, the United States could not seek to fill the gap with enriched uranium produced at the URENCO facility in New Mexico without first gaining approval from the United Kingdom, the Netherlands, and Germany. In contrast, the United States could fill the gap with enriched uranium produced by a domestic plant using U.S. enrichment technology without foreign government approval.
- Approvals may be routinely granted or granted in advance for shipments to certain countries, and so in the usual case, it is unlikely foreign government approval would be an obstacle. However, absent a domestic enrichment capacity, the United States eventually would have no source of LEU that is not subject to some form of foreign government approval, which is an untenable position vis-à-vis a key resource that the United States may wish to be able to supply to other countries.

Tracking the Uranium Enrichment Programs of U.S. Competitors

In contrast to the United States, other major economies view uranium enrichment as a strategic industry that requires government financial and political backing. Whereas USEC is a privately owned company, foreign enrichment suppliers are state-owned enterprises—including TENEX, which is controlled by the Russian government, URENCO, which is majority owned by the British and Dutch governments,³⁸ and Areva, which is more than 90 percent owned by the French State.

With the global market for enriched uranium dominated by state-owned enterprises, U.S. global market share of the nuclear fuel cycle has tumbled. From 1994 to 2008, U.S. exports of natural uranium, enriched uranium, and plutonium remained relatively

³⁸ A third of URENCO is also owned by German utilities E.ON and RWE.

consistent, while global exports of these materials more than doubled. As a result, the U.S. market share for these materials dropped from 29 percent in 1994 to just 10 percent in 2008.³⁹

European Union

The European Union (EU) has long recognized the strategic importance of the uranium enrichment industry and has aggressively promoted its development. As a result of the Treaty of Almelo, Germany, the Netherlands, and the United Kingdom created URENCO in 1971 to develop and deploy centrifuge enrichment technology.

In 1973, the Council of the European Communities recognized the necessity “for industry within the Community to acquire a uranium enrichment capacity enabling it to cover...at least a substantial and growing part of the Community’s requirements.” The following year, the council recommended that European utilities “given equal economic and commercial conditions, place their orders preferably with the European uranium-enrichment firms.”⁴⁰ By 1980, EURODIF⁴¹ and URENCO had emerged as significant suppliers in Europe.

After failing to reach an agreement on nuclear trade with Moscow in 1994, Brussels stipulated that the share for European enrichers should be maintained at around 80 percent of the European market.⁴² This “unpublished” resolution—known as the “Declaration of Corfu”—is enforced by the European Atomic Energy Community (EURATOM) Supply Agency, which has the exclusive authority to approve or deny supply contracts for nuclear fuel to EU utilities, as well as monitoring contracts for nuclear services.

Since 2005, the Declaration of Corfu has been identified by the United States Trade Representative (USTR) as a trade barrier every year in its National Trade Estimate Report. However, the market obstacle remains in place, ensuring that URENCO and Areva dominate the European market for enriched uranium. More recently, URENCO has received loans from the EU’s European Investment Bank (EIB)⁴³ to expand its capacity, with a stated goal of supplying global needs for enriched uranium.⁴⁴

³⁹ GAO, *Nuclear Commerce*.

⁴⁰ Council Resolution of 4 June 1974 Concerning the Supply of Enriched Uranium of the Community, O.J. C069, June 14, 1974, pp. 1–2.

⁴¹ EURODIF (European Gaseous Diffusion Uranium Enrichment Consortium) is a subsidiary of Areva. Sweden’s 10 percent share in EURODIF was transferred to Iran in 1975 via an agreement between Paris and Tehran. France and Iran established SOFIDIF (Société franco-iranienne pour l’enrichissement de l’uranium par diffusion gazeuse). SOFIDIF then acquired a quarter-share in EURODIF, which it still owns. Tehran, thus, remains a shareholder of EURODIF via SOFIDIF.

⁴² See Office of the U.S. Trade Representative (USTR), “2012 National Trade Estimate Report on Foreign Trade Barriers regarding the European Union,” http://www.ustr.gov/sites/default/files/European%20Union_0.pdf. See also European Commission, “Nuclear Observatory: Uranium Production and Demand,” http://ec.europa.eu/euratom/observatory_data.html.

