ENERGY
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ERI-2142.20-1701

Analysis of the Potential Effects on the Domestic Uranium Mining, Conversion, and Enrichment Industries of the Introduction of DOE Excess Uranium Inventory During CY 2017 Through 2026

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Office of Nuclear Energy

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NOTICE

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DISCLAIMER

Any views expressed or conclusions made in this independent report are solely the opinion of Energy Resources International, Inc. and do not necessarily represent the views of the Department of Energy.

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1. Introduction

Section 3112(d) of the United States Enrichment Corporation (USEC) Privatization Act requires the U.S. Department of Energy (DOE), when applicable, to ensure that prior to covered sales or transfers of natural or low-enriched uranium, the Secretary of Energy determines that those transfers will not have an adverse material impact on the domestic uranium mining, conversion or enrichment industry (Secretarial Determination).

Section 306(a) of Title III, Division D of the Consolidated and Further Continuing Appropriations Act of 2015 requires that:

> *Any determination (including a determination made prior to the date of enactment of this Act) by the Secretary of Energy under section 3112(d)(2)(B) of the USEC Privatization Act (110 Stat. 1321-335), as amended, shall be valid for not more than 2 calendar years subsequent to such determination.*

The most recent multi-year Secretarial Determination for the sale or transfer of natural or low-enriched uranium was issued by the Secretary of Energy on May 1, 2015 (May 2015 Determination). It covered DOE transfers of natural uranium hexafluoride (UF_6) provided to contractors for cleanup services at Paducah or Portsmouth Gaseous Diffusion Plant and LEU transfers to contractors for down blending HEU that were, at that time, planned by DOE from 2015 through 2024.

DOE requested that Energy Resources International, Inc. (ERI) perform an analysis of the potential effects on the domestic uranium mining, conversion, and enrichment industries of the introduction of DOE excess uranium inventories in various forms and quantities during calendar years (CYs) 2017 through 2026. This analysis updates the February 2015 ERI market analysis[1] performed prior to the May 2015 Determination. The current analysis considers all of DOE's contemplated uranium sales and transfers during the period 2017 to 2026, using information concerning quantities and schedules provided to ERI by DOE. ERI's analysis focuses on the sales and transfers of natural UF_6 by DOE's Office of Environmental Management (EM) to the DOE contractor, Fluor-B&W Portsmouth LLC (FBP), for services being provided to DOE in support of the environmental cleanup of the Portsmouth gaseous diffusion plant (GDP) that are under consideration for the next Secretarial Determination consistent with section 3112(d). ERI's analysis also takes into account the effects of the introduction of DOE excess uranium inventory from other programs not part of the next Secretarial Determination under 3112(d), which include planned transfers of low enriched uranium (LEU) resulting from the down blending of HEU by the National Nuclear Security Administration (NNSA); prior and additional new transfers of off-spec HEU in the Blended Low-Enriched Uranium (BLEU) program with

[1] Energy Resources International, Inc., "Analysis of the Potential Effects on the Domestic Uranium Mining, Conversion and Enrichment Industries of the Introduction of DOE Excess Uranium Inventory During CY 2015 Through 2024", ERI-2142.18-1501, February 20, 2015.

the Tennessee Valley Authority (TVA); the prior transfer of high assay depleted uranium tails (DUF_6) to Energy Northwest (ENW); proposed transfers of DUF_6 under an agreement between DOE and GE-Hitachi Global Laser Enrichment, LLC (GLE); and, to the extent relevant, transfers of high-assay LEU for research reactor use or medical isotope development and production purposes. ERI's analysis will also consider the effects of proposed transfers of DOE excess uranium, involving transfers of off-spec LEU and off-spec non-UF_6 currently under negotiation pursuant to a July 2013 Request for Offers (RFO).[2] The quantities used in the February 2015 ERI market analysis have been updated to reflect DOE's current considerations regarding transfers in the near term. While the prior DOE transfers of off-spec HEU to TVA and the transfer of DUF_6 to ENW have already taken place, this material will be loaded into commercial reactors over a period of many years. For purposes of evaluating the effect of these prior transfers on the commercial markets and U.S. industry, ERI continues to find it appropriate to evaluate the effects of this material according to the schedule of the delivery of the processed inventory as reactor fuel, adjusted for industry standard lead times.

Section 2 provides updated background information on each of the nuclear fuel markets - uranium concentrates, conversion services, and enrichment services - that would potentially be affected by DOE inventory. For each of these markets, both spot and term price indicators are presented as well as a projected supply-demand balance. The discussion focuses on market developments over the past year.

Section 3 identifies and discusses the quantities of DOE-attributable natural uranium (NU) equivalent and enrichment services expected to affect the commercial markets during the time period addressed by this analysis (2017 - 2026). The categories of material include (i) historical DOE transfers, the uranium from which will continue to displace commercial supply in the market in the future, (ii) current and near-term inventory transfers in exchange for services (transfers for services), and (iii) future transfers of DOE inventory, primarily additional DUF_6 under agreement with GLE, but also proposed transfers of off-spec LEU and off-spec non-UF_6 that are currently under consideration. Four scenarios, which were provided to ERI by DOE, are examined, rather than the three scenarios examined in the February 2015 ERI market analysis. The four scenarios demonstrate the sensitivity of the commercial markets to a range of possible DOE transfer rates.

Section 4 presents quantitative and qualitative estimates of the potential effect of the introduction of these DOE materials and services into the domestic uranium, conversion, and enrichment markets. The potential effect is evaluated using market clearing price analysis[3], as well as an econometric model of the spot market price for uranium

[2] U.S. DOE, Portsmouth/Paducah Project Office, Request for Offers for the Sale of Depleted and Off-Specification Uranium Hexafluoride Inventories, Request for Offers Number: DE-SOL-0005845, July 3, 2013.

[3] In any particular year, the market clearing price (or equilibrium price) for uranium concentrates, for example, is based on the cost of production of the last increment of uranium that must be supplied by the market in order to provide the total quantity of uranium concentrates that is demanded by the market during that year.

concentrates. In addition to addressing the effect of DOE inventory on market clearing price, other metrics associated with the domestic industries are evaluated including: employment, production, volumes of inventory relative to market volumes, market capitalization, realized prices and production costs for the uranium production industry; U.S. converter sales volumes and production costs; and effect on volumes of enrichment services.

Section 5 provides a final summary of the potential market effects developed in this report.

2. Background on Nuclear Fuel Supply Markets

In order to better understand the potential effects that DOE inventory entering the commercial markets could have for nuclear fuel materials and services, it is useful to have some background regarding the current status of the world markets for uranium, conversion services and UF_6, and enrichment services and enriched uranium product (EUP).

The ERI Reference Nuclear Power Growth[4] forecasts (ERI Reference forecast) of installed nuclear generating capacity and the associated requirements for nuclear fuel that is used in this analysis were developed on a plant-by-plant and country-by-country basis. ERI considers its Reference forecast to be the most likely scenario for the development of nuclear power worldwide through 2035. The ERI Reference forecasts reflect the temporary closure of nuclear power plants in Japan and permanent closure of plants in Germany following the March 2011 accident at the Fukushima Daiichi nuclear power plant. In addition, ERI's forecasts reflect recent and expected early closures of nuclear power plants in the U.S. and Western Europe for economic and other reasons, a reduction of nuclear energy in France consistent with legislation passed in 2015, plants under construction worldwide, and planned nuclear power program growth. The Reference forecast for total world nuclear power generation capacity is consistent with a steady average annual nuclear capacity growth rate of 2% through 2035, with related growth in nuclear fuel requirements. By 2035, a 9% decline is projected for the U.S., while a 30% decline is projected for Western Europe. In contrast, the other world regions are projected to demonstrate significant increases in nuclear generation capacity. Nuclear generation capacity expansion is strongest in China, but significant additions are expected in India and South Korea as well. Several new entrants (e.g., Belarus, Poland, Saudi Arabia, Turkey, the United Arab Emirates (U.A.E.) and Vietnam) are expected to join the ranks of countries with nuclear generation.

The nuclear power forecasts, nuclear fuel design, and management parameters for specific types of nuclear power plants are used to project future nuclear fuel material and services requirements. The requirements for each U.S. nuclear power plant now operating or under construction take into account plant specific discharge burn-up, reload fuel assays, fuel cycle lengths, first-core and reload lead times, and operating capacity factors. Generic plant type and country-specific operating and fuel cycle characteristics are used for nuclear power plants outside the U.S., and fuel recycle is included for specific countries in Western Europe, consistent with present and planned activities. It should be noted that, worldwide, not all reactors are light-water reactors that utilize enriched uranium. As such, the requirements for uranium, conversion services, and enrichment services are dependent upon the specific nuclear fuel designs for each reactor.

The nuclear fuel market over-supply situation described in the February 2015 ERI market analysis remains fundamentally unchanged. ERI's Reference forecasts of world nuclear

[4] ERI, 2016 Nuclear Fuel Cycle Supply and Price Report, Update, ERI-2006-1602, November 2016. DRAFT. Not publicly available, available only through subscription.

fuel requirements are somewhat lower than the forecasts in the February 2015 ERI market analysis through 2026. The reduction in nuclear fuel requirements in the near term in ERI's updated forecast is due to the slower pace assumed for the restart of Japanese reactors as well as the announced and projected premature closure of nuclear power plants in the U.S. and Western Europe due to economic and other reasons, while the reduction between 2020 and 2026 is due to a reduced contribution by nuclear in France and slower nuclear power growth in Russia. Since February 2015, there have also been changes to nuclear fuel supply forecasts that are reflected herein.

