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October 2014

DEPARTMENT OF ENERGY

Interagency Review Needed to Update U.S. Position on Enriched Uranium That Can Be Used for Tritium Production

GAO-15-123

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GAO Highlights

Highlights of GAO-15-123, a report to congressional requesters

Why GAO Did This Study

The United States needs an assured source of tritium to maintain the U.S. nuclear weapons stockpile. To produce tritium, DOE has stated that it can only use LEU with no obligation to other countries under international agreements to use it for only peaceful purposes. USEC, a government corporation privatized in 1998, was the only company enriching uranium that DOE said could meet its LEU needs, but USEC ceased enrichment operations in May 2013 and filed for Chapter 11 bankruptcy protection in March 2014. DOE is currently considering options for obtaining unobligated LEU. Only one enrichment facility, which is owned by URENCO, operates in the United States, and four other commercial facilities are planned. Four of the five facilities use or will use technology that carries peaceful use obligations to other countries.

GAO was asked to review international agreements addressing enrichment technology in the United States with respect to how peaceful use provisions apply to tritium production. This report examines (1) the extent to which DOE has adhered to its practice of using only unobligated LEU to produce tritium and (2) the basis for this practice. To address these issues, GAO analyzed agency documents and international agreements and interviewed DOE and Department of State officials, among other steps.

What GAO Recommends

GAO recommends that the Secretary of Energy work through an interagency working group to review DOE's current practice of using only unobligated LEU for the production of tritium. DOE neither agreed nor disagreed with GAO's recommendation.

View GAO-15-123. For more information, contact David C. Trimble at (202) 512-3841 or trimbled@gao.gov or Susan D. Sawtelle at (202) 512-6417 or sawtelles@gao.gov.

What GAO Found

The Department of Energy (DOE) has adhered to its practice of using only unobligated low-enriched uranium (LEU) to meet national security needs for tritium—a radioactive isotope of hydrogen used to enhance the power of U.S. nuclear weapons. LEU is considered unobligated when neither the uranium nor the technology used to enrich it carries an "obligation" from a foreign country requiring that the material only be used for peaceful purposes. These obligations are contained in international agreements to which the United States is a party. DOE has adhered to this practice by, for example, requiring in its interagency agreement for tritium production with the Tennessee Valley Authority (TVA) that TVA use only unobligated LEU as fuel in any nuclear reactor that is being used to produce tritium for national security purposes, and DOE is responsible for ensuring that TVA can obtain unobligated LEU for this purpose.

The basis for DOE's practice of using only unobligated LEU to produce tritium considers both law and policy.

- **Legal considerations:** GAO reviewed the three key international agreements that address the importation of foreign-owned enrichment technology that is operating or planned for operation in the United States. GAO found that only one agreement explicitly addresses tritium and this agreement likely prohibits the production of tritium for weapons purposes. This is also consistent with an executive branch interpretation of the agreement. The other two agreements do not explicitly address tritium production for weapons purposes, but Department of State officials told GAO that a reading of the agreements to prohibit the use of technology subject to the peaceful use restrictions for tritium production is consistent with U.S. nonproliferation policy interests.
- **Policy considerations:** Officials told GAO that using only unobligated LEU for national security purposes supports U.S. nonproliferation policy goals by, for example, avoiding setting a precedent for other countries that may seek to use purchased LEU for military purposes. A 1998 interagency report evaluated nonproliferation implications of U.S. tritium production and concluded that, in utilizing TVA's reactors for tritium production, DOE should fuel the reactors with LEU that does not have peaceful use obligations to best preserve a military-civilian dichotomy. DOE and State officials have also cited policy goals in response to questions about whether TVA can use LEU produced by a URENCO enrichment facility for tritium production.

However, a key assumption underlying the decision to use only unobligated LEU for national security purposes has changed. The United States no longer has a ready capability to enrich unobligated LEU for tritium production because USEC ceased enrichment operations in 2013, and the future of the company's planned next-generation enrichment facility—the only planned enrichment facility that could produce unobligated LEU—is uncertain. According to DOE officials, the department is currently engaged with an interagency working group to assess options for obtaining unobligated LEU in the future. Given that the United States no longer has an assured source of unobligated LEU, the results of an updated interagency review that either reaffirms or supports a change in the current practice could help address questions about whether using certain other LEU for tritium production is an option for DOE at this time.

Contents

Abbreviations

ACP	American Centrifuge Plant
AEA	Atomic Energy Act
DOE	Department of Energy
GDP	Gaseous Diffusion Plant
GLE	Global Laser Enrichment
HEU	highly enriched uranium
LEU	low-enriched uranium
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
SILEX	Separation of Isotopes by Laser Excitation
TPBAR	tritium-producing burnable absorber rod
TVA	Tennessee Valley Authority

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October 14, 2014

The Honorable Edward J. Markey
Chairman
Subcommittee on International Development and Foreign Assistance, Economic Affairs, International Environmental Protection, and Peace Corps
Committee on Foreign Relations
United States Senate

The Honorable Michael C. Burgess
House of Representatives

Uranium has been enriched for over 60 years in the United States both for national security purposes, such as for nuclear weapons, as well as for commercial purposes to fuel nuclear power plants.[1] The enrichment process can result in low-enriched uranium (LEU), which DOE needs in order to produce tritium, a radioactive isotope of hydrogen, used to enhance the power of U.S. nuclear weapons. Beginning in the 1940s, the Department of Energy (DOE) and its predecessor agencies enriched uranium for both national security and civilian purposes. In 1992, the U.S. government established the United States Enrichment Corporation (USEC) as a government corporation to take over operations of DOE's enrichment facilities and to provide uranium enrichment services for the U.S. government and utilities that operate nuclear power plants.[2] In 1998, USEC was privatized under the USEC Privatization Act.[3] Since that time, USEC has been the only company that uses U.S.-developed technology to enrich uranium.

[1]To transform uranium ore into a form that can be used in nuclear weapons and to fuel nuclear reactors, uranium goes through a number of steps including mining, conversion, and enrichment. Enrichment is the process of separating uranium-235—the form, or isotope, that undergoes fission to release enormous amounts of energy in nuclear reactors and weapons—from much of the uranium-238 to increase the concentration of uranium-235.

[2]The corporation was initially established as the United States Enrichment Corporation. The privatization was accomplished by an initial public offering with the United States Enrichment Corporation becoming a subsidiary of the newly created USEC Inc., a Delaware corporation.

[3]USEC Privatization Act, 42 U.S.C. §§ 2297h-2297h-13 (2012).

In May 2013, USEC ceased enrichment at its last commercially active enrichment plant—the Gaseous Diffusion Plant (GDP) in Paducah, Kentucky, that it had leased from DOE since the time of USEC's establishment. In recent years, USEC's financial condition has deteriorated, due in part to decreased commercial demand for LEU and high production costs associated with the energy intensive GDP enrichment technology, which is more than 60 years old.[4] USEC filed for Chapter 11 bankruptcy protection in March 2014 in order to strengthen its balance sheet and replace notes maturing in October 2014 with equity and new notes maturing in 5 years and extendable to 10 years.[5] The bankruptcy placed in question the future of next-generation enrichment technology called the American Centrifuge, which USEC has spent $2.5 billion developing at a site in Ohio and recently demonstrated under a cooperative agreement with DOE.[6] If successfully deployed, the American Centrifuge Plant (ACP)—the facility where the American Centrifuge technology is currently operating in a demonstration environment—would again provide the United States with U.S.-developed technology to enrich uranium.[7] In the wake of USEC's bankruptcy filing in April 2014, the Secretary of Energy tasked its Oak Ridge National Laboratory with maintaining the operability of the centrifuges and associated technology, while DOE assesses options for meeting DOE's national security needs for enriched uranium and preserves the option of commercial deployment. While DOE has taken steps to maintain the operability of the ACP in the interim, it is uncertain what the department's future plans are for the ACP

[4]See GAO, *Department of Energy: Enhanced Transparency Could Clarify Costs, Market Impact, Risk, and Legal Authority to Conduct Future Uranium Transactions*, GAO-14-291 (Washington, D.C.: May 9, 2014) for a complete description of these events.

[5]On September 5, 2014, the U.S. Bankruptcy Court for the District of Delaware approved USEC's plans for reorganization. At that time, USEC announced that it planned to emerge from Chapter 11 reorganization under the name Centrus Energy Corp. On September 30, 2014, Centrus Energy Corp. announced that it had satisfied all conditions set forth in its Plan for Reorganization and that it was emerging in a stronger position to support the energy and national security needs of the United States.

[6]USEC has also developed a manufacturing and testing facility in Oak Ridge, Tennessee, and established an extensive domestic supply chain for acquiring and constructing components of the centrifuge units.

[7]Gas centrifuge technology employs rapidly spinning rotors inside cylinders containing uranium hexafluoride to separate the fissile uranium-235 from the nonfissile uranium-238. The centrifuge requires significantly less power to operate than the gaseous diffusion process.

and the extent to which the plant may also be used for commercial purposes.

DOE has two primary national security needs for enriched uranium: (1) obtaining LEU, which is primarily needed for the production of tritium and (2) obtaining highly enriched uranium (HEU), which is needed to fuel the reactors that power the U.S. Navy's aircraft carriers and submarines. With respect to LEU used for the production of tritium, tritium is a key component of nuclear weapons, and an assured source of tritium is necessary to maintain the U.S. nuclear weapons stockpile.[8] However, tritium has a relatively short half-life of 12 years and decays at a rate of about 5.5 percent per year. As long as the United States relies on nuclear weapons, DOE requires a continuous supply of LEU in order to produce tritium. Tritium is produced as a by-product in nuclear reactors, and DOE's National Nuclear Security Administration (NNSA) supports a program that produces tritium as a primary product to collect enough tritium to meet stockpile demands.[9] With respect to HEU, the United States does not currently have a domestic capability to enrich HEU. Instead, national security needs are met using an inventory of HEU that was enriched prior to 1992.[10]

According to DOE, USEC has been the only potential commercial supplier of enrichment services for LEU that could be used for the production of tritium.[11] DOE has asserted that international agreements to which the United States is a party prohibit the use of LEU for military purposes, such as tritium production, if the LEU was enriched by a facility

[8]DOE analysis of stockpile demand for tritium is classified.

[9]NNSA was created as a semiautonomous agency within DOE by the National Nuclear Security Administration Act. Pub. L. No. 106-65, § 3211, 113 Stat. 512 957 (1999). NNSA is responsible for the management and security of the nation's nuclear weapons, nonproliferation, and naval reactors programs.

[10]According to DOE, the department's current HEU inventory allocations are sufficient to meet national security demands through 2064, based on several assumptions, including no reallocation of non-excess HEU to downblending operations in support of tritium production.

[11]There are no U.S.-owned enrichment facilities or foreign-owned enrichment facilities that use U.S. technology operating outside of the United States.

that relies on technology subject to these same prohibitions.[12] Under the "peaceful use" provisions of these agreements, LEU produced at these facilities can only be used for peaceful, nonexplosive purposes. In other words, the LEU carries an obligation to the foreign countries that exported the technology that it will only be used for peaceful purposes. For example, obligated LEU cannot be used in a bomb or be further enriched to HEU for other military purposes. DOE has further asserted that obligated LEU cannot be used to make tritium for military purposes.[13]

Since USEC ceased enrichment at the Paducah GDP in May 2013, and the United States lost what DOE considered to be its sole supplier of enrichment services for national security purposes, Congress has raised questions about a future source of unobligated LEU for tritium production. Only one commercial facility currently enriches uranium in the United States, and it is operated by URENCO—a consortium of companies owned or controlled by the British and Dutch governments and by two German utilities. The LEU produced by URENCO is enriched using foreign technology and is subject to a peaceful use provision in an international agreement between the United States and Germany, the Netherlands, and the United Kingdom. In addition to the ACP, three other enrichment facilities are planned for construction in the United States, but these too will use foreign technology and will be subject to peaceful use provisions contained in other international agreements.[14] Under the Consolidated Appropriations Act of 2014,[15] DOE was directed to submit a tritium and enriched uranium management plan to Congress by June 30, 2014, that includes, among other things, an assessment of the national security demand for tritium and LEU through 2060, as well as an analysis of alternative technologies that are planned or available to meet the supply needs for tritium and enriched uranium for national security

[12]According to DOE officials, all steps in the nuclear fuel cycle must be free from peaceful use restrictions to result in wholly unobligated LEU that can be used for tritium production. GAO did not evaluate steps in the nuclear fuel cycle other than enrichment for this review.