⁴³ According to the European Investment Bank (EIB) website, “the EIB is the European Union’s financing institution...; [i]ts shareholders are the 27 Member States of the Union, which have jointly subscribed its capital; and]...the EIB’s Board of Governors is composed of the Finance Ministers of these States.”

⁴⁴ The EIB website reflects over €500 million in financing for URENCO. See EIB, “Energy: Finance contracts signed,” <http://www.eib.org/projects/loans/sectors/energy.htm>.

Russia

Like the United States, Russia (the Soviet Union) began producing enriched uranium for military purposes, but in the 1960s, Moscow expanded production to include enrichment for domestic and foreign power reactors, located in countries aligned with the Soviet Union. Because defense needs, which required the production of HEU, necessitated more capacity than needed for LEU in commercial use, Russia installed an enrichment capacity that was more than five times larger than the production at the Paducah plant prior to ending enrichment there.

With the cessation of production of highly enriched uranium in 1987, Russia's enrichment capacity far exceeded its commercial needs. However, Moscow decided to preserve production capacity by first enriching Russian depleted uranium tails and then tails from Areva and URENCO. With the execution of the Megatons to Megawatts (M2M) contract with USEC, about 20 to 25 percent of Russia's enrichment capacity was used to make slightly enriched uranium from tails for downblending purposes with highly enriched uranium.

Moscow, in an effort to support Russian enrichment operating capacity, requires all of the country's commercial reactors to be sourced entirely by enriched uranium produced from Russian plants. Today, total Russian production capacity is at least 27–28 million SWU per year, against 4 million SWU in annual Russian needs. The balance of Russian production not used for M2M is used to supply export customers, including utilities in the United States.

Japan

Tokyo's "Nuclear Energy National Plan" promotes domestic nuclear fuel cycle capabilities as a means of strengthening national security. Specifically, the strategy calls for reinforcement of nuclear industries that will "boost industries for uranium enrichment and reprocessing...to achieve nuclear energy self-sufficiency...in the face of resource oligopoly and stricter non-proliferation rules."⁴⁵

Despite Fukushima, plans for operating the Rokkasho Uranium Enrichment facility are moving forward. Rokkasho eventually intends to produce 1.5 million SWU per year, enough to meet 25–30 percent of Japan's annual needs. Despite its reported costs being at least 20 percent higher than Russian and European enrichers,⁴⁶ Tokyo requires Japanese utilities to purchase the entire output from Rokkasho.

China

Beijing initially deployed enrichment plants for defense purposes. To support a growing domestic commercial nuclear power program, China reached an agreement with Russia to build enrichment capacity using Russian centrifuge technology. Subsequently, China replicated that technology with Chinese-produced centrifuges.

⁴⁵ See Ministry of Economy, Trade, and Industry, "Main Points and Policy Package in 'Japan's Nuclear Energy National Plan,'" September 2006, <http://www.enecho.meti.go.jp/english/report/rikkokugaiyou.pdf>.

⁴⁶ See GlobalSecurity, "Weapons of Mass Destruction (WMD): Rokkasho Processing Plant," <http://www.globalsecurity.org/wmd/world/japan/rokkasho.htm>.

Ultimately, Beijing has stated its goal is to be completely self-sufficient in all areas of the nuclear fuel cycle.⁴⁷

Policy Recommendations

The U.S. government is in dire need of implementing policies that support the domestic uranium enrichment industry as a strategic national asset—for defense and commercial purposes. The United States would then have access to enriched uranium and technology that could be used to meet defense needs, serve U.S. foreign policy, and promote energy security in the face of EPA greenhouse gas regulations that likely will fundamentally transform the face of the nation’s electricity supply.

Unfortunately, Washington lacks a national policy to support a domestic enrichment industry based on U.S. technology. Unlike foreign governments that promote indigenous enrichment capacity, the United States has sought market neutrality as evidenced most recently by the decision by DOE to preliminarily approve a government loan guarantee for Areva to deploy an enrichment plant in the United States using European centrifuge technology.⁴⁸ As a result, with the end of enrichment at Paducah, there are no operating commercial plants using U.S. technology today and no clear path to ensure a replacement plant is deployed. This lack of policy support poses a clear and credible threat to U.S. national security interests.