2.1 Uranium Concentrates

2.1.1 Uranium Market Price Activity

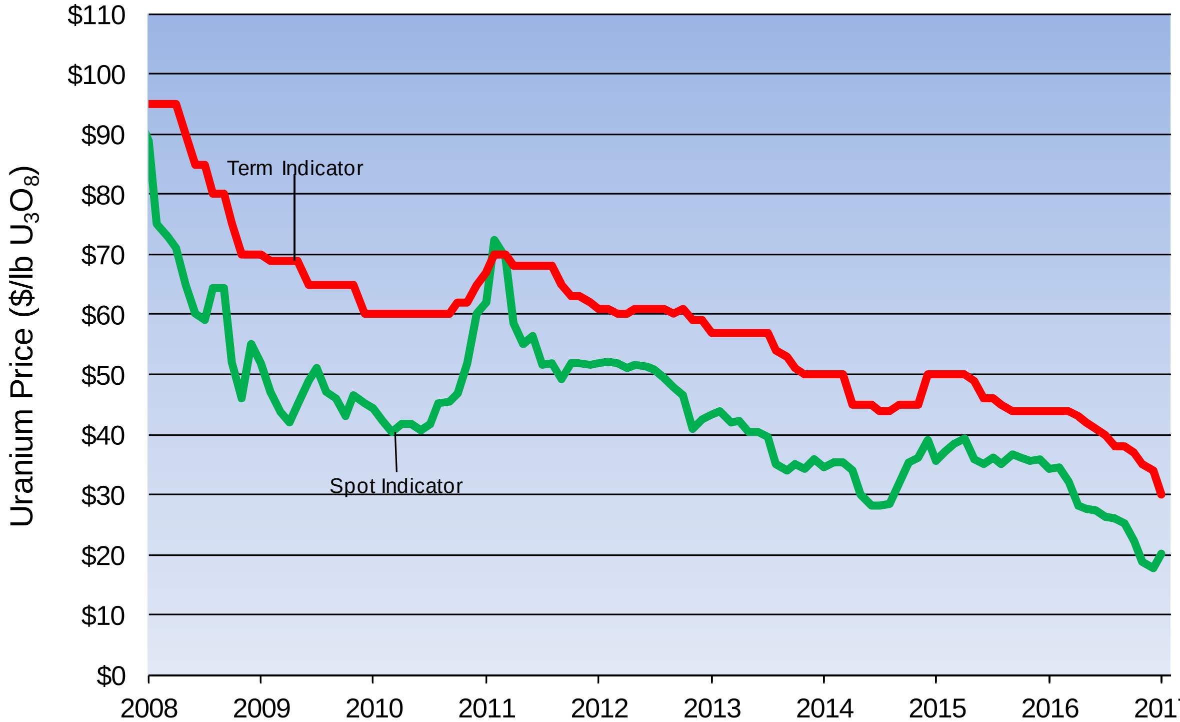
Figure 2.1 provides uranium market price indicators updated to include activity through December 31, 2016.[5] As noted in the February 2015 report, the spot market price, which hit a high of $135 per pound U_3O_8[6] in June 2007, began to fall thereafter, reaching $47 per pound by January 2009. While the rate slowed, the spot price continued in a downward direction, reaching a low of $40.50 per pound U_3O_8 in February 2010. Spot price once again started rising rapidly, rebounding to $72.25 per pound in January 2011 based on renewed enthusiasm for nuclear power's future prospects. Following the accident at Fukushima Daiichi in March 2011, the spot price began to decline once again. A dramatic decline has occurred in 2016 and as of December 31, 2016, the spot market indicator was $20.25 per pound, a net decrease of $17 per pound (46%) since the end of January 2015.[7]

As noted in the February 2015 report, the term (also referred to as long-term) contract price for uranium concentrates remained at $95 per pound U_3O_8 from March 2007 to March 2008 and then declined slowly to $65 per pound by May 2009, where it remained through October 2009. In January 2011, the long-term price indicator reached $70 per pound U_3O_8. Following the accident at Fukushima Daiichi, the term price began a steady decline from $68 per pound U_3O_8 in March 2011, to $30 per pound in December 2016 as shown in Figure 2.1. Since January 2015, the term price has declined by $20 per pound (40%).

[5] Market price and term market indicators are as reported in TradeTech's Nuclear Market Review. www.uranium.info.

[6] Uranium concentrates prices are in units of $ per pound U_3O_8 unless stated otherwise.

[7] Prices in effect as of previous ERI market analysis performed prior to the May 2015 Determination



Source: TradeTech

Figure 2.1 Historical Uranium Spot and Term Market Price Indicators

2.1.2 Uranium Requirements

"Requirements" for nuclear fuel, as used herein, refers to the quantity of uranium that will be needed to produce nuclear fuel for reactors which are expected to be operating during the forecast period.[8] As noted in Section 2 above, ERI's forecast of requirements are calculated on a plant-by-plant basis, based on fuel discharge burn-up, reload fuel assays, fuel cycle lengths, first-core and reload lead times, and operating capacity factors. Annual "demand" for uranium, which is different than "requirements" as shown in Figure 2.3, includes not only annual "requirements" but also purchase of strategic inventory (as indicated in Figure 2.3). Inventory draw downs, such as those expected in Japan due to excess inventories built up following the Fukushima accident, will reduce uranium demand.

World requirements for uranium were 152 million pounds in 2015. ERI projects that total world requirements for uranium are 161 million pounds in 2016. Uranium requirements

[8] Reactor operators may buy more or less uranium in a given year than their requirements for that year, depending on their existing inventories and any planned buildup of strategic inventory. In addition, a given reactor could temporarily consume more or less uranium than its expected requirements—for example because of an unplanned outage or better-than-expected operation. ERI's forecast of annual "requirements" is based on expected plant-by-plant cycle lengths, capacity factors, and fuel utilization and does not take account of such temporary fluctuations.

begin to increase by 2020 as uranium requirements return to a pre-Fukushima level of 172 million pounds. Requirements are forecast to rise steadily thereafter, to 190 million pounds in 2025, 200 million pounds in 2030 and to 223 million pounds in 2035. Compared to the uranium requirements forecast in the February 2015 ERI market analysis, there has been a 10% decrease in world uranium requirements over the next ten years (2017-2026) or 19 million pounds annually. During the same period, U.S. requirements remain essentially flat, averaging nearly 45 million pounds per year.

Compared to ERI's Reference forecast in February 2015, the reduction in world uranium requirements in the near term in the updated ERI Reference forecast is due to the slower pace assumed for the restart of Japanese reactors and an expected reduction in nuclear power installed capacity in France. In addition, ERI's forecasts reflect recent and expected early closures of nuclear power plants in the U.S. and Western Europe for economic and other reasons. In Japan, five units have been given approval to restart from the Japanese Nuclear Regulatory Authority during 2014 and 2015; however, Takahama units 3 and 4 have been idled after a court issued a temporary injunction halting the operation of those units following protests lodged by anti-nuclear activists. In addition, it is expected that some older units will not restart and that the need for local government and prefecture approval for restart may complicate the process and timing. In 2015, legislation was passed in France that set a cap on the contribution of nuclear energy in France to 50% by 2025. ERI's Reference forecast has been updated to reflect this, resulting in a reduced contribution by nuclear power in France beginning in 2018. The longer term steady increase in world uranium requirements is associated with an expansion of nuclear generation in China, India, and South Korea, as well as uranium requirements for new nuclear power entrants (e.g., Belarus, Poland, Saudi Arabia, Turkey, the United Arab Emirates (U.A.E.) and Vietnam).

2.1.3 Uranium Supply

Uranium supply includes primary uranium production worldwide and secondary supply sources. Regarding U.S. uranium production, ERI generates projections for uranium production based on individual producer's published production capacities for individual uranium production centers worldwide. U.S. uranium production for 2015 was 3.3 million pounds, a 34% decline from 2014 and the lowest production level since 2005. Cameco halted new wellfield development at its Crow Butte and Highland/Smith Ranch centers and production declined as a result. Willow Creek, Palangana, and Alta Mesa all halted new wellfield installation in 2013 and 2014 and registered no or minimal production in 2015 and 2016. Energy Fuels operated the White Mesa mill at low levels, processing alternative feed material and stockpiled ore from prior conventional mining in Arizona. The newer in-situ recovery (ISR) projects at Nichols Ranch and Lost Creek held production steady rather than continue to ramp up to planned levels. Peninsula's Lance ISR project began operation in late 2015 and began shipping drummed uranium for conversion services in mid-2016. These trends will continue into 2017 and although Lance is expected to add some production, Cameco's U.S. production will continue to drop and total U.S. production is expected to decline at least an additional 12% in 2016 as a result. Figure 2.2 provides a summary of U.S. uranium production from 2008 through 2016's projected production of just under 3 million pounds.