[13]LEU that does not carry "peaceful use" restrictions is referred to as "unobligated LEU."

[14]The ACP would use U.S.-developed technology, thus producing unobligated LEU. The focus of this report is on enrichment facilities that use or will use foreign technology and are subject to peaceful use provisions contained in international agreements.

[15]Consolidated Appropriations Act, 2014, Pub. L. No. 113-76, § 311, 128 Stat. 5, 175.

purposes.[16] As DOE assesses future options for obtaining unobligated LEU to produce tritium, one option may be to pay the costs to operate the ACP—potentially hundreds of millions of dollars a year. In this context, you asked us to review the peaceful use provisions in international agreements pertaining to enrichment facilities using foreign technology in the United States, particularly as they pertain to the production of tritium.[17] This report examines (1) the extent to which DOE has adhered to its practice of using only unobligated LEU to meet national security needs for tritium and (2) the basis for DOE's practice of using only unobligated LEU to meet national security needs for tritium.

To determine the extent to which DOE has adhered to its practice of using only unobligated LEU to meet national security needs for tritium, we reviewed DOE and NNSA documents. In addition, we interviewed officials from DOE, NNSA, the Department of State, and the Tennessee Valley Authority (TVA)—which produces tritium through an interagency agreement with DOE. We also reviewed documents and interviewed officials from the Nuclear Regulatory Commission (NRC). To determine the basis for DOE's practice for using unobligated LEU to meet national security needs for tritium, we reviewed DOE and NNSA documents and assessed relevant international agreements pertaining to the transfer of enrichment technology into the United States and the extent to which these agreements compel DOE to use exclusively unobligated LEU for meeting national security needs. We interviewed officials from NNSA, TVA, and the Department of State, as well as representatives from USEC and URENCO.[18] We also reviewed two analyses completed by the Congressional Research Service, including one on peaceful use restrictions applicable to uranium enriched at the URENCO facility, and we interviewed staff regarding their conclusions. To inform both objectives, we conducted site visits to the ACP in Piketon, Ohio; the Paducah GDP in Paducah, Kentucky; and DOE's Oak Ridge Office and

[16]As of October 2, 2014, DOE had not yet submitted this tritium and enriched uranium management plan to Congress.

[17]This request was originally made by the Ranking Member of the House Committee on Natural Resources, Representative Edward J. Markey, who is now a member of the Senate, and Representative Michael C. Burgess.

[18]DOE, NNSA, and Department of State officials discussed various aspects of the international agreements and nonproliferation policy with us. We only identified a public interpretation of one of the agreements, however, and, thus for the other two agreements, this report identifies a range of possible readings.

NNSA's Y-12 National Security Complex in Oak Ridge, Tennessee. Additional details on our objectives, scope, and methodology can be found in appendix I.

We conducted this performance audit from January 2013 to October 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

This section describes international agreements and peaceful use restrictions; existing and proposed enrichment facilities in the United States that use or will use foreign technology; the U.S. involvement in the markets that comprise the nuclear fuel cycle; and tritium production.

International Agreements and Peaceful Use Restrictions

The United States is a party to various treaties and international agreements that promote the peaceful use of nuclear energy. As detailed below, these include the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), peaceful nuclear cooperation agreements, and other international agreements that restrict the use of certain foreign nuclear technology and material to peaceful purposes.

- The NPT, which entered into force in 1970, distinguishes between nuclear-weapon and nonnuclear-weapon states.[19] It is considered the cornerstone of the nuclear nonproliferation regime and aims to prevent the proliferation of nuclear weapons to nonnuclear-weapon states, facilitate the use of nuclear energy for peaceful purposes, and promote nuclear disarmament. Membership in the NPT includes 190 countries, including the United States, which makes it the largest arms control treaty in the world.
- Section 123 of the Atomic Energy Act of 1954, as amended (AEA), establishes the conditions for civilian nuclear cooperation between the United States and foreign partners. The United States has 21 nuclear cooperation agreements ("123 agreements") in force with 18

[19]Nuclear-weapon states under the NPT are those that manufactured and exploded a nuclear weapon or other nuclear explosive device before January 1, 1967; nonnuclear-weapon states are those that had not.

countries, the International Atomic Energy Agency, the European Atomic Energy Community (EURATOM), and Taiwan.[20] Peaceful nuclear cooperation agreements must include, among other things, peaceful use provisions that guarantee that material and equipment transferred from the United States to its foreign partners, as well as certain material produced through the use of such material and equipment, not be used for any nuclear explosive device, for research on or development of any nuclear explosive device, or for any other military purpose.

- Three other international agreements specifically address the importation of uranium enrichment technology into the United States.[21] They include peaceful use provisions that require that transferred technology and certain material produced through the use of such technology be used only for peaceful purposes. While each agreement contains peaceful use provisions, the specific language differs among the agreements.

Existing and Proposed Enrichment Facilities in the United States That Use or Will Use Foreign Technology

There are four enrichment facilities that are currently operational or planned for operation in the United States that use or will use foreign technology. All four facilities operate or will operate under one of the three international agreements described above, which include peaceful use provisions, or obligations, on the technology and on certain material produced through the use of that technology. Each facility is briefly described below. See appendix II for the peaceful use language contained in each agreement.

- URENCO operates the only enrichment facility that is currently operating in the United States at a plant near Eunice, New Mexico. The URENCO USA plant is owned and operated by Louisiana Energy Services (LES), a subsidiary of URENCO. The URENCO centrifuge technology was initially developed in the 1960s as part of a joint venture between the United Kingdom, Germany, and the Netherlands. Use of this centrifuge technology in the United States is addressed by the *Agreement between the Three Governments of the United Kingdom of Great Britain and Northern Ireland, the Federal Republic*

[20]The parties to the agreement are the American Institute in Taiwan and the Taipei Economic and Cultural Representative Office in the United States.

[21]In this report, we use the term “technology” to refer to any technology, equipment, components, or facilities addressed by these agreements. The full language of the peaceful use provisions in these agreements is laid out in appendix II.

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, hereafter referred to as the "Washington Agreement."[22] The Treaty of Almelo[23] laid out the framework for the three countries to collaborate on the development and use of gas centrifuge uranium enrichment technology under one entity—which came to be known as URENCO.[24] The foreign governments and companies that own URENCO have expressed interest in selling the company on separate occasions since fall 2011.

- AREVA has proposed building an enrichment facility, known as Eagle Rock, near Idaho Falls, Idaho, and in October 2011 received a license from the NRC to construct and operate the facility.[25] AREVA is 90 percent owned by the French government and operates internationally. At Eagle Rock, AREVA plans to build an enrichment facility that uses the same gas centrifuge technology developed by URENCO.[26] The facility will be operated under the *Agreement between the Governments 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*

[22]*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*, July 24, 1992.

[23]*Agreement between the United Kingdom of Great Britain and Northern Ireland the Federal Republic of Germany and the Kingdom of the Netherlands on Collaboration in the Development and Exploitation of the Gas Centrifuge Process for producing Enriched Uranium*, Mar. 4, 1970.

[24]URENCO is currently owned in equal parts by the government of the Netherlands, the government of the United Kingdom, and two German utility companies.

[25]The NRC is the federal agency that regulates, among other things, the civilian uses of nuclear materials and production facilities (such as a uranium enrichment facility) in the United States.

[26]*Agreement between the Governments of the United Kingdom of Great Britain and Northern Ireland, the Kingdom of the Netherlands, the Federal Republic of Germany, and the French Republic regarding Collaboration in Centrifuge Technology*, July 12, 2005 (hereafter referred to as the "Cardiff Agreement"), laid out the framework for this collaboration between the URENCO governments and France.

Gas Centrifuge Technology in the United States of America, hereafter referred to as the "Paris Agreement."[27]

- Global Laser Enrichment (GLE) has proposed building an enrichment facility in Wilmington, North Carolina, and in September 2012 received a license from NRC to construct and operate the facility. GLE is a joint venture by General Electric, Hitachi, and Cameco.[28] GLE plans to utilize an Australian uranium enrichment technology known as Separation of Isotopes by Laser Excitation (SILEX), which is still in development for commercial demonstration. The facility, if constructed, will be operated under the *Agreement for Cooperation Between Australia and the United States of America Concerning Technology for the Separation of Isotopes of Uranium by Laser Excitation*, hereafter known as the "SILEX 123 Agreement"—a peaceful nuclear cooperation agreement.[29]
- In 2013, GLE also proposed building an enrichment facility at the site of the former Paducah GDP near Paducah, Kentucky. This facility would also use SILEX laser enrichment technology and operate under the SILEX 123 Agreement, but this facility has not yet been licensed by the NRC.[30]

Figure 1 shows the existing or planned locations of these four foreign-owned enrichment facilities, as well as the location of the planned ACP and the now-closed USEC and DOE facilities.

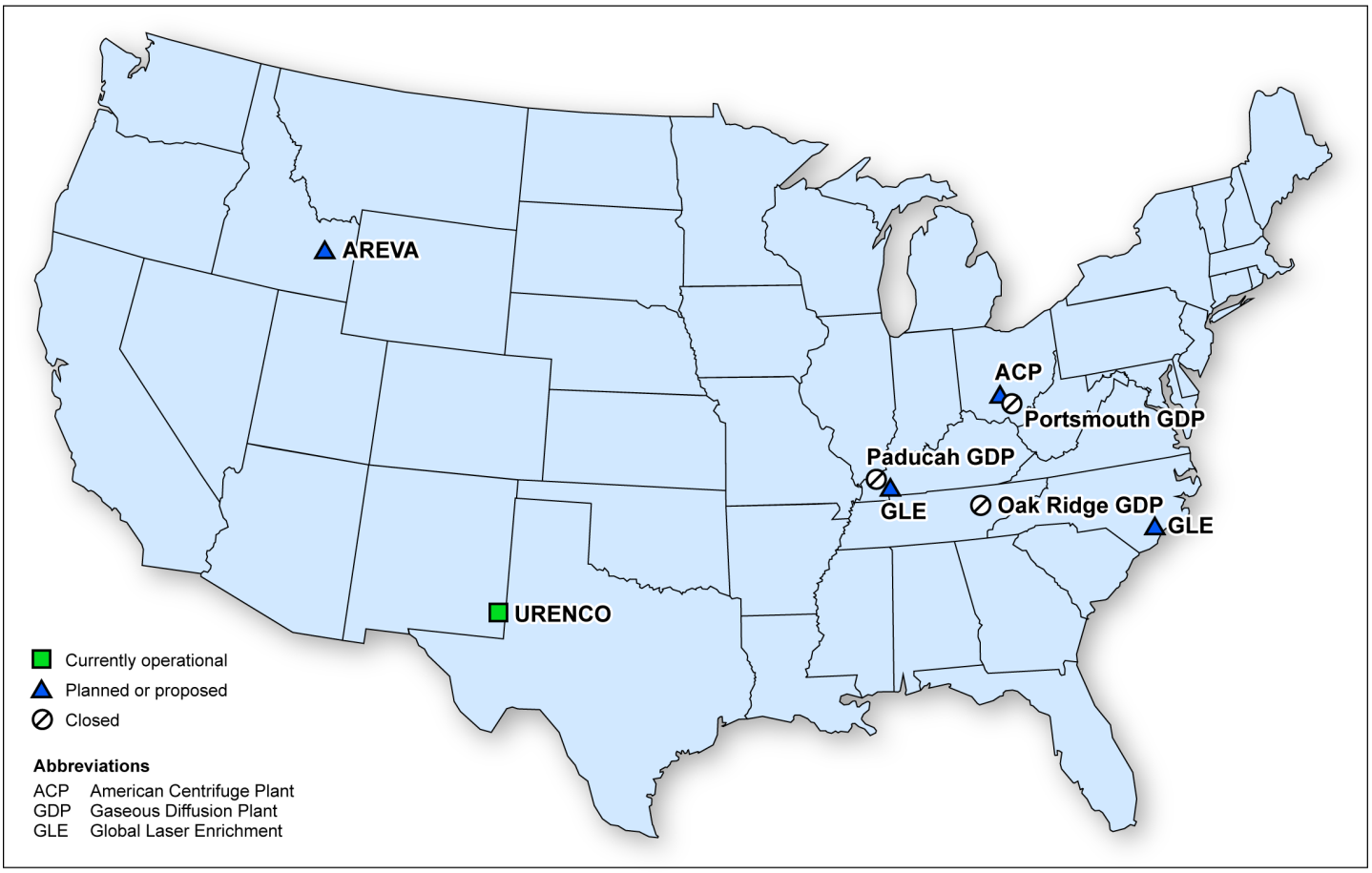
[27]*Agreement between the Government of the United States of America and the Four Governments of the French Republic, the United Kingdom of Great Britain and Northern Ireland, the Kingdom of the Netherlands, and the Federal Republic of Germany regarding the Establishment, Construction and Operation of Uranium Enrichment Installations using Gas Centrifuge Technology in the United States of America*, Feb. 24, 2011.