Consequently, we propose the following measures, based on the assumption that the United States should shift away from the policy of market neutrality. In so doing, we assume that significant U.S. public programs supporting domestic enrichment technology and production are highly unlikely in an era of tight budget constraints. Moreover, we support a policy approach that minimizes the cost to the taxpayer and preserves as much of the free market as possible in meeting U.S. national security objectives. We do not advocate the shutting out of foreign enriched uranium from our utilities—as the Russians have—or the awarding of a monopoly of uranium enrichment to domestic providers *at a scale comparable* to the EU’s Corfu Declaration.

1. *Establish a Government-owned Minimum Production Facility.* The United States should have an ongoing enrichment capability for defense needs. This could be provided by either restarting the Paducah enrichment facility at the minimum production level needed for defense purposes, or building a similar-size facility using the more advanced domestic centrifuge enrichment technology. In both situations, the federal government would own and control an appropriately sized facility that could ensure vital national security requirements are met.
2. *Level the Playing Field for U.S. Enrichment Technology Plants.* The United States could further limit imports of low-enriched uranium. In 2008, Congress imposed a quota on imports of Russian enriched uranium.⁴⁹ This policy could be expanded to all imports and allowed to sunset after a U.S. technology

⁴⁷ See World Nuclear Association, “China’s Nuclear Fuel Cycle,” October 2013, <http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/China-Nuclear-Fuel-Cycle/>.

⁴⁸ Areva has indefinitely deferred deployment of its U.S. facility.

⁴⁹ See Section 8118(2), Public Law 110-329 (Sept. 30, 2008) *codified at* 42 U.S.C. § 2297-10a, <http://www.gpo.gov/fdsys/pkg/PLAW-110publ329/html/PLAW-110publ329.htm>.

enrichment plant has been deployed and other exporters of enriched uranium offer the United States similar access to their markets.

3. *Offer Tax Incentives or Credits to Purchase Fuel from U.S. Technology Plants.* The U.S. tax code provides mechanisms for the federal government to promote activity that is in the national interest. The Congress could approve tax incentives or credits to U.S. owners and operators of nuclear reactors to purchase fuel from a U.S. enrichment technology plant, which could help secure financing for its deployment.
4. *Impose Minimum Fuel Percentage Requirements on U.S. Owners and Operators.* In revising the Atomic Energy Act (AEA) and other laws governing the operation of U.S. reactors, the United States could mandate that a minimum percentage of the fuel used in U.S. nuclear reactors be produced using U.S. technology. Such a requirement could help domestic enrichers secure financing for deploying a U.S. technology plant.

The United States has taken such actions in the past, focusing on critical elements of the fuel cycle. In 1964, for example, the AEA was amended, prohibiting the Atomic Energy Commission from enriching foreign-origin uranium “to the extent necessary to assure the maintenance of a viable domestic uranium industry.”⁵⁰ In addition, from 1983 to 1992, the secretary of energy monitored executed contracts or options for natural or enriched uranium for U.S. reactors in an effort to protect uranium interests.⁵¹

As discussed previously, the stovepiping of U.S. nuclear energy policymaking—compartmentalized in defense and energy policy channels—has resulted in unintended consequences, including the predicament we face as a nation in regards to enriched uranium policy. The governments of foreign enrichers, in contrast, view their domestic uranium enrichment industries for what they are—a strategic asset that enhances defense interests, provides leverage in defining the nonproliferation agenda, and helps power their economies. Consequently, those foreign governments and their state-owned firms now lead the way, while the United States finds itself increasingly marginalized in the trade of nuclear technology and services. Fortunately, however, it is not too late for the United States to reverse this trend and recapture its leadership, but the window for doing so is narrowing. The time for action is now.

⁵⁰ See Public Law 88-488 (1964), <http://www.gpo.gov/fdsys/pkg/STATUTE-78/pdf/STATUTE-78-Pg602-2.pdf>.

⁵¹ See 42 U.S.C. § 2210b, <http://uscodebeta.house.gov/view.xhtml?req=granuleid:USC-prelim-title42-section2210b&num=0&edition=prelim>.

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