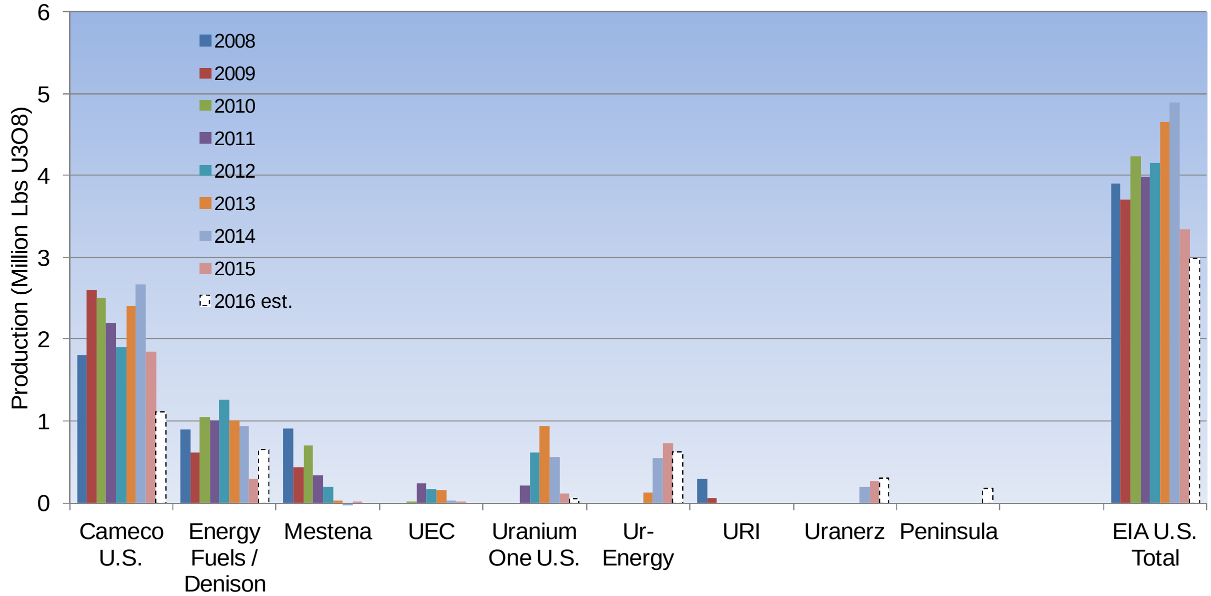


Figure 2.2 U.S. Uranium Production History by Company

2.1.4 Adequacy of Uranium Supply Relative to Requirements

ERI develops its Reference forecast for uranium supply based on published supplier plans for production from existing mines as well as plans for expansion of existing mines and new mines under active development. The initial production schedules for planned and prospective mines are dependent on market conditions and support, and therefore are speculative. While optimistic or "earliest possible" initial production schedules are often available, current projections indicate an average delay of eight years as consistent with actual market need for new planned and prospective mines. ERI also assumes that, on average, mine production will be 90% of nominal capacity over the long term due to production interruptions from unforeseen events such as accidents, floods, equipment failures, etc. As used here, uranium "supply" includes both primary production and secondary supply. Primary production refers to the amount of uranium actually produced, which may or may not represent the full or available capacity of a given mine. Secondary supply sources include: commercial inventories that may enter the market; government excess inventories, such as the DOE material that is the subject of this report and excess Russian inventories; material from Russian tails recovery; enricher underfeeding, and plutonium and uranium recycle. Ideally, available supply will be somewhat greater than demand, which consists of reactor requirements for immediate consumption plus strategic inventory building needs. When actual production causes supply to exceed demand, excess inventories are created. Based on ERI's November 2016 Reference forecast for uranium supply adequacy through 2035, Figure 2.3 presents the projected world uranium supply and requirements relationship using the updated ERI Reference requirements and accounting for recent developments, discussed below, on the primary supply side. The figure includes existing mine supply, including expansions and supply from mines being ramped up to full production (previously referred to as "under active development"). Potential supply from planned and prospective mines is excluded.[9]

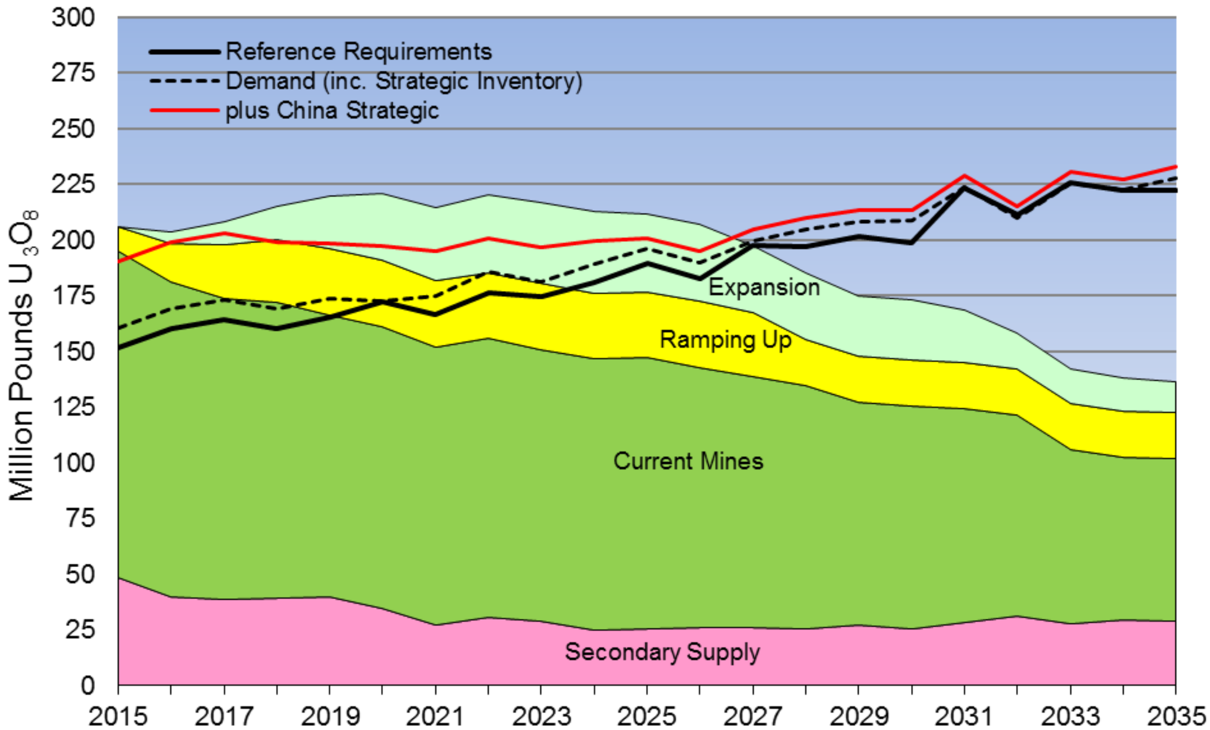


Figure 2.3 Supply Adequacy Assuming Scheduled Supply and Reference Requirements

Regarding recent developments in uranium supply, primary production of uranium increased by 8% from 2014 to 2015. For the first three quarters of 2016, primary production has continued to increase somewhat, due in part to the rapid ramp up of production at Cigar Lake, but production slowdowns and mine closures by a number of primary producers are starting to take effect. While not all suppliers report production on a quarterly basis, announcements have been made by suppliers responsible for 76% of 2016 total production. Production by these suppliers has increased by approximately 7% during the first nine months of 2016. World uranium production for 2016 is projected to be 158 million pounds, which represents a minor increase of 0.8 million pounds, or less than a 1% increase, from production in 2015.

The expected minor increase in primary production is the result of continued ramping up of the Cigar Lake and Husab mines, offset by announced production cutbacks and delays of

[9] Production from mines ramping up to full production consists of two large projects – Cigar Lake in Canada and Husab in Namibia.

expansion plans including Cameco's Key Lake as well as its U.S. ISL operations. In early January 2017, Kazatomprom announced that due to the prolonged recovery in the uranium market, planned 2017 production from Kazakhstan would be reduced by approximately 10%. Additional producer announcements may be forthcoming. The cutbacks and delays are in response to the reduction in uranium requirements in the near term as well as the continued drag on uranium prices. Despite production cutbacks and delays, as shown in Figure 2.3, significant oversupply exists through the year 2026 if all current mine expansions and mines under development proceed according to schedule.

More than half of the secondary supply shown in Figure 2.3 for 2015 and 2016 originates directly or indirectly from tails material: Russian tails recovery (26%); underfeeding of Russian enrichment plants (13%); and Western enricher underfeeding (18%). Other secondary supply sources include DOE transfers affecting the market (15%); plutonium and uranium recycle (14%); and commercial inventories (12%).

As shown by the dashed line in the figure labeled "Demand (inc. Strategic Inventory)", actual demand for uranium will be greater than nuclear power plant requirements, as end-users normally increase the amount of uranium held in strategic inventory as new units are brought on line and uranium requirements increase. Some offsets can occur by end-users reducing strategic inventory levels as plants are retired (or to make use of excess inventory accumulated during the reactor outages in Japan). The world average strategic target is assumed to be two years of forward requirements, resulting in additional demand above requirements that is estimated to average greater than 6 million pounds annually (net)[10] over the next ten years. China has been purchasing large amounts of uranium well in excess of the two years of forward requirements typical for other end users. This additional demand is captured by the red line labeled "plus China Strategic" in Figure 2.3. The discretionary strategic inventory building by China has averaged over 30 million pounds per year since 2010. ERI projects that these purchases will continue at their current rate in the near term, consistent with China’s actions over the past several years, but that the inventory building will taper off to 10 million pounds per year by 2025.

Figure 2.3 makes it clear that supply from existing mines, from expansions and from mines ramping up as currently scheduled, needs to be adjusted downward if significant over supply is to be avoided over the next ten years. In the longer term, new production will be needed from planned and prospective mines. Figure 2.4 presents the projected world uranium supply and requirements relationship for ERI's Reference Supply and Reference Nuclear Power Requirements forecast when all supply sources are included by adding planned and prospective mines; however under this projected uranium supply scenario, some adjustments are made with respect to how quickly mines under development, planned mines, and prospective mines come online. In addition, the forecast assumes that mines

[10] The net demand reflects the average 2 million pounds per year reduction in inventories by those end-users scaling back their nuclear generating capacity. The strategic inventory target of two years of forward requirements is an ERI estimate based on typical behavior which can vary in different world regions and is consistent with inventory data provided by the EIA and the Euratom Supply Agency.

ramping up will reach full capacity at a slightly slower rate than originally planned. This scenario represents ERI's best estimate of the long-term relationship between uranium supply and demand. As observed in Figure 2.3, output from mines that are ramping up (Cigar Lake and Husab) could cause total supply to exceed demand (reactor requirement plus expected changes in end-user inventories) through the year 2026. Based on this supply adequacy analysis, output from expansions need to begin in 2022, while output from planned mines is not needed until 2025 and will not be a major contributor until after 2027. First output from prospective mines is not needed until 2027 but then must grow rapidly, averaging 23 million pounds per year in 2030 and 36 million pounds in 2035.