[28]General Electric is an American company. Hitachi is a Japanese company. Cameco is a Canadian uranium mining and conversion company. Its subsidiary, Cameco USA, is the largest uranium mining producer in the United States.

[29]*Agreement for Cooperation Between Australia and the United States of America Concerning Technology for the Separation of Isotopes of Uranium by Laser Excitation*, Oct. 28, 1999.

[30]GLE's stated use for this facility is to re-enrich depleted uranium to the level of natural uranium for further enrichment in another enrichment facility.

Figure 1: Uranium Enrichment Facilities Closed, Currently Operating, or Planned for Operation in the United States



Sources: GAO analysis of Nuclear Regulatory Commission, USEC Inc., and Department of Energy documents; Map Resources (map). | GAO-15-123

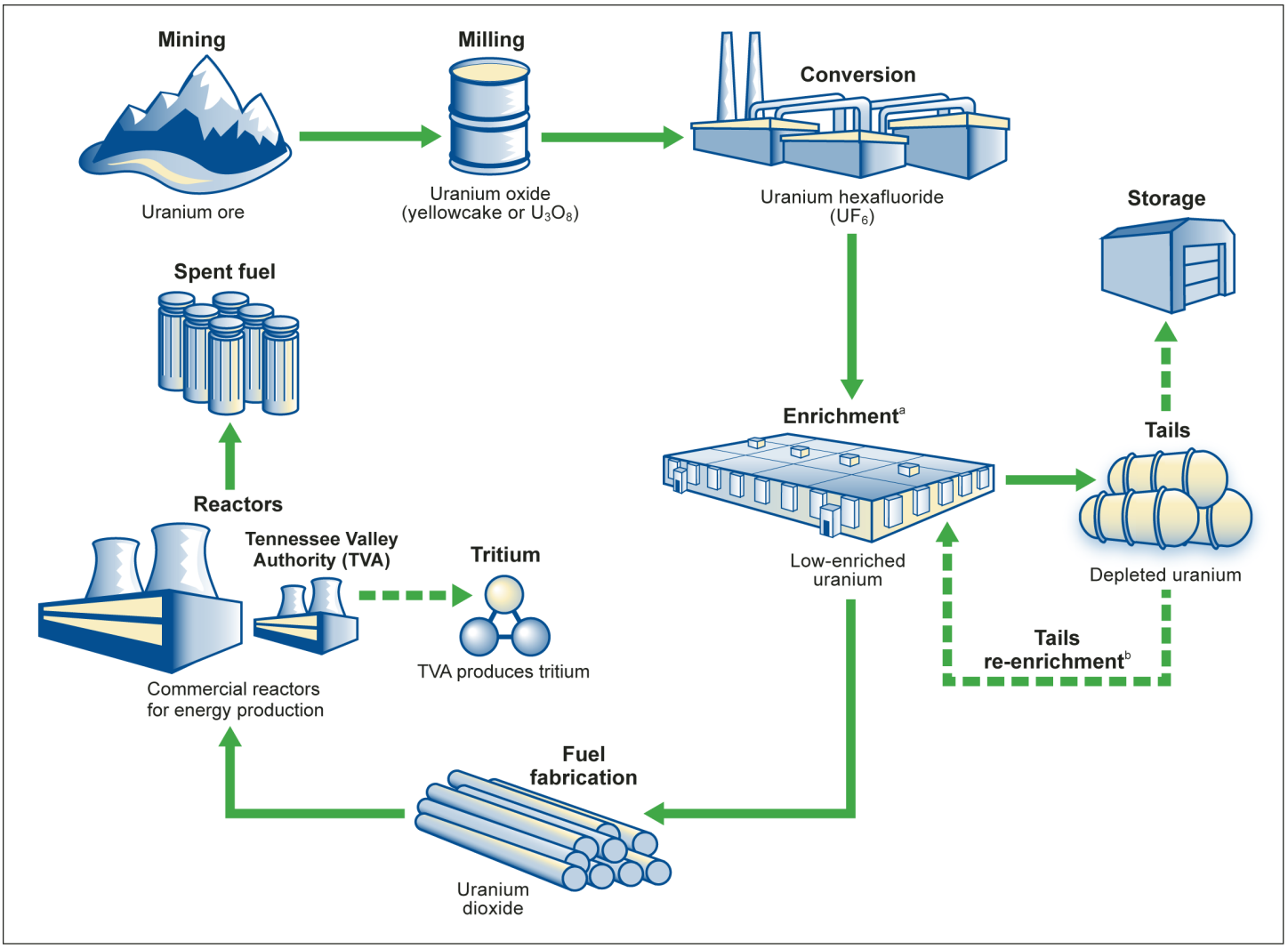
Note: DOE ceased enrichment at its Oak Ridge GDP in 1985 as a result of decreased demand for enrichment services. In 1993, the government leased the Portsmouth and Paducah GDPs to the United States Enrichment Corporation, which became a subsidiary of USEC Inc., created in 1998 at the time of privatization. USEC ceased enrichment activities at the Portsmouth GDP in 2001 also because of decreased demand for enrichment services and the high costs of operating the GDP, and it ceased enrichment activities at the Paducah GDP in 2013. The ACP is currently being maintained in operating status.

U.S. Involvement in the Nuclear Fuel Cycle Markets

According to DOE documents, all stages of the nuclear fuel cycle—the series of steps necessary to produce LEU fuel for nuclear reactors (see fig. 2)—must use unobligated natural uranium and unobligated processing technology if the resulting LEU will be used for national security purposes. Several facilities from the fuel cycle stages operate in the United States; however, the U.S. commercial nuclear industry is

highly dependent on imports of mined uranium concentrates and uranium conversion and enrichment services.

Figure 2: The Nuclear Fuel Cycle



Sources: GAO analysis of International Atomic Energy Agency, Nuclear Regulatory Commission, Congressional Research Service, Department of Energy, and TVA documents. | GAO-15-123

[a]The enrichment process results in two principal products: (1) enriched uranium hexafluoride and (2) leftover "tails" of uranium hexafluoride, also called depleted uranium because the material is depleted in uranium-235 compared with natural uranium.

[b]Tails can only be re-enriched once, if at all, after which their uranium content is too depleted to make further re-enrichment economically feasible using current centrifuge and gaseous diffusion technology.

- **Mining**: The nuclear fuel cycle begins with the mining of uranium. Uranium is relatively abundant in the earth's crust and can be found by detecting the presence of radioactivity from the air, from the earth's surface, or by excavation. The United States had a large uranium mining industry in the 1950s, but the number of domestic mines declined over time, falling from a peak of over 250 in 1980 to 11 in 2012, according to the U.S. Energy Information Administration. In 2012, the United States produced about 2.7 percent of the world's mined uranium, compared with Kazakhstan (36.5 percent); Canada (15 percent); and Australia (12 percent), according to the World Nuclear Association.
- **Milling and conversion**: After mining, the ore goes to a milling facility, where it is crushed and concentrated. There is currently only one uranium mill in operation in the United States. It is located in Utah and is operated by a Colorado-based subsidiary of a Canadian company.[31] The uranium milled at this facility is purchased by utility companies and then shipped to a conversion facility. At the conversion facility, the uranium is combined with fluorine gas to produce uranium hexafluoride, a powder at room temperature and a gas when heated. At present, there is one uranium hexafluoride conversion facility in the United States that uses U.S.-developed technology, which is located in Illinois.
- **Enrichment**: The next step is the enrichment process, which entails concentrating the uranium-235—the isotope of uranium that undergoes fission to release enormous amounts of energy—in the uranium hexafluoride. Through enrichment, uranium-235 atoms are increased to 3-5 percent, the level required for fuel used in most U.S. commercial power plants.[32] In 1993, the United States produced more than 90 percent of the enriched uranium used in U.S. nuclear reactors but, by 2008, only 15 percent was domestically produced. Currently, URENCO operates the only commercial enrichment facility operating in the United States, and it uses European-developed technology. As previously noted, there is currently no commercial facility operating that uses U.S.-developed technology to enrich uranium in the United States.

[31]According to NRC officials, because the milling technology is originally derived from U.S. refinement methods, the uranium processed in the United States by this company is not considered to be obligated.

[32]Natural uranium has a concentration of uranium-235 of 0.7 percent, while depleted uranium has a concentration of uranium-235 less than 0.7 percent.

- **Fuel fabrication**: The enriched uranium is then shipped to a fuel fabrication facility. At the fuel fabrication facility, the enriched uranium is converted to uranium dioxide powder and formed into ceramic pellets about the size of a pencil eraser. The pellets are loaded into metal tubes that are bundled together to form fuel assemblies, which are typically about 5 to 10 inches square and are 12 to 14 feet long. The fuel assemblies are then shipped to nuclear power plants. According to the NRC, several nuclear fuel fabrication facilities are licensed to operate in the United States.[33]

Tritium Production

In 1998, DOE sought to develop tritium production technology because the last of its reactors used for tritium production was shut down in 1988 due to safety concerns. Between 1988 and 1998, DOE was able to meet its tritium requirements by harvesting and recycling it from dismantled nuclear warheads, as the United States decreased the size of its nuclear arsenal. However, because of tritium's short half-life, DOE could not meet its long-term tritium needs in this manner indefinitely and established the Commercial Light Water Reactor Program in 1996 to resume new tritium production; the program was renamed the Tritium Readiness Subprogram in 2003.[34] DOE ultimately decided to produce tritium through an interagency agreement with TVA at the Watts Bar and Sequoyah commercial nuclear reactors, which are owned and operated by TVA, a government corporation, and produce electricity as their principal purpose.[35]

[33]According to NNSA officials, because the facilities are old, DOE has reasonable assurance that the existing technology and components of the fuel fabrication facility that it uses are of U.S. origin.

[34]The Department of Defense is responsible for implementing the U.S. nuclear deterrent strategy, which includes establishing the military requirements associated with planning for the nuclear weapons stockpile. NNSA and the Department of Defense work together to produce the Nuclear Weapons Stockpile Memorandum. This memorandum outlines a proposed plan for the President to sign to guide U.S. nuclear stockpile activities. This plan specifies the size and composition of the stockpile and other information concerning adjustments to the stockpile for a projected multi-year period. While the exact requirements are classified, NNSA uses the detailed information included in the memorandum on the number of weapons to be included in the stockpile to determine the amount of tritium needed to maintain these weapons.

[35]In 1999, DOE entered into an interagency agreement with TVA to produce tritium in its Watts Bar and Sequoyah reactors, for which DOE would pay TVA approximately $1.5 billion for its costs over the agreement's 35-year term. To date, only TVA's Watts Bar 1 reactor has been used to produce tritium under this agreement.

Small quantities of tritium are normal by-products of the process nuclear power plants use to generate electricity. Nuclear power plants routinely and safely release diluted concentrations of water containing tritium. For DOE's (now NNSA's) tritium production program, TVA takes several steps to produce tritium for NNSA's use. Specifically, to produce tritium, stainless steel rods containing lithium aluminate clad in zirconium—called tritium-producing burnable absorber rods (TPBAR)—are irradiated in the Watts Bar 1 reactor. Instead of the ceramic rods containing boron that are inserted in most U.S. commercial nuclear reactors—as a subset of the fuel assembly rods, most of which contain nuclear fuel—TPBARs are inserted into the Watts Bar 1 reactor core during refueling and are irradiated for approximately 18 months. They are then removed and transported to DOE's Tritium Extraction Facility at the Savannah River Site in South Carolina, where they are processed in a specialized facility to extract and then prepare the tritium for nuclear warheads.