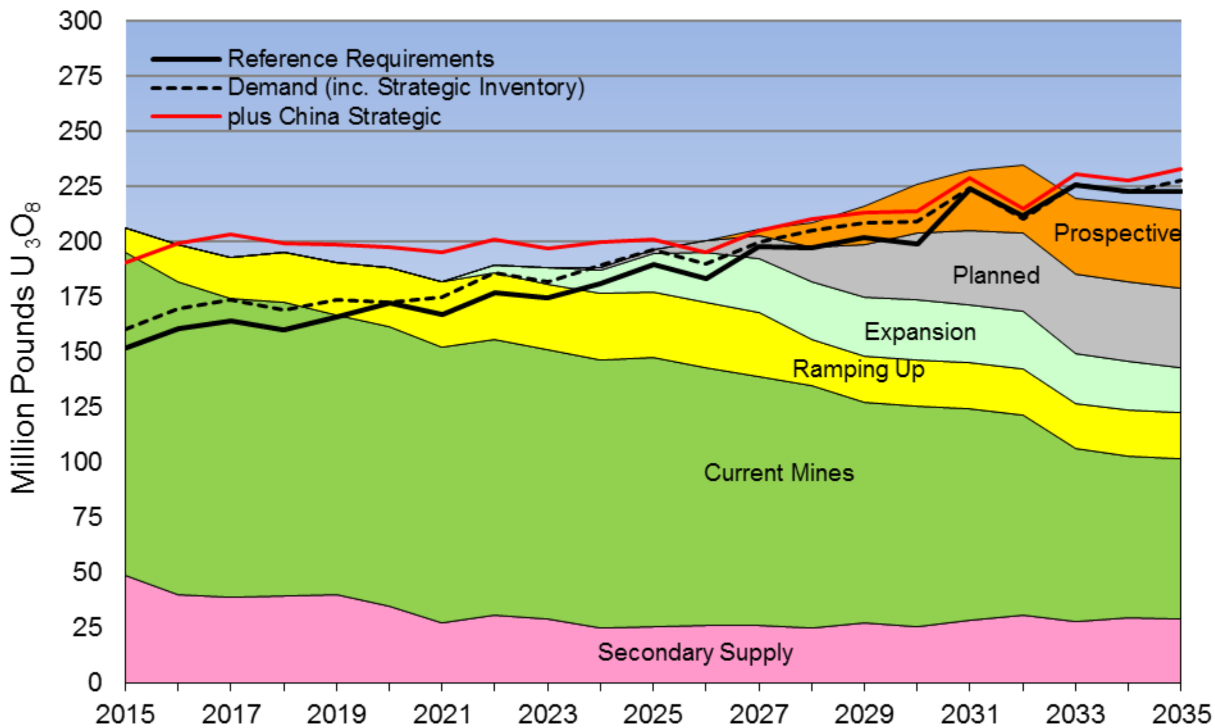


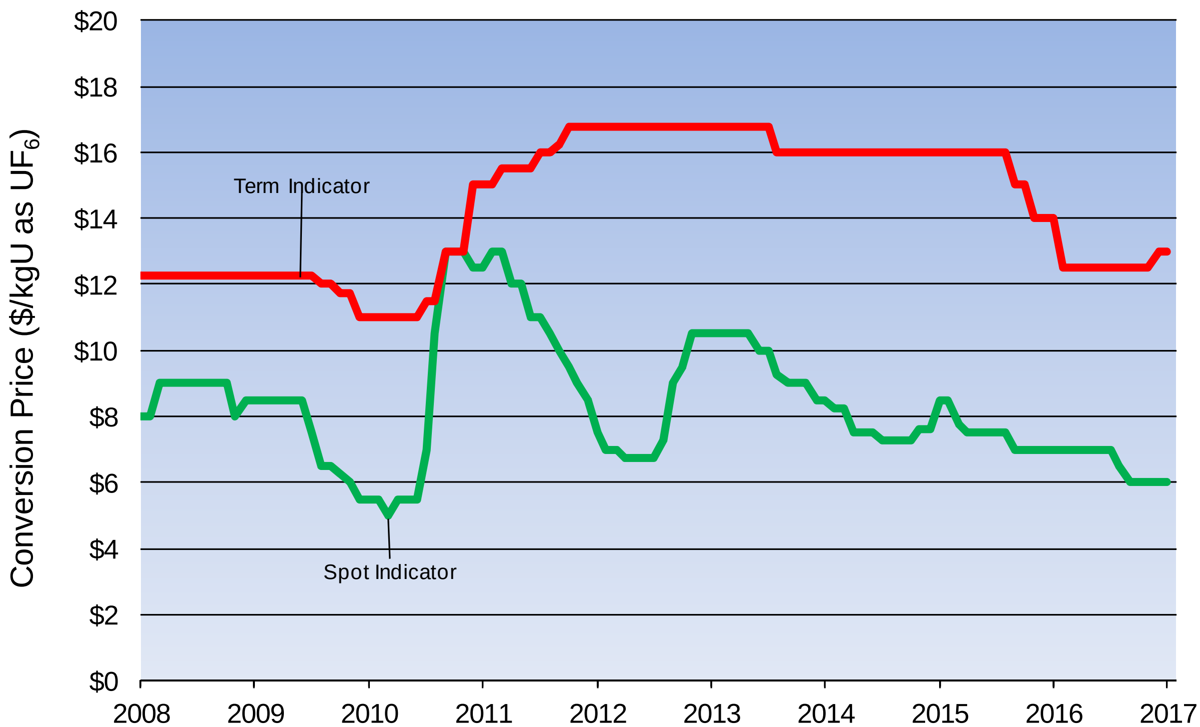
Figure 2.4 Supply Adequacy Assuming Delayed Supply and Reference Requirements

Total mine production for 2016 is projected to be 158 million pounds, which represents 0.8 million pounds or a 0.5% increase in production from 2015. Mine production is expected to remain flat through 2021, averaging 154 million pounds per year. Mine production will then increase to 171 million pounds in 2025 and to 201 million pounds in 2030. Output from existing mining operations will decline to 121 million pounds by 2025 and 100 million pounds by 2030. However, the existing operations will benefit from expansion activities supplying an additional 18 million pounds per year by 2025 and 27 million pounds a year by 2030. Supply from secondary sources is projected to remain a significant contributor at 15% of total supply through 2035, but will gradually decline through 2024. Over the next ten years secondary supply will include DOE inventory (16%), Russian and western enricher underfeeding (52%), plutonium and uranium recycle (24%) and other commercial inventories (7%).

2.2 Conversion Services

2.2.1 Conversion Market Price Activity

Figure 2.5 provides North American conversion market price indicators from 2008 to the present. Over the past ten years, the spot market for conversion services has been highly volatile, marked by rapid increases and severe declines. As a result of the temporary closure of Metropolis Works in 2012, the North American spot market price for conversion services reported by TradeTech rose from $6.75 per kgU in June 2012, to a high of $10.50 per kgU by October 2012. With the announced restart of the plant in June 2013, the North American spot market price began to fall reaching $7.25 by June 2014. The price rose slightly to $8.50 in December 2014, before beginning a decline to its present level of $6.00 as of December 31, 2016. As shown in Figure 2.5, since January 2015, the spot market indicator for North American conversion services has fallen by $2.50 per kgU (30%).



Source: TradeTech

Figure 2.5 Historical North American Market Indicators for Conversion Services

The North American long-term market price has historically been much less volatile. The reported term price remained in a tight range of $11.00 to $12.25 per kgU from January 2005 through mid-2010. The term price then steadily increased over the following year, reaching \$16.75 in September 2011[11], where it had remained until July 2013, when it fell to \$16.00 per kgU. The conversion term price started a more dramatic decline in August 2015, reaching \$12.50 per kgU in January 2016. The price increased at the end of the year to \$13.00 per kgU. As shown in Figure 2.5, the term market indicator has decline by \$3.00 (19%) since January 2015.

2.2.2 Conversion Services Requirements

ERI's Reference forecast of requirements for conversion services are calculated on a plant-by-plant basis, based on fuel discharge burn-up, reload fuel assays, fuel cycle lengths, first-core and reload lead times, and operating capacity factors. Annual projected requirements for uranium as UF_6 for ERI's November 2016 Reference forecast world requirements are projected to rise gradually from 52 million kgU in 2015 to 57 million in 2016, to 62 million kgU by 2020 and to 80 million kgU by the period 2032 to 2035. ERI projects that U.S. requirements for conversion services will remain essentially unchanged from 2016 through 2035 and to average 17 million kgU.

2.2.3 Adequacy of Conversion Supply Relative to Requirements

Figure 2.6 provides an updated requirements and supply forecast for conversion services as UF_6 in order to provide an updated supply adequacy examination. Conversion supply includes primary production of UF_6 and secondary supply sources. Assumptions regarding annual production of UF_6 are based on information from producer annual reports, data from other industry sources, and ERI analyses of the conversion market. As discussion in Section 2.1.4, China has imported large quantities of U_3O_8 (not natural UF_6) in order to build its strategic inventory during the past five years. If China does not grow its indigenous UF_6 production capacity, it will have to re-export the U_3O_8 for conversion, and again import the UF_6 – a scenario that seems unlikely. This is consistent with expected Chinese policy of self-sufficiency and ERI assumes that China will continue to expand its indigenous conversion production capacity in order to meet growing Chinese requirements. While AREVA's Comurhex II can be expanded further, AREVA has stated that it will not expand capacity beyond 15 million kgU per year unless warranted by market conditions. As such, ERI assumes that Comurhex II capacity remains at 15 million kgU per year through 2035. New supply from the planned expansion of Rosatom's Siberian Chemical Combine center is assumed to come on line in 2019 and Rosatom's Angarsk plant was closed in 2014.

Within the secondary supply component shown in Figure 2.6, in 2015 and 2016, the largest component of secondary supply is uranium from enricher underfeeding and Russian tails recovery (57%); DOE inventory entering the market (15%); plutonium and uranium recycle

[11] The 46% increase in term price in mid-2011 followed an October 2010 announcement by ConverDyn regarding its pricing in future contracts.

(14%); and commercial/other inventories (13%). As indicated by Figure 2.6, total expected world conversion supply exceeds projected requirements for conversion services through 2035. The supply excess averages nearly 13 million kgU as UF_6 annually over the next ten years (2017-2026) and is equivalent to 20% of requirements. Available supply exceeded requirements by an average of 12 million kgU as UF_6 (22%) annually over the last two years (2014-2015).

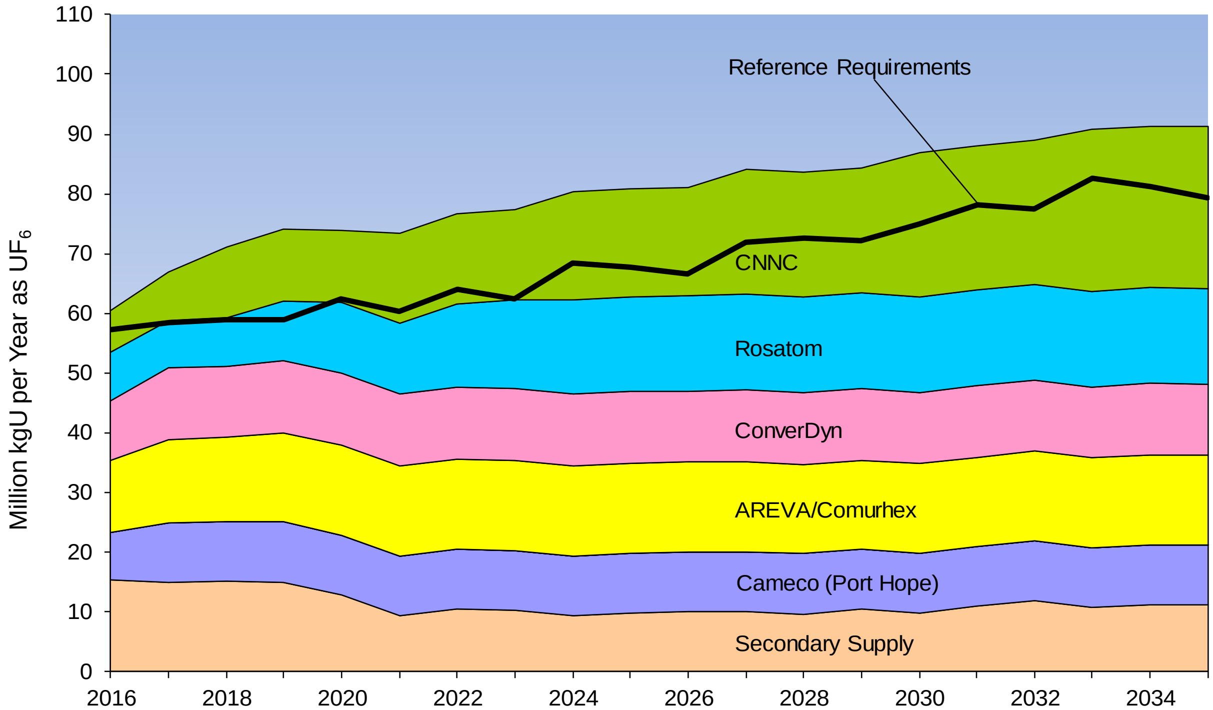


Figure 2.6 Forecast of World Supply and Requirements for Conversion Services

2.3 Enrichment Services

2.3.1 Enrichment Market Price Activity

As shown in Figure 2.7, the long-term price indicator for enrichment services, as reported by TradeTech, reached a high of $165 per separative work unit (SWU) in May 2009. However, by early 2010 the price began a steady decline, reaching $135 per SWU in October 2012, and further declining during 2013 to the present price of $53 per SWU in December 2016. While more than 90% of enrichment requirements are covered under long-term contracts, enrichment services and EUP are also traded on the spot market although in lower volumes than uranium. Enrichment spot market indicators also rose to a high of $165 per SWU in May 2009 but then steadily declined steadily similar to the behavior of the long-term SWU price indicator as shown in Figure 2.7. The spot market indicator has declined to $47 per SWU as of December 31, 2016. The term market indicator is $105/SWU (66%) lower and the spot market indicator is $108/SWU (70%) lower when compared to the February 2011 pre-Fukushima values. More recently, the term market indicator is $37/SWU (41%) lower and the spot market indicator is $41/SWU (47%) lower when compared to the January 2015 values.

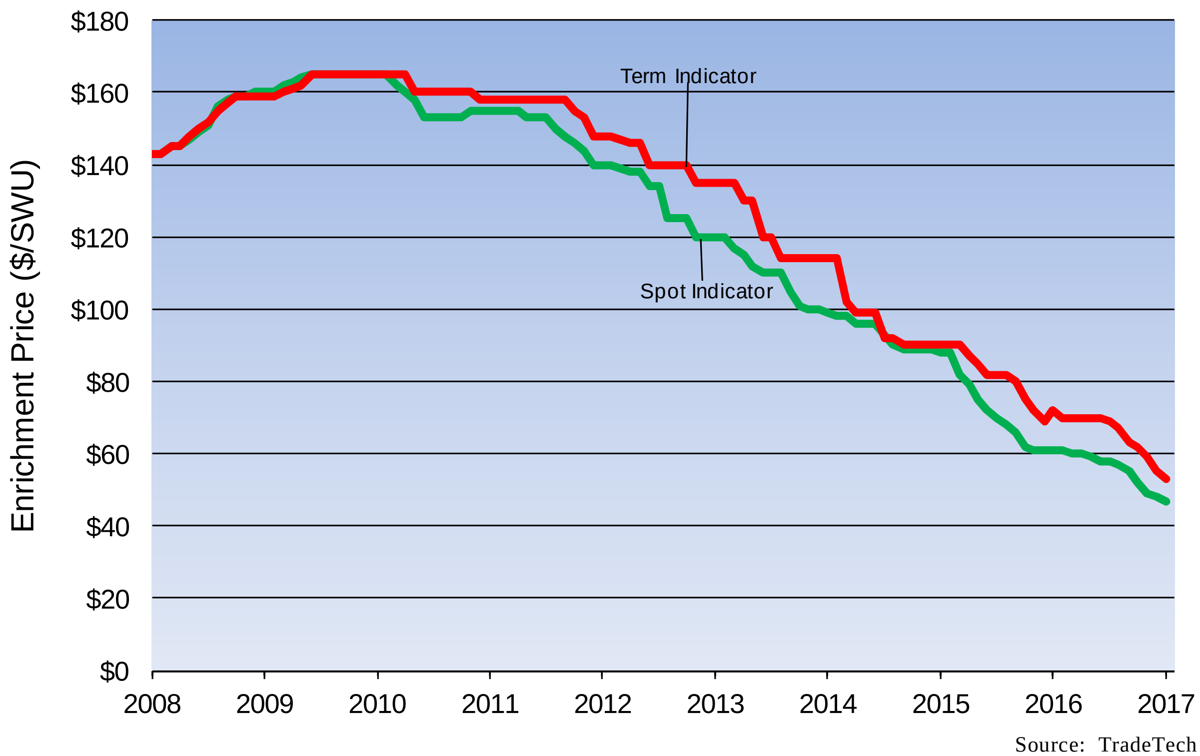


Figure 2.7 Historical Spot and Long-Term SWU Market Price Indicators

2.3.2 Enrichment Services Requirements

ERI’s Reference forecast of requirements for enrichment services are calculated on a plant-by-plant basis, based on fuel discharge burn-up, reload fuel assays, fuel cycle lengths, first-core and reload lead times, and operating capacity factors. “Requirements” for enrichment services, as used herein, refers to the quantity of enrichment services that will be needed to produce nuclear fuel for reactors which are expected to be operating during the forecast period. ERI's November 2016 Reference forecast for enrichment services requirements projects that annual world requirements for enrichment services in 2016 are 45.4 million SWU, but should then increase to 49 million SWU in 2017. Requirements are forecast to average 52 million SWU per year between 2018 and 2020, 58 million SWU per year between 2021 and 2025, 64 million SWU per year between 2026 and 2030, and 71 million SWU per year between 2031 and 2035. U.S. requirements are projected to be essentially flat, averaging almost 15 million SWU per year between 2016 and 2035.

2.3.3 Adequacy of Enrichment Supply Relative to Requirements

Figure 2.8 provides an updated requirements and supply forecast in order to provide an updated supply adequacy examination. Enrichment services supply includes primary production of EUP and secondary supply sources. Assumptions regarding annual production of EUP are based on information from producer annual reports, data from other industry sources, and ERI analyses of the enrichment market. For Western enrichers, only existing capacity and firmly planned[12] new capacity are assumed and the supply shown is for all enrichment capacity, prior to any redirection for uranium production via underfeeding and refeeding of existing tails stockpiles.

Major supply expansion at several sites has now been completed. AREVA increased Georges Besse II (GB II) capacity to 7.4 million SWU and Urenco USA capacity increased to 4.6 million SWU by the end of 2015. Urenco USA capacity will slowly increase to 5.7 million SWU by 2022. In 2016, Urenco reduced its production capacity at the Capenhurst site when it mothballed two production halls (out of 15). Urenco has also made small capacity reductions by not replacing aging centrifuges at its European sites when centrifuges go out of service. Urenco and industry overcapacity coupled with very low prices for enrichment services as well as uranium led to the decision.

[12] Firmly planned new capacity refers to enrichment facility capacity additions which have been announced by primary producers.