Under the interagency agreement between DOE and TVA, TVA must use unobligated LEU in its reactors that are used to produce tritium for NNSA. It is the responsibility of DOE/NNSA to ensure that TVA can obtain unobligated fuel to support tritium production, and DOE/NNSA is responsible for reimbursing TVA for any additional costs associated with this exclusivity.[36] According to DOE, unobligated LEU has a premium—that is, it costs more than other LEU that may carry obligations from other countries—because the gaseous diffusion technology USEC had been using to enrich uranium was older, less energy efficient, and more expensive than the centrifuge technology used by USEC's main foreign competitors.

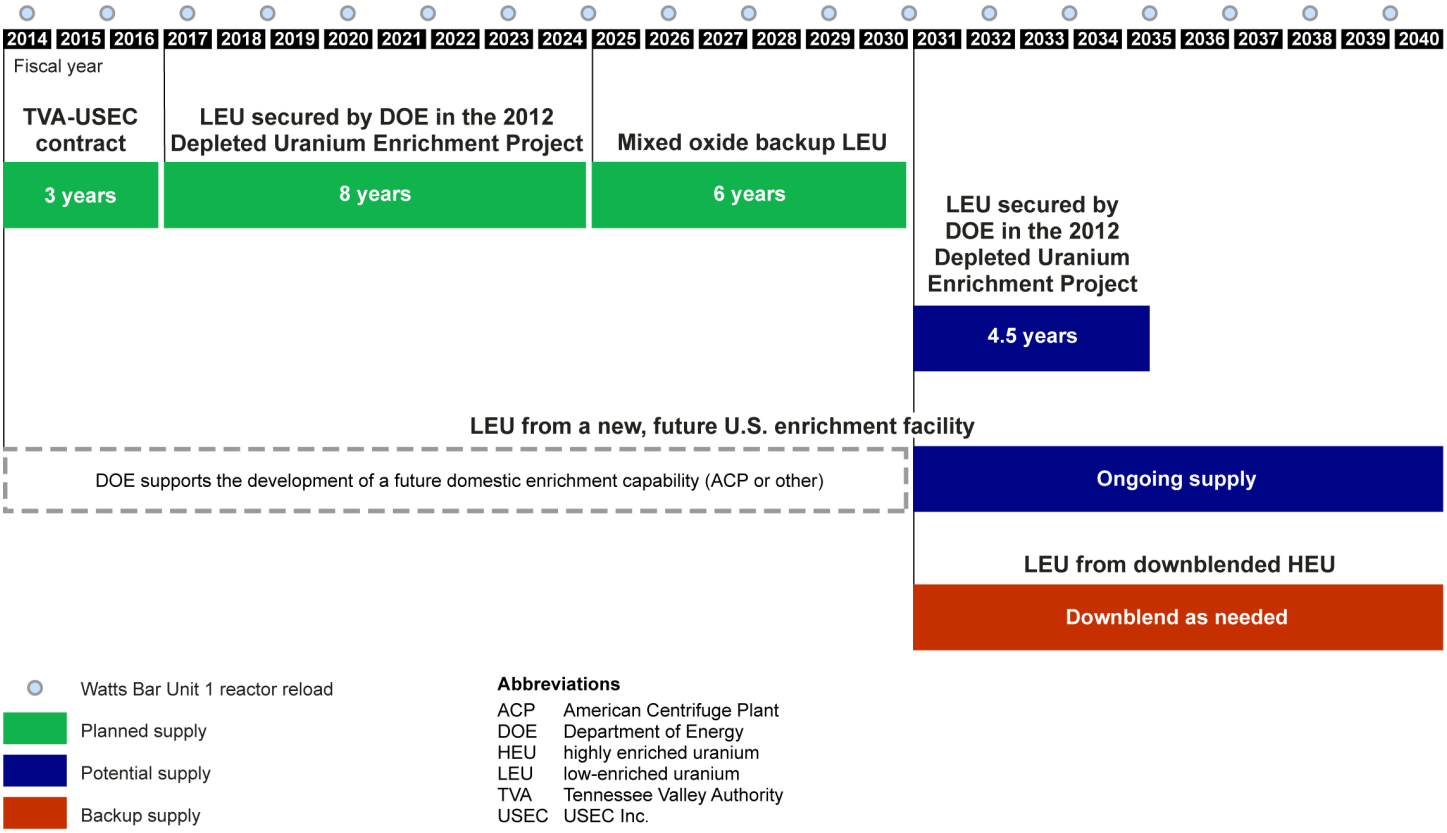
According to DOE's November 2013 draft *Tritium and Enriched Uranium Management Plan through 2060*, DOE's tritium production needs can be met using unobligated LEU inventories that will last through the mid-2030s. These inventories include the final deliveries of unobligated LEU from three sources (see fig. 3):

[36]The interagency agreement is intended to be at cost such that TVA neither loses money nor profits from it. NNSA agreed to pay TVA the cost difference—known as the enrichment price differential—for TVA's commercial nuclear power reactors that are part of the tritium program. To determine the differential, the cost of fuel in TVA's tritium program reactors is compared with the market price for LEU at a reference location (regardless of obligations). The reference location was selected as the best proxy for market prices TVA would have paid if it did not participate in the tritium program.

- **TVA's contract with USEC**: TVA signed a contract with USEC in December 1999 to purchase unobligated LEU from USEC through the middle of fiscal year 2015.
- **The 2012 Depleted Uranium Enrichment Project**: In May 2012, DOE initiated a series of uranium transfers between multiple parties to ensure availability of a supply of unobligated LEU for TVA to purchase from an energy company starting in mid-2015 through 2022. DOE expects that this will result in up to 15 years of unobligated LEU for tritium production, assuming the use of a single TVA reactor.[37]
- **Mixed Oxide Fuel Backup LEU Inventory Project**: DOE maintains a reserve of unobligated LEU from an NNSA HEU disposition program referred to as the Mixed Oxide Backup LEU Inventory Project. DOE plans to use this unobligated LEU directly or for obligation exchanges—the process of swapping obligated uranium for similar types and amounts of unobligated uranium—to obtain additional LEU suitable for tritium production. DOE expects that this will provide about 6 years of unobligated LEU for tritium production, assuming the use of a single TVA reactor.

[37]See GAO-14-291 for additional details on this series of uranium transfers described as the "May 2012 Tails Transfer."

Figure 3: Planned, Potential, and Backup Supplies of Unobligated Low-Enriched Uranium for Tritium Production, 2014 to 2040



Sources: GAO analysis of DOE and National Nuclear Security Administration (NNSA) documents and interpretation of a graphic from DOE's Fiscal Year 2015 Stockpile Stewardship and Management Plan. | GAO-15-123

Notes: The low-enriched uranium supply projections are based on TVA using one nuclear reactor to produce tritium.

According to DOE, the LEU secured by DOE in the 2012 Depleted Uranium Enrichment Project will result in up to 15 years of unobligated LEU for tritium production. DOE's fiscal year 2015 Stockpile Stewardship and Management Plan only details the use of 12.5 years of LEU from the Depleted Uranium Enrichment Project for tritium production.

However, this plan also notes that, if it becomes necessary to use more than one TVA nuclear reactor to meet DOE's tritium production goals, the current LEU inventory intended for tritium production could be exhausted by the mid-2020s. Despite redesigns of several components of the TPBARs, tritium has been leaking—or "permeating"—out of the TPBARs at higher-than-expected rates into the Watts Bar reactor's coolant water. As a result, TVA has had to limit the number of TPBARs irradiated per cycle to keep the total amount of tritium released into the reactor coolant below regulatory limits, thereby resulting in significantly lower tritium

production than originally planned. NNSA and TVA have consequently been developing plans to seek a license amendment to irradiate increased numbers of TPBARs, which could result in a need to expand tritium production to TVA's Sequoyah reactor. Such an expansion would essentially double unobligated LEU consumption, using the unobligated LEU supply at an accelerated rate.

DOE is currently analyzing options for meeting national security needs for LEU after the supply sources noted above have been exhausted. Such options could include utilizing the American Centrifuge technology, developing a new domestic enrichment capability, or downblending HEU—which is the process of mixing HEU with either depleted or natural uranium, or LEU, to produce a new product that has a lower concentration of uranium-235. In the absence of a domestic enrichment capability, DOE documents state that it would consider downblending HEU only as a backup plan because most of the HEU it possesses is currently dedicated to other national security missions, such as for naval reactors.[38]

DOE Has Only Used Unobligated LEU to Meet National Security Needs for Tritium Production

DOE uses only unobligated LEU to meet national security needs for tritium production and has taken several steps to adhere to this practice. In several key DOE documents—dating back to 1998 and as recent as 2014—that we reviewed, DOE has stated that tritium will only be produced using unobligated LEU. For example, in its fiscal year 2011 draft report, *National Strategic Plan for Nuclear Materials*, DOE stated that tritium production requires a supply of domestic-origin LEU fuel not subject to the peaceful use restrictions applied to foreign-origin uranium. In addition, in its fiscal year 2015 *Stockpile Stewardship and Management Plan*, DOE discussed the various sources of unobligated LEU available to support tritium production. Numerous senior DOE and NNSA officials also consistently told us in interviews that tritium can only be produced using

[38]Quantities of HEU were declared excess to national security needs in 1994 and 2005, which made some of this excess HEU available for downblending. According to DOE documents, the 1994 declaration by the President pledged that 174 tons of HEU would never again be used for any military purpose, including naval propulsion and tritium production. In 2005, the Secretary of Energy declared 200 tons of HEU excess to the weapons program. According to DOE documents, the 2005 declaration specifically allowed for use of this material for naval propulsion and tritium production. Most of this declared HEU has already been dedicated to specific purposes, such as for naval reactors and downblending to fuel research reactors.

unobligated LEU. Finally, in letters to congressional representatives, former Secretary of Energy Steven Chu and other senior DOE officials have indicated that unobligated LEU is needed to support tritium production. In certain cases, only one supplier in the nuclear fuel cycle is available to provide unobligated services. For example, there is only one conversion facility that uses U.S. technology and only one milling company that uses U.S. technology.[39]

In addition, for over six decades, DOE has taken a number of steps to ensure that only unobligated LEU is used for tritium production for national security purposes, as described in the following examples:

- To secure and develop a domestic supply of uranium for the nation's defense needs, beginning in 1948, the U.S. Bureau of Land Management withdrew certain uranium-rich land from the public domain and reserved it for the use of DOE's predecessor agency, the Atomic Energy Commission. Through this land, DOE has ensured that natural uranium, domestic in origin, and therefore unobligated, is available to be mined for national security purposes.
- DOE's 1999 interagency agreement with TVA for the production of tritium states that any reactor core that is irradiating TPBARs must contain unobligated fuel.[40] According to this agreement, DOE is responsible for ensuring that TVA can obtain unobligated LEU to support tritium production. As previously discussed, DOE is responsible for reimbursing TVA for any additional costs associated with using unobligated LEU, as obligated LEU is generally less expensive.
- DOE has worked with USEC to help ensure that the American Centrifuge technology and its components are domestic in origin. The ACP is intended to produce LEU both for tritium production and potentially for commercial nuclear power plants. According to USEC officials, 100 percent of the centrifuge components are domestic or

[39]GAO did not evaluate steps in the nuclear fuel cycle other than enrichment for this review.

[40]Currently, TVA produces tritium in one reactor, Watts Bar 1. However, a second reactor, Sequoyah, is considered to be in backup status and may also be used for tritium production. As such, TVA is required by its agreement with DOE to use only unobligated LEU in Watts Bar 1 and may use obligated LEU in the Sequoyah reactor until formally notified by DOE to do otherwise.

unencumbered,[41] and a few peripheral support systems contain foreign components, but steps have been taken to bypass the foreign components that carry obligations if the plant is used to enrich LEU for use in tritium production. For example, USEC procured foreign-produced feed and withdrawal system components for the American Centrifuge technology. USEC officials demonstrated to us a specific work-around that will enable it to bypass the foreign equipment should the ACP be used to produce LEU for national security purposes.[42]

- In May 2012, in anticipation of USEC ceasing enrichment operations at the Paducah GDP, DOE initiated a complex series of transactions to ensure availability of a supply of unobligated LEU from USEC for future tritium production. The transactions involved DOE transferring U.S. origin depleted uranium tails to an energy company, which then contracted with USEC to enrich those tails to LEU. The energy company entered into an agreement with TVA to sell the majority of the resulting unobligated LEU to TVA starting in 2015, which TVA then plans to use to produce tritium for NNSA. DOE estimates that this series of transactions, known as the 2012 Depleted Uranium Enrichment Project, will provide up to 15 years of unobligated LEU for tritium production. According to DOE, this, along with other potential available sources, such as the Mixed Oxide Backup LEU Inventory Project, will help ensure a supply of unobligated LEU that will last through the mid-2030s, depending upon whether one or two reactors are needed to use this unobligated LEU to produce NNSA's annual tritium requirements.
- DOE has used a practice called an "obligation exchange"—or flag swapping—in which DOE may swap obligated uranium with itself, or with other parties such as NRC regulated entities, for similar types and amounts of unobligated uranium (*e.g.*, 1 ton of obligated natural uranium for 1 ton of unobligated natural uranium). Because uranium is considered by the industry to be fungible—that is, being of a nature that is easily exchangeable—the obligation exchange is made on the uranium inventory records, and no physical material is actually moved. DOE has used obligation exchanges in the past to ensure that LEU—and all of the processes that uranium undergoes before it is in a form useful for tritium production—is preserved as unobligated. For

[41]Unencumbered LEU refers to LEU that is not encumbered by peaceful use restrictions and is thus considered to be unobligated.