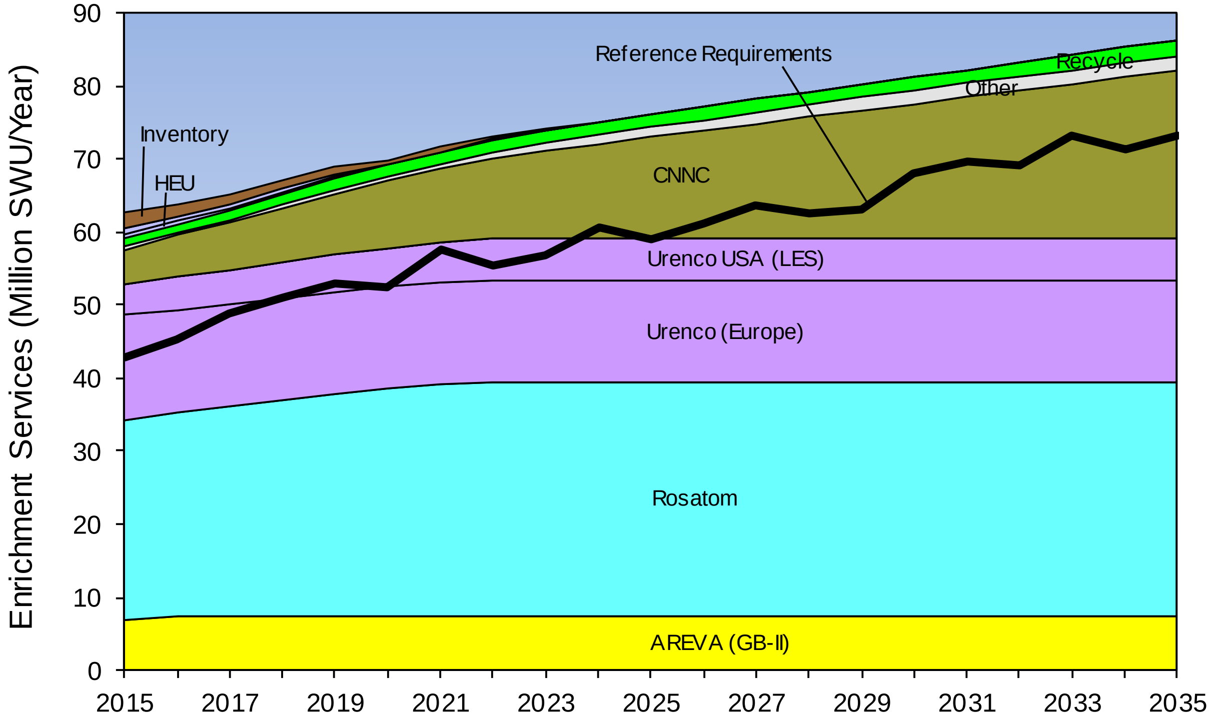


Figure 2.8 Forecast of World Supply and Requirements for Enrichment Services

As indicated by Figure 2.8, total expected world enrichment supply significantly exceeds projected requirements for enrichment services by a significant margin over the long term. However, it is expected that enrichers will continue to redirect enrichment capacity to underfeeding and that Rosatom will likely continue to re-enrich existing uranium tails. The long-term supply adequacy shown in Figure 2.8 includes the assumption that Urenco will replace cascades at the European sites as they retire after 25 years of operation, keeping installed capacity constant.

As indicated by Figure 2.8, total expected world enrichment supply significantly exceeds projected requirements for enrichment services. However, as noted above, it has long been recognized that Rosatom devotes a significant portion of its enrichment supply to uranium production. Rosatom utilizes enrichment capacity for uranium production by operating at low tails assays (underfeeding) and by refeeding existing tails inventory. As noted above Figure 2.8 assumes that Urenco will replace cascades at the European sites as they retire after 25 years of operation, keeping installed capacity constant. However, during 2013 Urenco retired a total of 0.3 million SWU at its three European sites and in mid-2016 additional capacity was mothballed at the Capenhurst site. Figure 2.9 examines supply adequacy after redirection of Rosatom and Western enricher supply to uranium production and assuming that Urenco does not replace cascades after 25 years of operation, resulting in decreased capacity in European enrichment capacity. Even with these assumed changes in enrichment supply, excess supply is still apparent on a world basis, particularly over the next ten years, but is dramatically reduced when enrichment supply directed to uranium production is removed.

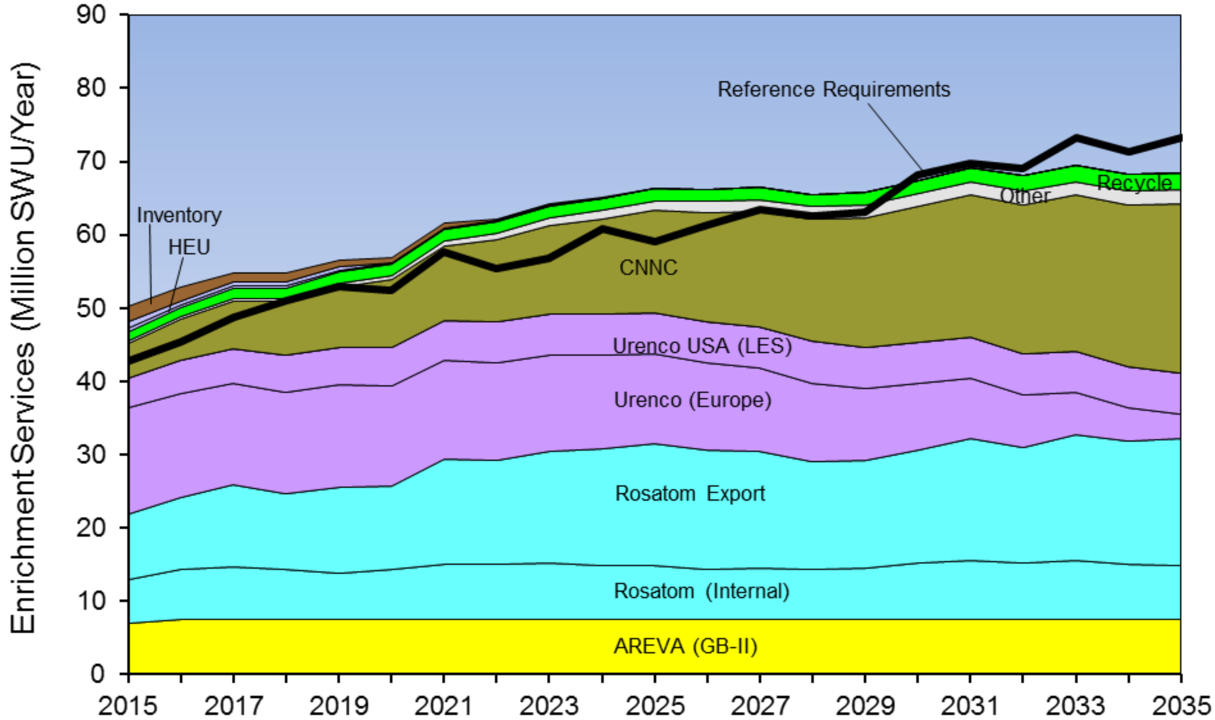


Figure 2.9 Supply Adequacy After Redirection of Enrichment Capacity for Uranium Production and Without Urenco Capacity Replacement

2.4 Summary of U.S. Requirements for Nuclear Fuel

Figure 2.10 provides a summary of U.S. requirements for nuclear fuel materials and services over the period 2014 through 2026 that is based upon ERI's current Reference Nuclear Power Growth forecasts. ERI's Reference forecast of requirements for nuclear fuel materials and services are calculated on a plant-by-plant basis, based on fuel discharge burn-up, reload fuel assays, fuel cycle lengths, initial core and reload lead times, and operating capacity factors. The saw tooth nature of these annual requirements reflects that nearly all U.S. nuclear power plants operate on 18 or 24 month refueling cycles.

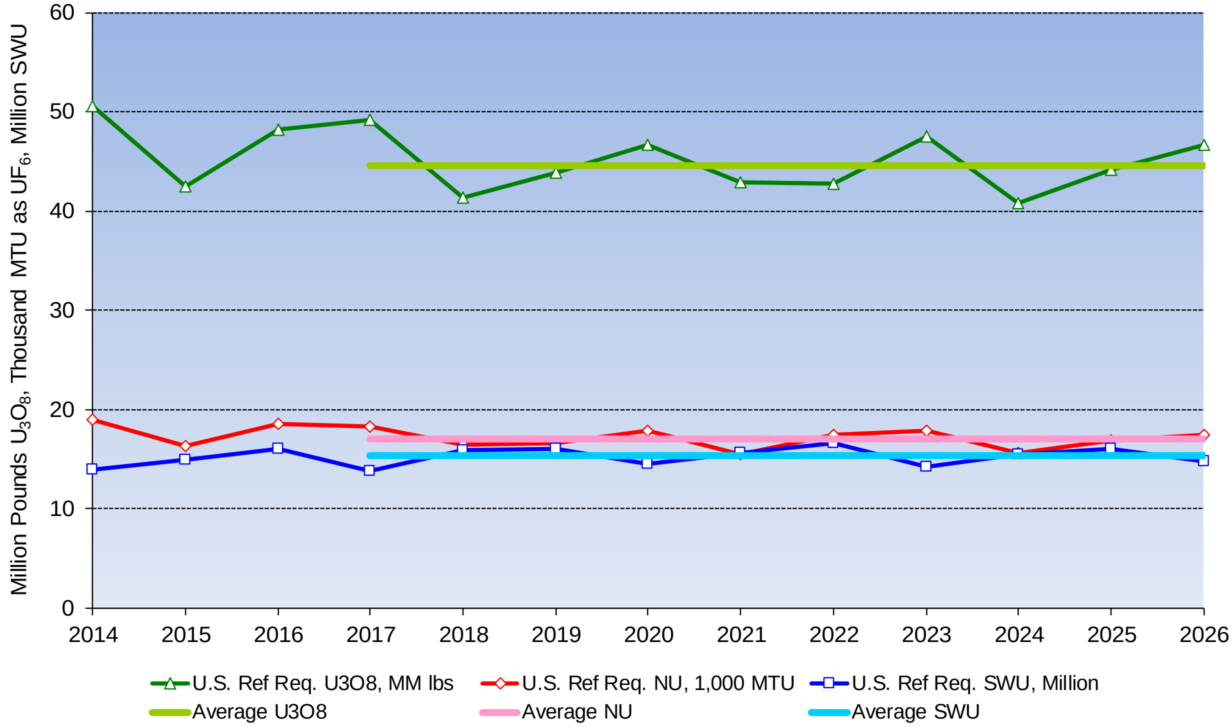


Figure 2.10 U.S. Requirements for Nuclear Fuel Materials and Services

Since the underlying change in average U.S. requirements over time is relatively small, but with significant year-to-year variation, average values that represent forecast years 2016 through 2026 are presented in Table 2.1. These values may be used to provide perspective regarding the quantities of DOE material released to the global commercial markets relative to U.S. requirements.