[42]According to a senior NNSA official, the foreign government that placed the peaceful use obligations on the component agreed to this resolution.

example, if DOE were to use LEU from the Mixed Oxide Backup LEU Inventory Project as discussed above, then it could pursue flag swapping as a way to ensure that this additional LEU would not carry obligations and would therefore be suitable for tritium production.

DOE's Practice of Using Unobligated LEU for Tritium Production Is Based on a Mix of Legal and Policy Considerations, but a Key Assumption Underlying This Practice Has Changed

According to DOE and the Department of State, DOE's practice of using exclusively unobligated LEU to meet national security needs for tritium production is based on both legal and policy considerations, including the U.S. commitment under international agreements that contain peaceful use provisions and U.S. nonproliferation policy goals. We found that there are three key international agreements that address foreign uranium enrichment facilities currently operating or planned for future operation in the United States. DOE believes that such agreements must be interpreted in light of U.S. nonproliferation policy and goals—including preventing other countries from producing tritium from U.S.-obligated uranium—and State officials told us that to construe the Washington and Paris Agreements regarding the permissibility of tritium production without regard to U.S. nonproliferation policy and goals could be detrimental. We found that only one of the agreements explicitly addresses by-product material such as tritium and that this agreement likely prohibits the production of tritium for any nuclear explosive device or for any military purpose. The other two agreements do not explicitly address whether only unobligated LEU may be used for tritium production; they are silent on this point. However, a key assumption underlying the decision to rely exclusively on unobligated LEU—that the United States has an ample supply of unobligated LEU—has changed with USEC ceasing enrichment operations and the uncertain future of the ACP. This change has led some parties to question whether a change in DOE's practice could result in the United States obtaining LEU for national security purposes from other enrichment facilities, such as URENCO, and avoid the potentially significant expense of paying the costs to operate the ACP.

DOE's Practice of Using Unobligated LEU Is Based on a Mix of Legal and Policy Considerations

DOE documents state and officials from DOE and the Department of State told us that DOE's practice of using only unobligated LEU for the production of tritium is based on both legal and policy considerations. For example, DOE's November 2013 draft *Tritium and Enriched Uranium Management Plan through 2060* links its practice to both law and policy when it states that, "U.S. nuclear nonproliferation policy and U.S. international agreements for peaceful uses of nuclear materials require that any nuclear weapons materials be produced using materials,

technologies, production equipment, and infrastructure that is free of foreign peaceful use restrictions."

DOE References Legal Considerations for Its Practice; Only One of the Three International Agreements We Reviewed Explicitly Addresses By-product Material Such as Tritium

Various DOE documents state that international agreements require that it use exclusively unobligated LEU for tritium production. DOE and Department of State officials explained that the United States has nonproliferation obligations under agreements to which the United States is a party that pertain to uranium enrichment facilities and associated technology imported into the United States. As discussed above, these agreements contain peaceful use provisions that require that transferred equipment and certain material produced through the use of such equipment be used only for peaceful, nonexplosive, purposes. The Executive Branch has made public its interpretation that the SILEX 123 agreement does not allow the use of SILEX technology for tritium production.[43] However, we did not identify any public interpretation of the peaceful use restrictions of the Washington Agreement or the Paris Agreement with respect to tritium production for national security purposes. State officials noted that primary responsibility within the executive branch for the interpretation of U.S. obligations under an international agreement falls to the Secretary of State. State officials indicated that "concerns about this issue [specifically interpreting the peaceful use restrictions in the Washington Agreement] have been raised within the executive branch."

As noted above, Section 123 of the AEA requires a guarantee that U.S. exports and special nuclear material used in or produced through those exports will not be used for any nuclear explosive device, or for research on or development of any nuclear explosive device, or for any military purpose. Department of State officials told us that it would be inconsistent to read the peaceful use provisions implementing that requirement in U.S. peaceful nuclear cooperation agreements to prohibit the use of nuclear material covered by such agreements to produce tritium for weapons, while at the same time construing the substantively similar peaceful use provision of the Washington Agreement to permit use of the LEU covered by that agreement to produce tritium for weapons, even if the specific language of that agreement does not explicitly reference use of special nuclear material for production or use of by-product material.

[43]President's Message to Congress Transmitting the Australia-United States Agreement on Technology for the Separation of Isotopes of Uranium by Laser Excitation with Documentation, 35 Weekly Comp. Pres. Doc. 2243 (Nov. 3, 1999).

We analyzed the three key agreements that specifically address the importation of uranium enrichment technology into the United States—the Washington Agreement, the Paris Agreement, and the SILEX 123 Agreement, which address the URENCO facility, the planned Eagle Rock facility, and the planned GLE facility, respectively—and we found that only one of the three international agreements we reviewed explicitly addresses by-product material, which includes tritium. However, DOE interprets and applies these agreements through the lens of U.S. nonproliferation goals, and thus it has consistently used only unobligated LEU for tritium production.[44]

The peaceful use provisions of the Washington and Paris Agreements are substantially the same. They provide as follows:

> Any [technology], equipment and components transferred into the United States subject to this Agreement, [the facility itself and any nuclear material in the facility], any special nuclear material 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 [the facility which] is designated Restricted Data while such data is under the jurisdiction of the United States Government or [applicable foreign governments] shall only be used for peaceful, non-explosive purposes.[45]

Two clauses from these provisions are specifically relevant to this analysis. The first provides that special nuclear material produced through the use of transferred enrichment technology must only be used for peaceful, nonexplosive purposes. We refer to this clause as “the first clause.” The second clause provides that special nuclear material produced through the use of such special nuclear material must only be used for peaceful, nonexplosive purposes. We refer to this clause as “the second clause.” “Special nuclear material” as defined in these two

[44]We also analyzed the peaceful use language in a selection of other international treaties and agreements that relate more generally to nonproliferation and nuclear trade. As summarized in appendix III, we found that those agreements do not speak directly to whether only unobligated LEU may be used for tritium production.

[45]See appendix II for the complete text of these provisions.

agreements includes LEU and plutonium, but not tritium.[46] Accordingly, these agreements explicitly prohibit (1) using the technology to enrich uranium for nuclear weapons and (2) using uranium enriched by the technology to produce additional special nuclear material, such as plutonium, for nuclear weapons. Since tritium is not a special nuclear material, it is unclear whether using obligated LEU to produce tritium for nuclear weapons is prohibited under the Washington and Paris Agreements.

There are alternative ways to interpret the peaceful use provisions in the Washington and Paris Agreements with regard to the production of tritium. One alternative reflects a narrower reading of the agreements just to prohibit (1) the use of obligated uranium in weapons or (2) the use of obligated uranium to produce additional special nuclear material for weapons. Under this reading, the breadth of the first clause—which limits the use of uranium enriched by the technology to peaceful purposes—is limited by the second clause, which specifically prohibits the production of additional special nuclear material from the uranium enriched by the technology. Arguably the imposition of limits only on the use of special nuclear material derived from obligated uranium suggests that no limits on other types of material, such as by-product material like tritium, are to be inferred. Furthermore, the second clause of the provision arguably serves no purpose in the text if it does not limit the breadth of the first clause because the first clause on its own would already prohibit the production of special nuclear material from the obligated uranium, along with all other military purposes. Under this reading, obligated uranium may not be used directly in weapons and may not be used to produce additional special nuclear material, such as plutonium, for weapons. The agreements are silent as to tritium production.

[46]Specifically, the agreements define "special nuclear material" to include "plutonium, uranium-233, and uranium enriched in the isotopes U-233 or U-235." By comparison, "special nuclear material" is defined by the AEA to include plutonium or uranium enriched in the isotope 233 or in the isotope 235 and any other material that NRC determines to be special nuclear material, but it does not include source material. The NRC has not declared any other material—including tritium—as special nuclear material. In addition, the 1998 interagency review, *Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies under Consideration by the Department of Energy*, states that, "…tritium is not a fissionable material capable of sustaining a nuclear reaction. Thus, it is not classified as a special nuclear material...".

Another interpretation reflects a broader reading of the agreements, to prohibit the use of obligated uranium for any military purpose. Under this reading, the scope of the first clause is not limited by the second clause; rather, the second clause simply emphasizes a particular prohibition on the use of uranium enriched by the technology. Under this reading, obligated uranium may not be used for any non peaceful purpose, specifically including the production of additional special nuclear material and more generally including the production of any other weapons material, such as by-product material like tritium.[47] This reading is consistent with DOE's long-standing practice of using only unobligated uranium for the production of tritium for nuclear weapons.

The peaceful use provision of the third agreement—the SILEX 123 Agreement—differs somewhat from those of the Washington and Paris Agreements. It provides as follows:

> 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.

This provision prohibits the use of the transferred enrichment technology and any material produced through their use for any nuclear explosive device or for any military purpose. "Material" is defined by the agreement to include enriched uranium, plutonium, and by-product material, such as tritium.[48] Accordingly, it prohibits using the technology to enrich uranium

[47]This broader reading would also arguably prohibit the use of obligated uranium for the production of power to be used for any military activities. For example, under this reading, the uranium enriched by a facility using power produced from obligated uranium would itself be obligated. As noted above, the Paducah GDP was, until May 2013, DOE's sole supplier of enrichment services for national security purposes. While the Paducah plant obtained its power from TVA, that power was provided by the Shawnee Power Plant, which is a coal-fired power plant.

[48]Specifically, the agreement defines "material" to mean "source material, special nuclear material, byproduct material, radioisotopes other than byproduct material, or any other such substance so designated by agreement of the Parties." "Special nuclear material" is defined to mean "(1) plutonium, uranium 233, or uranium enriched in the isotope 235 or (2) any other material so designated by agreement of the Parties." "Byproduct material" is defined to mean "any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material." Tritium is produced in this way.

directly for nuclear weapons and likely also prohibits using obligated LEU for the subsequent production of other weapon materials such as plutonium and tritium. The presidential message transmitting the SILEX 123 agreement to Congress in 1999 supports this conclusion. Specifically, the letter stated that all material produced by and through the use of the SILEX technology would be precluded from use in U.S. nuclear weapons and naval nuclear propulsion programs and that, furthermore, "…all other military uses of this material, such as tritium production and material testing, would . . . not be possible because of the assurances given to the Government of Australia."

We sought to identify a range of readings of these three agreements because, while DOE has stated what it believes the agreements require, and the Department of State discussed various aspects of the agreements with us, we only identified a public interpretation of one of the agreements. If DOE and State were to put forth a formal interpretation, we note that courts have found that such interpretations are entitled to "great weight."[49] In addition, it is the Administration's prerogative to make international nonproliferation policy,[50] and State officials stated that their reading of the agreements is supported by the text of those agreements and consistent with U.S. nonproliferation policy interests, as described below, and is also reflected in nuclear cooperation agreements with other

[49]*Factor v. Lauenheimer*, 290 U.S. 276, 295 (1933); *Kolovrat v. Oregon*, 366 U.S. 187, 194 (1961); *Sumitomo Shoji America, Inc. v. Avagliano*, 457 U.S. 176, 184-85 (1982); *Restatement (Third) of the Foreign Relations Law of the U.S.* § 326 (1987).

[50]*Societe Nationale Industrielle Aerospatiale v. United States Dist. Court for S. Dist. Of Iowa*, 482 U.S. 522, 552 (U.S. 1987); *see also Restatement (Third) of the Foreign Relations Law of the U.S.* § 1 (1987) (In strictly domestic matters, Congress enacts laws and the President takes care that the laws be faithfully executed. In domestic affairs, presidential action can be seen as a source of law primarily as he exercises authority delegated to him by Congress, and secondarily insofar as some law-making is inherent in the interpretation and execution of laws. In foreign affairs, however, the President is clearly a separate source of law since he makes treaties (with the advice and consent of the Senate), which are the law of the land. As the 'sole organ of the nation in its external relations,' in whom is lodged 'the executive power,' and as Commander in Chief, the President also has authority to make other agreements wholly on his own authority") (internal citations removed).

countries.[51] Officials told us that they believe that U.S. practice is in keeping with that of other countries on this point and that the best way to ensure that U.S. policy is upheld with respect to our requirements on other countries is to interpret our obligations to other countries in a similar manner.

U.S. Nonproliferation Policy Goals Call for DOE to Use Unobligated LEU for Tritium Production

According to DOE officials, U.S. policy considerations are furthered by having a domestic uranium enrichment capability for tritium production. Specifically, the United States has broad nonproliferation policy goals that build on its commitments under the NPT regarding the prevention of the proliferation of nuclear weapons.[52] A 1998 interagency report concluded that, in utilizing commercial light water reactors owned by TVA to produce tritium for defense purposes, to preserve the military-civilian dichotomy, DOE should fuel such reactors only with U.S. LEU fuel that was "unencumbered by peaceful use pledges." This report, entitled *Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies under Consideration by the Department of Energy*, was prepared following a review conducted by DOE, the Departments of State and Defense, and several other agencies to consider nonproliferation issues associated with using a commercial reactor—in this case, TVA's Watts Bar 1 and potentially Sequoyah

[51]For example, they cited the U.S. 123 Agreement with India, which explicitly prohibits the use of by-product material, such as tritium, produced through the use of transferred nuclear material or equipment for any nuclear explosive device or for any military purpose. We note that, unlike certain of the agreements discussed in the text above, there is only one interpretation of the 123 Agreement with India in this regard. This is because the equipment transferred under the agreement is reactor equipment—which can be used to produce tritium in one generation—not enrichment equipment, which can only be used to produce tritium in a subsequent generation and through the use of additional reactor equipment.

[52]Under the NPT, the United States is obligated not to transfer possession or control of nuclear weapons or other nuclear explosive devices, and not in any way to assist, encourage, or induce any nonnuclear-weapon state to manufacture or otherwise acquire or control such weapons or devices. According to Department of State officials, the United States must therefore ensure that its nuclear cooperation with nonnuclear weapon states is exclusively for peaceful purposes. It implements this obligation, among other ways, through the peaceful use provisions in U.S. 123 Agreements.

reactors—to establish a new domestic means for tritium production.[53],[54] The interagency review determined that several factors could mitigate the potential impact of this path forward for tritium production on U.S. nonproliferation policy. First, the review concluded that using a commercial light water reactor was not prohibited by law or international treaty,[55] and second that the use of a government-owned and -operated nuclear reactor (a TVA reactor) to produce an essential material for nuclear weapons contributed to minimizing a divergence from the separation between civil and military nuclear applications that evolved in the 1950s and 1960s.[56] According to this review, the United States

[53]*Interagency Review of the Nonproliferation Implications of Alternative Tritium Production Technologies under Consideration by the Department of Energy*, Report to the Congress, July 1998. Participants in the review included the Departments of Defense, Energy, and State; the Arms Control and Disarmament Agency; the Nuclear Regulatory Commission; the National Security Council; the White House Office of Science and Technology Policy; and the Office of the Vice President.

[54]The report analyzed the nonproliferation implications of the United States pursuing three tritium production technologies: a commercial light water reactor, a proton accelerator, and the Fast Flux Test Facility. The accelerator technology would accelerate protons (particles within an atom that have a positive electrical charge) to nearly the speed of light. The protons would impact or collide with tungsten, releasing neutrons through a process called spallation, which can be used to change helium into tritium. The Fast Flux Test Facility is a sodium-cooled, fast-neutron flux reactor plant designed specifically for irradiation testing of nuclear reactor fuels and materials for liquid metal fast breeder reactors. Neither of the latter two options was ultimately pursued.

[55]Specifically, the review notes that (1) the sole prohibition in U.S. law against the use of a commercial reactor for defense purposes relates to a ban on the use for nuclear explosive purposes of special nuclear material, such as uranium or plutonium produced in a commercial reactor, not tritium; (2) the NPT would not ban the use of U.S. commercial reactors for defense purposes because, as a nuclear-weapon state party to the treaty, the United States is not prohibited from manufacturing weapons or materials needed for their production; (3) the U.S Safeguards Agreement with the International Atomic Energy Agency would not ban the production of tritium in a commercial reactor because safeguards are applied to source materials, such as LEU and purified natural uranium, and special fissionable materials, such as HEU and plutonium, but not to tritium; and (4) to the extent that nuclear cooperation agreements prohibit imported fuel and equipment from being used for explosive purposes, the United States would assure its foreign trading partners that no restricted fuel or equipment was used for tritium production.

[56]In addition, the report asserted that, although use for tritium production of a nuclear reactor producing energy for civilian use could raise concerns about the practice of military-civilian dichotomy separation in U.S. nuclear energy programs, the particular reactors proposed to be used for this purpose would be wholly owned by the U.S. government, rather than by a private entity and, therefore, would be in effect extending the past practice of using government-owned facilities simultaneously for civil and military purposes rather than setting a precedent.

developed its commercial nuclear power industry beginning in the 1950s and by the mid-1960s had insulated that industry from producing materials for nuclear weapons. To mitigate concerns associated with using a commercial light water reactor for tritium production, the review concluded that DOE should exclusively use LEU that is unobligated by peaceful use restrictions to maintain the separation between the military and civilian sectors. Notably, this conclusion was predicated on an assumption that the United States had a sufficient supply of unobligated LEU available for use in the TVA reactor. Specifically, the report states that "there are ample supplies of unencumbered U.S. low enriched uranium to satisfy the fueling needs of a CLWR [commercial light water reactor] used for the production of tritium." On these bases, the administration determined that the nonproliferation policy issues associated with using a commercial light water reactor were manageable and that DOE should pursue this option for future tritium production, which it did. A subsequent 1999 Record of Decision for tritium supply and recycling incorporated the conclusion about using only unobligated uranium by indicating that production of tritium for nuclear weapons by commercial reactors "would be operated in compliance with international agreements imposing restrictions on use of transferred materials for peaceful purposes only, *e.g.*, no reactor fuel or component transferred under these agreements would be used by any reactor making tritium."[57]

Officials from DOE, NNSA, and the Department of State outlined a number of additional policy considerations that inform DOE's interpretation of international agreements and its associated practice of using only unobligated LEU for the production of tritium, including the following.

- In keeping with broad nonproliferation goals, NNSA officials told us that, if the United States did not require the use of unobligated LEU for its own national security purposes, it could cause an unintended "domino effect" abroad. For example, some countries purchase LEU on the open market, and the United States would not want to set a precedent for "blurring the line" between using LEU for energy purposes and using LEU for tritium production or other military purposes when the LEU carries broad peaceful use obligations.

[57]64 Fed. Reg. at 26,369 (May 14, 1999).

According to NNSA officials, the consequences of setting such a precedent could be severe.

- Furthermore, according to State officials, they believe that permitting the use of foreign-obligated nuclear fuel for tritium production for nuclear weapons could encourage other countries to argue that they could use U.S.-obligated material for production of tritium for foreign military purposes under their peaceful nuclear cooperation agreements with the United States.
- NNSA officials told us that, if DOE were to allow the use of LEU carrying broad peaceful use obligations for tritium production, then other countries that are a party to those agreements could also ask for concessions from the United States on other issues—such as for the United States to relax polices on the physical protection of nuclear materials, which could have severe negative consequences if the materials were not adequately protected from theft.
- A May 2012 DOE briefing document states that having a domestic enrichment capability enhances the nation's nonproliferation credibility by assuring other nations that they do not need their own enrichment capability because the United States can provide them with LEU for the purpose of generating power. For example, officials told us that if the United States were to permanently lose its domestic enrichment capability, it could cause concern among other countries that the United States may not be able to ensure a guaranteed LEU supply, and other countries may then seek to acquire their own indigenous enrichment capability. This could, in turn, create new proliferation concerns, as the use of sensitive nuclear fuel enrichment technologies that are used to develop LEU for nuclear fuel could also be used for a clandestine nuclear weapons program.[58]
- State officials also indicated that, from a policy perspective, as a nuclear weapon state, it would not be ideal for the United States to rely on a foreign entity to meet national security needs.
- Finally, NNSA officials told us in written correspondence that having a domestic enrichment capability provides the United States with information about how uranium enrichment facilities operate, which

[58]In 2013, we found that there is potential overlap among the U.S. nuclear fuel bank—which seeks to guarantee the supply of fuel for civilian nuclear power programs and offer countries an alternative to developing their own indigenous fuel supplies—and other guaranteed fuel supply options, such as the International Atomic Energy Agency's fuel bank, and questioned the need for the U.S. nuclear fuel bank. See GAO, *Nuclear Nonproliferation: IAEA Has Made Progress in Implementing Critical Programs but Continues to Face Challenges*, GAO-13-139 (Washington, D.C.: May 16, 2013).

could help the United States maintain both information and expertise to detect new proliferation programs in other countries.

DOE and Department of State officials have cited these U.S. nonproliferation goals in response to questions about whether TVA could use LEU produced by URENCO LES for tritium production. Specifically, URENCO's corporate position has been that the Washington Agreement, under which its uranium enrichment facility in the United States operates, does not restrict the use of its LEU for the production of tritium. In 2006 and 2010, URENCO LES entered into a contract with TVA to provide LEU for use in TVA's commercial nuclear reactors. Because TVA produces tritium for NNSA in one of its nuclear reactors, URENCO LES evaluated the extent to which the Washington Agreement precludes the use of LEU produced with URENCO technology in TVA's tritium-producing reactor. According to a URENCO legal memorandum, in a July 2005 meeting of the Joint Committee—the British-Dutch-German government body supervising company activities under the Treaty of Almelo—URENCO corporate management posited that providing LEU enriched by URENCO LES to TVA for use in any of its reactors was not in conflict with the Washington Agreement's peaceful use provisions. As reported to company officials in the United States, the Joint Committee confirmed that the Washington Agreement's provisions restrict special nuclear material produced by URENCO LES to peaceful purposes. According to URENCO's legal memorandum, it was further discussed that URENCO LES's LEU will be used by TVA principally to produce electricity and that, if used in TVA's tritium producing reactor, the resulting tritium produced in that reactor is a by-product material and not a special nuclear material. According to senior URENCO officials, the Joint Committee further discussed the fact that TVA would primarily use URENCO LES's LEU for the purpose of producing commercial power. According to company officials, the Joint Committee did not place restrictions on the URENCO LES's contract with TVA and did not distinguish between TVA's reactors that produce tritium and those that do not. Furthermore, according to TVA officials, URENCO has consistently informed TVA that it places no restrictions on TVA using URENCO LES's LEU in its tritium-producing reactors.

URENCO's reading of the Washington Agreement is consistent with the narrower reading of the agreement outlined above rather than the broader reading, which prohibits the use of obligated uranium for any military purpose. DOE states that TVA may not use LEU produced by URENCO LES for tritium production because the output of URENCO's facility is obligated. NNSA's interagency agreement with TVA for tritium production

requires TVA to use unobligated LEU in the reactors being used for tritium production. Department of State officials also noted that the view of a private entity does not have weight in the interpretation of an agreement binding under international law between governments.

The Key Assumption Underlying DOE's Practice, Available Unobligated LEU, Has Changed

Although DOE has only used unobligated LEU for tritium production, a key assumption underpinning the decision to use unobligated LEU to meet national security needs for tritium production has changed. As previously discussed, in 1998, when the interagency report was drafted that advised DOE to use only unobligated LEU in the TVA reactors that produce tritium, the government had a ready supplier of enrichment services to produce unobligated LEU. Because USEC ceased enrichment operations in May 2013, and because of the uncertain future of the ACP following USEC's March 2014 bankruptcy filing, the United States no longer has a domestic enrichment capability that will provide an assured source of unobligated LEU for tritium production. As explained above, while DOE's November 2013 draft *Tritium and Enriched Uranium Management Plan through 2060* estimates that DOE's tritium production needs can be met using unobligated LEU inventories that will last through the mid-2030s, the inventories could be exhausted by the mid-2020s if it becomes necessary to use a second TVA nuclear reactor to meet DOE's tritium production goals.