	Average Over Period 2017 – 2026	Average Used in February 2015 Analysis 2015 – 2024
U.S. Uranium Concentrates Requirements Million Pounds U_3O_8	44.6	45.6
U.S. Uranium Conversion Requirements Million kgU as UF_6	17.0	17.4
U.S. Enrichment Services Requirements Million SWU	15.3	14.8

Note: 1,000 MTU = 1 million kgU
Source: ERI 2016 Nuclear Fuel Cycle Supply and Price Report, Update, Reference Nuclear Power Growth Forecast, November 2016

Table 2.1 Summary of U.S. Requirements for Nuclear Fuel Materials and Services

The updated projections for average U.S. requirements for uranium and conversion services are lower than those used in the February 2015 ERI market analysis, although enrichment requirements have increased somewhat due to lower tails assay assumption. Projected U.S. uranium and conversion requirements have declined by 2% while U.S. enrichment requirements increased by 4%. The percent change in uranium, conversion and enrichment requirements differ due to a variety of factors, including the fact that nuclear fuel assemblies may contain NU pellets, such that some uranium does not require enrichment; the feed material for these NU pellets may also be made from UO_2, which did not undergo conversion from U_3O_8 to UF_6; and the enrichment tails assay will also impact the NU and enrichment requirements. ERI's projection of U.S. requirements assumes additional delays in the start of new reactors that are under construction and additional reactor retirements due to economic pressures. Economic pressures that impact decisions regarding continued nuclear plant operation, as reflected in ERI's lower projection of U.S. requirements, include low natural gas prices, the completion of higher-priced power purchase agreements, competition from subsidized renewables and low value placed on base-load capacity in deregulated markets. In addition to the early U.S. plant retirements that have occurred over the period 2013 to 2015, ERI expects an additional nine retirements totaling 7 GWe to take place in the U.S. through 2025.[13] No additional new build beyond four AP1000's currently under construction is expected to occur in the U.S. until around 2030 in the Reference projection.

As a point of comparison, the ERI requirements forecasts shown in Table 2.1 are more conservative than the most recent analysis by the World Nuclear Association (WNA), which was published in September 2015 and is entitled "The Nuclear Fuel Report, Global Scenarios for Demand and Supply Availability 2015-2035" (WNA 2015). Over the 2017 through 2026 period, the total U.S. nuclear fuel requirements forecasts published by WNA are approximately 10% higher than those shown in Table 2.1 for uranium and conversion and 3% higher for enrichment. After accounting for the difference in tails assay assumed, the WNA requirements are about 7% higher. In general, the WNA projection is based on more optimistic assumptions regarding new capacity additions and early retirements in both the U.S. and the world as well the restart schedule for reactors in Japan. However, ERI expects that these assumptions will be adjusted downward by WNA in its 2017 report.

2.5 Summary of Published Market Prices

Current monthly spot and term market prices[14] (also referred to as "price indicators") are summarized in Table 2.2. The current market prices for uranium concentrates are 50%

[13] Could be as high as 17 reactors totaling 15 GWe.

[14] TradeTech's spot prices "reflect the company's judgment of the price at which spot and near-term transactions for significant quantities [of that product or service] could be concluded as of the last day of the month". TradeTech's long-term price indicators are "TradeTech's judgment of the base price at which transactions for long-term delivery of that product or service could be concluded as of the last day of the month, for transaction in which the price at the time of delivery would be an escalation of the base price from a previous point in time." While ERI utilizes price indicators published by TradeTech in this report, it

lower than the then-current prices used in the February 2015 ERI market analysis and long-term prices are 30% lower. Conversion services spot market prices are 30% lower and long-term prices are 22% lower, while the prices for enrichment services are 44% to 34% lower. The price for uranium as natural UF_6 based on spot market prices is 48% lower and UF_6 long-term prices are 29% lower.

	Spot Market Price	Long-Term Market Price
Uranium Concentrates $/lb U_3O_8	$20.25	$30.00
Uranium Conversion Services (North American) $/kgU as UF_6	$6.00	$13.00
Enrichment Services $/SWU	$47.00	$53.00
Uranium as Natural UF_6 $/kgU as UF_6	$58.75	$91.39
Market Price Indicators are as published by TradeTech in the December 31, 2016 issues of its weekly publication, Nuclear Market Review. http://www.uranium.info. Term UF_6 price calculated from component prices by ERI.		

Table 2.2 Recently Published Market Prices

Market prices have declined considerably since the Fukushima event in March 2011, with prices declining steadily over the past year in both the uranium and enrichment markets. Uranium, conversion and enrichment spot price indicators have all demonstrated similar declines, with prices as of December 31, 2016 ranging between 54% and 71% lower than prices on February 28, 2011 just prior to the Fukushima event. For the term markets, enrichment prices are down 66%, a similar decline to the spot price behavior. Uranium term prices are down 57%, which is a lower decline than observed for the uranium spot price. Conversion term prices are just 16% lower than on February 28, 2011, a more modest decline than seen in the uranium and enrichment term indicators.

should be noted that fuel supply contracts that have market-related pricing generally reference the TradeTech price indicators as well as price indicators published by Ux Consulting (www.uxc.com). While the indices published by these companies are not identical at all times, they do closely track one another. For example, over the period January 2015 through December 2016, the uranium, conversion and enrichment spot and term indicators have differed by an average of ±1% or less with one exception -the Ux spot indicator for North American conversion services has averaged 2.6% lower than the TradeTech indicator. Both provide a reliable measure of the spot- and term-market prices and are widely quoted. Price indicators published by other companies are not as widely used.

3. DOE Inventory Expected to Affect the Commercial Markets

As was described in the February 2015 ERI market analysis, there are three broad categories of material for which DOE inventory is expected to affect the commercial markets during the period of time that is addressed by this analysis (2017 through 2026). They are (i) historical DOE transfers, the natural and enriched uranium from which will continue to displace commercial supply in the market in the future, (ii) current and near-term inventory transfers in exchange for services (transfers for services), and (iii) future transfers of DOE inventory, primarily additional DUF_6 under agreement with GLE, but also proposed transfers of off-spec LEU and off-spec non-UF_6 that are currently under consideration. As reflected below, DOE has asked ERI to assess quantities somewhat different from those used in the February 2015 ERI market analysis.

3.1 Historical DOE Transfers Resulting in Natural and Enriched Uranium Which Continue to Displace Commercial Supply

DOE has transferred inventories in the past, and the resulting natural and enriched uranium will continue to displace commercial supply in the market in the future, even though the transfers are completed. The historical transfers include off-spec HEU to the TVA and high assay DUF_6 to ENW. In each case, the transferred DOE inventories were to be processed (down blended or re-enriched) and the resulting LEU product loaded into reactors over a period of many years. For purposes of evaluating the effect of the transferred inventories on the commercial markets and U.S. industry, the time at which DOE transferred the material to a recipient is not necessarily the most important fact. It is appropriate to evaluate the effect according to the schedule of the delivery of the processed inventory as reactor fuel, consistent with the times at which commercial supply would otherwise be used to fulfill the reactor fuel requirements.

Off-Spec HEU to TVA

TVA has been blending off-spec HEU from the NNSA since 2005 under the BLEU program.[15] A total of 46 metric tons (MT) of HEU has been processed. The transfer to and down blending of the off-spec LEU by TVA's down blending contractors was completed in 2012. The first BLEU reload was introduced into a TVA reactor in 2005. BLEU reloads continue to be loaded into the Browns Ferry reactors. At the time of the February 2015 ERI market analysis, NNSA had indicated that it planned to extend the BLEU program by down blending an additional small quantity (less than 3 MT) of off-spec HEU, which would result in this material entering the market over the period 2018 to 2023. However, these additional small quantities of off-spec HEU have not yet been identified nor has their schedule been finalized. The final BLEU reload is expected to be loaded in 2017. This

[15] This is a long-term contract between DOE and TVA under which the first fuel assemblies that contained the NNSA off-spec material were loaded into a TVA nuclear power plant in March 2005.

results in there being no further transfers of material associated with the TVA BLEU material during the period 2017 to 2026 as shown in Table 3.1.

DOE Depleted UF_6 Transferred to ENW and Subsequent ENW LEU Sale to TVA

DOE transferred 9,075[16] MTU of high assay DUF_6 to ENW in 2012 and early 2013. The DUF_6 was then enriched to LEU by ENW, with enrichment services provided under a contract with USEC. The enrichment took place between June 2012 and May 2013 at the Paducah GDP. ENW entered into a contract with TVA for the purchase by TVA of most of the enrichment services content contained within the LEU as well as a significant portion of the NU content. The enrichment services and NU equivalent are to be delivered to and used by TVA between 2015 and 2023. ENW will use a portion of the NU content starting in 2018 to help meet reload requirements for the Columbia Generating Station.[17] As indicated by the above discussion, while the DUF_6 was transferred to ENW in 2012, the NU and enrichment contents of the resulting LEU started to displace commercial supply in the market in 2015 consistent with actual use by TVA and ENW. The NU and enrichment services content of the LEU created from the DUF_6 are being delivered under long-term contract arrangements.

Summary of Historical DOE Transfers Resulting in Natural and Enriched Uranium Which Continue to Displace Commercial Supply

Table 3.1 presents a summary of the year and quantities of NU as UF_6, equivalent uranium concentrates, and enrichment services from historical DOE transfers that will continue to affect the commercial markets. Totals are provided for the period 2017 to 2026 covered by this analysis. Quantities affecting the markets in 2014 through 2016 are also shown to provide additional perspective.

[16] DOE's July 2013 Excess Uranium Inventory Management Plan indicates 9,082 MTU of high assay DUF_6 while ENW's Fuel Management Plan specifies 9,075 MTU. ENW delivered 600 MTU of natural UF_6 to USEC along with the DUF_6.

[17] Quantities and scheduled use of natural UF_6 and enrichment services confirmed by private communications with ENW and information provided by DOE.

Year	MTU as UF_6			Equivalent Million Pounds of U_3O_8 (a)			Equivalent SWU (Millions)		
	TVA BLEU	ENW DUF_6	Total	TVA BLEU	ENW DUF_6	Total	TVA BLEU	ENW DUF_6	Total
2014	318		318	0.8		0.8	0.7		0.7
2015	318		318	0.8		0.8	0.3	0.1	0.5
2016	105		105	0.3		0.3	0.1	0.4	0.5
2017								0.3	0.3
2018		296	296		0.8	0.8		0.5	0.5
2019		677	677		1.8	1.8		0.4	0.4
2020		377	377		1.0	1.0		0.3	0.3
2021		317	317		0.8	0.8		0.6	0.6
2022		258	258		0.7	0.7		0.4	0.4
2023		450	450		1.2	1.2		0.3	0.3
2024								0.0	0.0
2025		450	450		1.2	1.2			
2026									
Total 2017-26	0	2,825	2,825	0.0	7.4	7.4	0.0	2.6	2.6

Table 3.1 Historical Transfers That Continue to Displace Commercial Supply

Note that a total of 4.4 million SWU were contracted with USEC to enrich the DUF_6 to commercial LEU between June 2012 and May 2013, allowing USEC's Paducah enrichment plant to remain open for one extra year. However the 4.4 million SWU was not considered as increasing demand when analyzing the effect of DOE inventory releases on the enrichment market in 2012-2013 and therefore an offset is not shown in Table 3.1. The new demand created was effectively balanced by the new supply created (one year extension of Paducah GDP), resulting in no net impact to the enrichment market.