In addition, over the last several years, DOE has, in some instances, provided vague reasoning to Congress for the United States' need to maintain a domestic uranium enrichment capability to produce unobligated LEU. In letters to members of Congress, congressionally mandated reports, and a congressional briefing document, DOE has stated that international agreements require their practice of using only unobligated LEU to produce tritium and has cited various policy considerations—such as national security interests and proliferation detection—as reasons why the United States needs to use unobligated LEU, without providing much detail about the rationale for each consideration. Without more information about the rationales for DOE's practice, decision makers may not have the information needed to consider the range of national security concerns raised by this issue.

The U.S. practice to use only unobligated LEU to produce tritium has not been examined collaboratively by the many interested entities of the government since 1998 when the conditions surrounding the availability of unobligated LEU for tritium production were quite different. Because the United States no longer has an assured source of enrichment

services to produce unobligated LEU for tritium production, DOE is currently assessing options for obtaining unobligated LEU, as required by the Consolidated Appropriations Act of 2014. According to DOE officials, DOE is currently engaged with an interagency working group under the National Security Council that includes representatives from the Departments of State and Defense to conduct such an analysis. While officials indicated that the short-term lack of a domestic enrichment capability is unlikely to shift long-established national policy, DOE and State officials also told us that, prior to this interagency working group, the two agencies had not communicated with each other on this topic in several years because they had not seen a need to do so. In prior work, we identified practices that can enhance and sustain collaboration among federal agencies, thereby improving performance and results.[59] One such practice is to define and articulate a common outcome. An updated interagency review to either reaffirm or support a change in the current practice of using unobligated LEU for tritium production could help address questions about whether using LEU produced, for example, under the Washington Agreement, is an option for DOE.

Conclusions

Conditions have changed since DOE, the Department of State, and other relevant U.S. government entities completed their 1998 interagency review of the nonproliferation implications of tritium production. Because USEC ceased enrichment operations in May 2013 and the future of the ACP is uncertain, the United States no longer has a domestic enrichment capability that will provide an assured source of unobligated LEU. DOE is currently collaborating with an interagency working group to assess options for obtaining unobligated LEU to produce tritium to meet national security needs, and it is possible that, among these options, DOE will revisit the advice it received in 1998. DOE and State officials told us that, prior to this interagency analysis, the two entities had not communicated about the interpretation of international agreements and nonproliferation concerns associated with using certain foreign-produced LEU for tritium production in several years. We believe the change in the assumption fundamental to the 1998 interagency review—that sufficient unobligated LEU would be available for tritium production—gives new importance to the need for the executive branch to review its position on how the United

[59]GAO, *Results-Oriented Government: Practices That Can Help Enhance and Sustain Collaboration among Federal Agencies*, GAO-06-15 (Washington, D.C.: Oct. 21, 2005).

States will obtain LEU for tritium production. By taking steps to coordinate the interagency community to review DOE's current practice of using unobligated LEU for tritium production, decision makers may have greater assurance that decisions on how to obtain future LEU for tritium production are based on a coordinated understanding of U.S. obligations consistent with international agreements and U.S. nonproliferation goals.

Recommendation for Executive Action

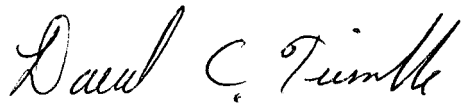
In light of the significantly reduced availability of unobligated LEU, the absence of a domestic enrichment capability, and the questions that this condition has raised about options for its supply, GAO recommends that the Secretary of Energy ensure that DOE's interagency review of options for obtaining unobligated LEU assesses DOE's current practice of using only unobligated LEU for the production of tritium for national security purposes. Further, we recommend that this review result in either an affirmation of DOE's continuing practice or a commitment to study alternative sources of LEU consistent with international agreements and U.S. nonproliferation goals.

Agency Comments and Our Evaluation

We provided a draft of this report for review and comment to the Secretary of Energy, the Secretary of State, Executive Director for Operations of NRC, and the Vice President for Government Relations of TVA on August 15, 2014. We also provided a technical statement of facts to the following third parties: USEC and URENCO. We received technical comments from these parties and incorporated them, as appropriate, prior to providing the draft of this report to the agencies noted above. DOE provided written comments on September 22, 2014, which are reproduced in appendix IV. DOE acknowledged our recommendation but did not agree nor disagree with our recommendation, and stated that the department will continue working with interagency partners, including on a collaborative review of current policies and practices. DOE also provided technical comments, which we incorporated as appropriate. The Department of State did not provide comments on GAO's findings and recommendation, but did provide technical comments on September 15 and September 18, 2014, which we incorporated as appropriate. We received a written response from NRC on September 9, 2014, which is reproduced in appendix V. NRC also provided technical comments, which we incorporated as appropriate. TVA did not provide comments on GAO's findings and recommendation, but did provide technical comments orally on September 8, 2014, which we incorporated as appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, the Secretary of Energy, and other interested parties. In addition, this report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have questions about this report, please contact David C. Trimble at (202) 512-3841 or trimbled@gao.gov or Susan D. Sawtelle at (202) 512-6417 or sawtelles@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix VI.



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Director, Natural Resources and Environment

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Appendix I: Objectives, Scope, and Methodology

The objectives of our review were to assess (1) the extent to which the Department of Energy (DOE) has adhered to its practice of using only unobligated low-enriched uranium (LEU) to meet national security needs for tritium and (2) the basis for DOE's practice of using only unobligated LEU to meet national security needs for tritium.

To determine the extent to which DOE has adhered to its practice of only using unobligated LEU to meet national security needs for tritium, we reviewed DOE and National Nuclear Security Administration (NNSA) documents. These included DOE strategic planning documents, contracts, internal memos and letters, internal analyses, and budget documents. In addition, we interviewed officials from DOE's Office of Management, Office of Nuclear Energy, and NNSA's Tritium Readiness Subprogram Office and the Office of Nonproliferation and International Security. We also interviewed officials from the Department of State's Bureau of International Security and Nonproliferation and Office of the Legal Advisor. Furthermore, we reviewed documents and interviewed officials from the Tennessee Valley Authority (TVA)—which produces tritium through an interagency agreement with DOE—and the Nuclear Regulatory Commission (NRC). Moreover, we interviewed USEC officials involved with the American Centrifuge project in Piketon, Ohio, at the Paducah Gaseous Diffusion Plant (GDP) in Paducah, Kentucky, and at USEC's headquarters in Bethesda, Maryland.

To determine the basis for DOE's practice for using only unobligated LEU to meet national security needs for tritium, we reviewed DOE and NNSA documents and assessed relevant international agreements pertaining to the transfer of enrichment technology into the United States and the extent to which these agreements require DOE to use exclusively unobligated LEU for meeting national security needs. In particular, we analyzed the following nuclear cooperation agreements and international agreements: the Treaty on the Non-Proliferation of Nuclear Weapons; the Paris Agreement; the Washington Agreement; the nuclear cooperation agreement between the United States and Australia; nuclear cooperation agreements between the United States and EURATOM; the Agreement Between the United States of America and the International Atomic Energy Agency for the Application of Safeguards in the United States of America; the Treaty of Almelo between Germany, the Netherlands, and the United Kingdom; and the Cardiff Agreement between France, Germany, the Netherlands, and the United Kingdom. We also interviewed officials from the Department of State's Bureau of International Security and Nonproliferation and Office of the Legal Advisor and NNSA's Office of Nonproliferation and International Security, as well as officials from TVA

and representatives from USEC and URENCO.[1],[2] We also reviewed two analyses completed by the Congressional Research Service on peaceful use restrictions applicable to uranium enriched at the URENCO facility and on potential sources of LEU for tritium production, and we interviewed staff regarding their conclusions.[3]

To inform both objectives, we conducted site visits to the Paducah GDP in Paducah, Kentucky, and the American Centrifuge Plant in Piketon, Ohio, because these are the two locations where USEC had been enriching or planning to enrich uranium. We also visited DOE's Oak Ridge Office, Oak Ridge National Laboratory, and NNSA's Y-12 National Security Complex in Oak Ridge, Tennessee, because these offices play a role in uranium management or collaboration with USEC, such as on the development of the American Centrifuge technology. We also interviewed senior USEC officials, including its Chief Financial Officer, to learn more about the company's financial condition and future plans.

We conducted this performance audit from January 2013 to October 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[1]DOE, NNSA, and Department of State officials discussed various aspects of the international agreements and nonproliferation policy with us. We only identified a public interpretation of one of the agreements, however, and, thus for the other two agreements, this report identifies a range of possible readings.

[2]NNSA was created as a semiautonomous agency within DOE under the National Nuclear Security Administration Act. Pub. L. No. 106-65, § 3211, 113 Stat. 512, 957 (1999). NNSA is responsible for the management and security of the nation's nuclear weapons, nonproliferation, and naval reactors programs.

[3]CRS, *Peaceful Use Restrictions on Uranium Enriched at the Urenco Uranium Enrichment Facility* (Washington, D.C.: May 21, 2012). CRS, *Potential Sources of Nuclear Fuel for Tritium Production* (Washington, D.C.: May 15, 2012).

Appendix II: Peaceful Use Language in Key International Agreements Addressing Uranium Enrichment Facilities Operating or Planned for Operation in the United States

International agreement	Date of agreement	Government signatories	Facility	Peaceful use language
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 (Washington Agreement)	July 24, 1992	• United States • Germany • Netherlands • United Kingdom	URENCO, Louisiana Energy Services (New Mexico)	"Any centrifuge technology, equipment and components transferred into the United States subject to this Agreement, the Installation, any nuclear material and the Installation, any special nuclear material 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 the Installation which is designated Restricted Data while such data is under the jurisdiction of the United States Government or of the Three Governments shall only be used for peaceful, non-explosive purposes."
Agreement 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 Gas Centrifuge Technology in the United States of America (Paris Agreement)	February 24, 2011	• United States • France • United Kingdom • Netherlands • Germany	AREVA, Eagle Rock (Idaho)	"Any ETC [Enrichment Technology Company] 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 material 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."
Agreement for Cooperation Between Australia and the United States of America Concerning Technology for the Separation of Isotopes of Uranium by Laser Excitation (SILEX 123 Agreement)	October 28, 1999	• United States • Australia	Global Laser Enrichment (any planned facility)	"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."

Sources: GAO analysis of international agreements. | GAO-15-123

Appendix III: Peaceful Use Language in Additional Select Treaties and International Agreements Related to Nonproliferation and Nuclear Trade

The Department of Energy (DOE), DOE's National Nuclear Security Administration (NNSA), and Department of State officials discussed various aspects of three international agreements specifically related to the import of uranium enrichment technology, as well as nonproliferation policy, with us, but they did not explain specifically how these international agreements affect their decisions regarding the production of tritium. In the body of this report, we analyze a range of possible readings of the text of those three enrichment technology agreements.[1] In this appendix, we summarize our analysis of peaceful use language in certain additional treaties and international agreements—agreements that are related more generally to nonproliferation and nuclear trade—to determine whether their provisions might affect DOE's ability to produce tritium from uranium enriched using foreign technology. For example, we analyzed agreements between the United States and the European Atomic Energy Community (EURATOM) because the European parties to the agreements pertaining to URENCO and AREVA are also members of EURATOM. As described in further detail below, we did not identify any provisions in these more general agreements that prohibit tritium production.

International agreement or treaty	Date of agreement or treaty	Government parties	Peaceful use language
Agreement Between the Government of the United States of America and the European Atomic Energy Community (EURATOM)[a] (EURATOM Agreement, May/June 1958)	May and June 1958 (Expired)	• EURATOM • United States	"The Parties will cooperate in programs for the advancement of the peaceful applications of atomic energy. Such cooperation will be undertaken from time to time pursuant to such terms and conditions as may be agreed and shall be subject to all provisions of law respectively applicable to the Parties."

[1]Relevant provisions of these three agreements are quoted in appendix II.

International agreement or treaty	Date of agreement or treaty	Government parties	Peaceful use language
Agreement for Cooperation Between the Government of the United States of America and the European Atomic Energy Community (EURATOM) *Concerning Peaceful Uses of Atomic Energy* (EURATOM 123 Agreement, 1958)[b]	November 1958 (Expired)	• EURATOM • United States	"The Community guarantees that: No material, including equipment and devices, transferred pursuant to this Agreement to the Community or to persons within the Community, will be used for atomic weapons, or for research on or development of atomic weapons, or for any other military purpose; …. No source or special nuclear material utilized in, recovered from, or produced as a result of the use of material, equipment, or devices transferred pursuant to this Agreement to the Community or to persons within the Community will be used for atomic weapons, or for research on or development of atomic weapons, or for any other military purpose." "The Government of the United States of America and the Community reaffirm their common interest in fostering the peaceful applications of atomic energy through the International Atomic Energy Agency and intend that the results of the joint program will benefit the Agency and the nations participating in it."
Additional Agreement for Cooperation Between the United States of America and the European Atomic Energy Community (EURATOM) *Concerning Peaceful Uses of Atomic Energy* (EURATOM 123 Agreement, 1960)	1960 (Expired)	• EURATOM • United States	"The Government of the United States of America and the Community reaffirm their common interest in fostering the peaceful applications of atomic energy through the International Atomic Energy Agency and intend that the results of the cooperation envisaged by this Agreement will benefit the Agency and the nations participating in it."

Discussion: The prior EURATOM Agreements, completed in 1958 and 1960, expired in 1996, so they were in force when the Washington Agreement was completed in 1992, but not when the SILEX 123 and Paris Agreements were completed in 1999 and 2011, respectively. The May/June 1958 Agreement and the 1960 123 Agreement contained only general language that related to peaceful use, which does not change our reading of the Washington Agreement. The November 1958 123 Agreement contains peaceful use language that applied only to EURATOM and not to the United States. We note that the agreement pertained to bringing into operation within EURATOM large-scale power plants using nuclear reactors on which research and development had been carried to an advanced stage in the United States at the time, as well as a joint research and development program centered on these types of reactors; accordingly, transfers under the agreement were likely mostly from the United States to EURATOM rather than from EURATOM to the United States. In any case, the agreement did not include peaceful use restrictions on transfers of enrichment technology from the member countries of EURATOM to the United States.

International agreement or treaty	Date of agreement or treaty	Government parties	Peaceful use language
Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	1968	• Australia • France • Germany • Netherlands • United Kingdom • United States • 184 others	"Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material[c] or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State[d] for peaceful purposes, unless the source or special fissionable material shall be subject to …safeguards [as set forth in an agreement with the International Atomic Energy Agency]."
Discussion: The NPT does not prohibit the United States from producing nuclear weapons or devices or the materials needed to produce them, such as tritium, and does not impose any restrictions on transfers of nuclear material or equipment, including enrichment technology, to the United States.			
Agreement between the United Kingdom of Great Britain and Northern Ireland the Federal Republic of Germany and the Kingdom of the Netherlands on Collaboration in the Development and Exploitation of the Gas Centrifuge Process for producing Enriched Uranium (Treaty of Almelo)	1970	• United Kingdom • Germany • Netherlands	"The Contracting Parties jointly and separately undertake to ensure that any information, equipment, source, or special fissionable material which may be at their disposal for the purpose of or as a result of the collaboration described in [this agreement] will not be used by or to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices or control over such nuclear weapons or explosive devices…. The Contracting Parties further undertake to ensure that the joint industrial enterprises [established by] this Agreement shall not produce weapons grade uranium for the manufacture of nuclear weapons or other nuclear explosive devices."
Discussion: Under the Treaty of Almelo, the United Kingdom, Germany, and the Netherlands agreed to collaborate on the development of gas centrifuge uranium enrichment technology. The United States is not a party to this treaty and is thus not bound by its language, but we reviewed it to see if its provisions could provide useful context for the provisions of the Washington Agreement, which relate to the same technology addressed by this treaty. Two provisions of the treaty address peaceful use of this technology. The first echoes the NPT, prohibiting the parties from helping nonnuclear-weapon States to produce or obtain nuclear weapons or devices. Since the United States is a nuclear-weapon State, this provision has no applicability to any subsequent agreement with the United States. The second provision specifically obligates the parties to ensure that the enrichment technology on which they agreed to collaborate is not used to produce weapons grade uranium for nuclear weapons or devices. The production of weapons grade uranium is not at issue in our analysis.			

International agreement or treaty	Date of agreement or treaty	Government parties	Peaceful use language
Agreement of 18 November 1977 Between the United States of America and the Agency [International Atomic Energy Agency, or IAEA][e] *for the Application of Safeguards in the United States of America* (United States Voluntary Offer Safeguards Agreement)	1977	• IAEA • United States	"The United States undertakes to permit the Agency to apply safeguards, in accordance with the terms of this Agreement, on all source or special fissionable material in all facilities within the United States, excluding only those facilities associated with activities with direct national security significance to the United States, with a view to enabling the Agency to verify that such material is not withdrawn, except as provided for in this Agreement, from activities in facilities while such material is being safeguarded under this Agreement."
Discussion: While, as a nuclear-weapon state, the United States is not required to accept safeguards to verify the fulfillment of its obligations under the NPT, the United States has voluntarily accepted certain safeguards on certain nuclear materials, which do not include tritium.			
Agreement for Cooperation in the Peaceful Uses of Nuclear Energy Between the European Atomic Energy Community and the United States of America (EURATOM 123 Agreement)	1995	• EURATOM • United States	"Cooperation under this Agreement shall be carried out for peaceful purposes... 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."
Discussion: The current EURATOM 123 Agreement was not in force when the Washington Agreement was completed in 1992, but was in force when the SILEX 123 and Paris Agreements were completed in 1999 and 2011, respectively. It addresses cooperation on nuclear trade, among other things. Specifically, the agreement addresses the transfer of nuclear material and equipment. "Equipment" is defined by the agreement to include "any reactor as a complete unit, other than one designed or used primarily for the formation of plutonium or uranium-233 or any other item so designated jointly by the appropriate authorities of the Parties." According to the Department of State, no uranium enrichment technology has been designated as "equipment" under this agreement. Accordingly, the agreement does not address the transfer of uranium enrichment technology between EURATOM and the United States.			

International agreement or treaty	Date of agreement or treaty	Government parties	Peaceful use language
Agreement between the Governments of the United Kingdom of Great Britain and Northern Ireland, the Kingdom of the Netherlands, the Federal Republic of Germany and the French Republic regarding Collaboration in Centrifuge Technology (Cardiff Agreement)	2005	• United Kingdom • France • Germany • Netherlands	"The Four Governments jointly and separately undertake to ensure, in conformity with the NPT, that any Centrifuge Technology, which may be at their disposal for the purpose of, or as a result of, the collaboration described in [this agreement] shall not be used in any way to assist, encourage or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices…. The Government of the French Republic shall ensure that any organisation which builds plants for the enrichment of uranium on the territory of the French Republic using or otherwise exploiting Centrifuge Technology owned by, held by, or deriving or arising from the operations of, ETC,[f] or operates such plants, shall not produce weapons grade uranium for the manufacture of nuclear weapons or other nuclear explosive devices."
Discussion: The Cardiff Agreement added France to the collaboration on gas centrifuge enrichment technology that was established by the Treaty of Almelo between the United Kingdom, Germany, and the Netherlands. As with the Treaty of Almelo, the United States is not a party to this agreement and thus is not bound by its language, but we reviewed it to see if its provisions could provide useful context for the provisions of the Paris Agreement, which relate to the same technology addressed by this agreement. The two provisions of the agreement related to peaceful use are substantively the same as those included in the Treaty of Almelo. The first echoes the NPT, prohibiting the parties from helping nonnuclear-weapon States to produce or obtain nuclear weapons or devices. Since the United States is a nuclear-weapon State, this provision has no applicability to any subsequent agreement with the United States. The second provision specifically obligates France to ensure that the enrichment technology is not used to produce weapons grade uranium for nuclear weapons or devices. The production of weapons grade uranium is not at issue in our analysis.			

Sources: GAO analysis of international agreements. | GAO-15-123

[a]EURATOM is composed of the 27 countries of the European Union.

[b]Under Section 123 of the U.S. Atomic Energy Act of 1954, as amended, nuclear cooperation agreements are a prerequisite to certain aspects of civilian U.S. nuclear cooperation with countries and other cooperating partners. Section 123 also requires that these agreements include, among other things, guarantees from the partners that they will maintain safeguards over nuclear materials and equipment transferred and adequate physical security for all nuclear material transferred. These nuclear cooperation agreements are referred to as "123 Agreements."

[c]Neither source material nor special fissionable material is defined in the treaty. The IAEA defines "source material" as "uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing in such concentration as the Board of Governors shall from time to time determine; and other such material as the Board of Governors shall from time to time determine. This definition is similar to the definition of "source material" provided in the Atomic Energy Act. The IAEA defines "special fissionable material" as "plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; and such other fissionable material as the Board of

Governors shall from time to time determine; but the term 'special fissionable material' does not include source material." This definition is similar to the definition of "special nuclear material" provided in the Atomic Energy Act.

[d]Nonnuclear-weapon states are those states that had not manufactured and exploded a nuclear weapon or other nuclear explosive device before January 1, 1967.

[e]IAEA, an independent international organization based in Vienna, Austria, is affiliated with the United Nations and has the dual mission of promoting the peaceful uses of nuclear energy and verifying that nuclear materials intended for peaceful purposes are not diverted to military purposes. IAEA had 162 member states as of February 2014.

[f]"ETC" refers to the joint venture established between URENCO and AREVA to carry out Centrifuge Technology research and development, manufacturing of gas centrifuges and related technology and activities, named Enrichment Technology Company Ltd, including its subsidiaries and their possible legal successors.

Appendix IV: Comments from the Department of Energy

Department of Energy
Under Secretary for Nuclear Security
Administrator, National Nuclear Security Administration
Washington, DC 20585

September 22, 2014

David Trimble
Director, Natural Resources
and Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Mr. Trimble,

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report titled *"DEPARTMENT OF ENERGY: Interagency Review Needed to Update U.S. Position on Enriched Uranium that Can Be Used for Tritium Production" (GAO-14-812).* I understand the GAO began this review in response to a request from Senator Edward J. Markey and Representative Michael C. Burgess to review the peaceful use provisions in international agreements addressing uranium enrichment technology in the United States. This includes the extent to which the Department of Energy (Department) has adhered to its policy of using only unobligated Low-Enriched Uranium (LEU) to produce tritium, and the basis for this practice.

The Department and the National Nuclear Security Administration (NNSA) appreciate GAO's report which highlights the inherent challenges of ensuring an adequate and sustainable supply of LEU for future tritium production, while continuing to pursue non-proliferation policy goals. The Department will continue to pursue effective strategies for addressing these challenges by leveraging the cooperation of our interagency partners to evaluate viable supply options, including a collaborative review of current policies and practices.

We have also enclosed technical comments for your consideration to enhance the clarity and factual accuracy of the report. If you have any questions regarding this response, please contact Dean Childs, Director, Office of Audit Coordination and Internal Affairs, at (301) 903-1341.

Sincerely,

Frank G. Klotz

Enclosure

Appendix V: Comments from the Nuclear Regulatory Commission

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 9, 2014

Mr. David Trimble
Director, Natural Resources
and the Environment
U.S. Government Accountability Office
Washington, DC 20548

Dear Mr. Trimble:

On behalf of the U.S. Nuclear Regulatory Commission (NRC), I am responding to your letter dated August 8, 2014, requesting comments on the U.S. Government Accountability Office (GAO) proposed report GAO 14-812, "Interagency Review Needed to Update U.S. Position on Enriched Uranium that can be used for Tritium Production." We appreciate the opportunity to provide our comments for your consideration.

As requested, the NRC has reviewed the draft report and has several comments. The enclosure contains the comments.

Sincerely,

Mark A. Satorius
Executive Director
for Operations

Enclosures:
1. NRC Comments
2. GAO Report

Appendix VI: GAO Contacts and Staff Acknowledgments

GAO Contacts

David C. Trimble, (202) 512-3841 or trimbled@gao.gov

Susan D. Sawtelle, (202) 512-6417 or sawtelles@gao.gov

Staff Acknowledgments

In addition to the individuals named above, Allison B. Bawden, Assistant Director; Eric Bachhuber; Antoinette Capaccio; Delwen A. Jones; Amanda K. Kolling; and Karen Villafana made key contributions to this report. Also contributing to this report were Elizabeth R. Beardsley; Doreen Eng; Karen K. Keegan; Risto Laboski; Dr. Timothy M. Persons; Dan C. Royer; and Rebecca Shea.