3.2 Current and Near-Term DOE Inventory Transfers for Services

Office of Environmental Management Transfers for Cleanup Services

DOE's Office of Environmental Management (EM) makes monthly transfers of natural UF_6 to its contractor, Fluor B&W Portsmouth (FBP), for services being provided in support of the environmental cleanup of the Portsmouth GDP. The material received by FBP subsequently enters the commercial markets, via a separate agreement FBP has with Traxys North America LLC (Traxys). DOE asked ERI to assess the market effects of this program assuming several scenarios.

Traxys has introduced the EM transferred material into the commercial markets partly through spot market and partly through term market transactions.[18] For uranium, Traxys seeks to sell at

[18] Smith, Kevin, Director Uranium Trading and Marketing, Traxys, Commercial View of DOE's 2013 Plan for Natural Uranium Barter Sales, Nuclear Energy Institute, International Uranium Fuel Seminar, October 6-9, 2013, San Antonio, Texas.

least 50% of its material on term contracts and at least 50% to non-U.S. customers. For conversion services, Traxys reported that it sold on non-U.S. markets 58% of what EM supplied in 2013, and sold 68% of what EM supplied in 2013 under term contracts. Traxys also reported that 90% of the conversion services to be supplied by EM in 2015 and 2016 (based on a total of 2,055 MTU per year supplied by EM) have already been committed under term contracts.[19] Since there is no guarantee that this same percentage of sales of EM transfer for services material will be made in later years, in this analysis, ERI conservatively assumes that 50% of the conversion component of the EM transfer for services material is sold on the spot market and 50% is sold under term contracts in 2015 and beyond, consistent with the Traxys goal.

NNSA Transfers for Down Blending Services

In recent years, the down blending of DOE HEU has been performed through a contract with WesDyne International, LLC, which subcontracts to the only domestic commercial down blender in operation (Nuclear Fuel Services, or NFS). A portion of the resulting down blended material, LEU with an enrichment assay of 4.95 w/o U^{235} or less, is transferred back to WesDyne from NNSA, as payment for the down blending services. Due to increased down blending costs and reduced market value of LEU, all derived LEU is currently transferred to WesDyne as compensation. The derived LEU material that is transferred to WesDyne from NNSA is then utilized[20] to support tritium production through a separate contract between WesDyne and the Tennessee Valley Authority (TVA) nuclear power plants.

Following the current down blend campaign that transfers LEU material, NNSA's Office of Defense Programs plans to conduct the HEU Down Blending Offering for Tritium (DBOT) campaign in FY 2019 to 2025. The NNSA does not plan to transfer any LEU arising from down blending under the HEU DBOT campaign during the time span of this analysis (through 2026).

Total Current and Near-Term Transfers for Services

Under the Base Scenario, DOE plans to limit the total NU equivalent in the EM and NNSA transfers to a total of 2,100 MTU per year. If the NNSA transfers required to pay for the HEU down blending services are less than 500 MTU per year, then a greater quantity of EM transfers could take place, keeping the combined total at the specified limit[21]. If this occurs in the future, the EM inventory of NU would be depleted more rapidly, resulting in a lower quantity in the

[19] Smith, Kevin P., Traxys North America LLC, Managing Director for Uranium Marketing and Trading, Declaration of Kevin P. Smith, Attachment 6 to Defendant's Opposition to Plaintiff's Motion for Preliminary Injunction, Case No. 1:14-cv-1012-RBW, Document 17-7, Filed July 7, 2014, at 23.

[20] Via an obligation swap as the tritium production requires unobligated material. The swapped material with national obligations is then marketed by Westinghouse.

[21] For example, in 2016 NNSA only used 450 MTU of their 500 MTU allocation, providing an additional 50 MTU allocation for EM to utilize (although it did not).

final transfer year. The Base Scenario is lower than releases of material by EM and NNSA in Scenario 1 of the February 2015 ERI market analysis.

DOE has requested that a total of four scenarios be analyzed in this report:

> Base Scenario: EM transfers for services at a rate of 1,600 MTU as UF_6 in 2017 and 2018, 1,569 MTU in 2019 and 559 MTU in 2020 when EM UF_6 supplies are exhausted. The NNSA release rate is 500 MTU per year from 2017 to 2019 for the current down blending activities. NNSA transfers would end in 2019, after which (2019 to 2025) NNSA would then down blend HEU under the DBOT campaign, but the resulting down blended LEU would be held for later use in the TVA tritium production program and not transferred during the time span of this analysis (through 2026). The blending process still requires the purchase of natural UF_6 blend stock each year ranging between 48 and 64 MTU as UF_6 in 2019 to 2025, as shown in Table 3.2. The blend stock purchases are shown as a negative as they offset a small amount of the total DOE transfers.
>
> Scenario 1: No EM transfers for services between 2017 and 2026. NNSA transfer rate does not change from the Base Scenario.
>
> Scenario 2: EM release rate of 1,295 MTU per year until 2020 and 148 MTU in 2021, when UF_6 supplies are exhausted. NNSA transfer rate does not change from the Base Scenario.
>
> Scenario 3: EM release rate of 1,905 MTU per year in 2017 and 2018 and 1,518 MTU in 2019, when UF_6 supplies are exhausted. NNSA transfer rate does not change from the Base Scenario.

The material transfers to DOE contractors as payment for services which are presently under consideration by DOE are summarized in Tables 3.2, 3.3, 3.4, and 3.5 for each of the scenarios. In addition to showing the annual and total equivalent net amounts of uranium as natural UF_6, which is also the quantity of equivalent conversion services, the corresponding equivalent net amount of uranium concentrates is shown, as is the net equivalent amount of enrichment services.[22] Totals are provided for the period 2017 to 2026 covered by this analysis. Quantities affecting the markets in 2014 through 2016 are also shown to provide additional perspective.

[22] These are referred to as being "net" amounts of materials and services since they account for any natural uranium diluent that would be purchased in the commercial market to support the down blending of HEU.

Year	MTU as UF_6			Equivalent Million Pounds of U_3O_8 (a)			SWU (Millions) (b)
	EM Transfers	NNSA Transfers	Total	EM Transfers	NNSA Transfers	Total	NNSA Transfers
2014	2,055	650	2,705	5.4	1.7	7.1	0.7
2015	2,000	534	2,534	5.2	1.4	6.6	0.6
2016	1,600	450	2,050	4.2	1.2	5.4	0.4
2017	1,600	500	2,100	4.2	1.3	5.5	0.5
2018	1,600	500	2,100	4.2	1.3	5.5	0.5
2019	1,569	452	2,021	4.1	1.2	5.3	0.5
2020	559	(64)	495	1.5	-0.2	1.3	0.0
2021		(64)	(64)		-0.2	-0.2	0.0
2022		(64)	(64)		-0.2	-0.2	0.0
2023		(64)	(64)		-0.2	-0.2	0.0
2024		(64)	(64)		-0.2	-0.2	0.0
2025		(48)	(48)		-0.1	-0.1	0.0
2026							0.0
Total 2017-26	5,328	1,084	6,412	13.9	2.8	16.8	1.6

(a) Calculated by multiplying the MTU as UF6 value by a conversion factor of 0.00261285.

(b) NNSA transfers are in the form of 4.95 w/o EUP and therefore have enrichment content.

Table 3.2 Current and Near-Term DOE Inventory Transfers for Services – Base Scenario

Year	MTU as UF_6			Equivalent Million Pounds of U_3O_8 (a)			SWU (Millions) (b)
	EM Transfers	NNSA Transfers	Total	EM Transfers	NNSA Transfers	Total	NNSA Transfers
2014	2,055	650	2,705	5.4	1.7	7.1	0.7
2015	2,000	534	2,534	5.2	1.4	6.6	0.6
2016	1,600	450	2,050	4.2	1.2	5.4	0.4
2017		500	500		1.3	1.3	0.5
2018		500	500		1.3	1.3	0.5
2019		452	452		1.2	1.2	0.5
2020		(64)	(64)		-0.2	-0.2	0.0
2021		(64)	(64)		-0.2	-0.2	0.0
2022		(64)	(64)		-0.2	-0.2	0.0
2023		(64)	(64)		-0.2	-0.2	0.0
2024		(64)	(64)		-0.2	-0.2	0.0
2025		(48)	(48)		-0.1	-0.1	0.0
2026							0.0
Total 2017-26	0	1,084	1,084	0.0	2.8	2.8	1.6

(a) Calculated by multiplying the MTU as UF6 value by a conversion factor of 0.00261285.

(b) NNSA transfers are in the form of 4.95 w/o EUP and therefore have enrichment content.

Table 3.3 Current and Near-Term DOE Inventory Transfers for Services – Scenario 1

Year	MTU as UF_6			Equivalent Million Pounds of U_3O_8 (a)			SWU (Millions) (b)
	EM Transfers	NNSA Transfers	Total	EM Transfers	NNSA Transfers	Total	NNSA Transfers
2014	2,055	650	2,705	5.4	1.7	7.1	0.7
2015	2,000	534	2,534	5.2	1.4	6.6	0.6
2016	1,600	450	2,050	4.2	1.2	5.4	0.4
2017	1,200	500	1,700	3.1	1.3	4.4	0.5
2018	1,200	500	1,700	3.1	1.3	4.4	0.5
2019	1,200	452	1,652	3.1	1.2	4.3	0.5
2020	1,200	(64)	1,136	3.1	-0.2	3.0	0.0
2021	528	(64)	464	1.4	-0.2	1.2	0.0
2022		(64)	(64)		-0.2	-0.2	0.0
2023		(64)	(64)		-0.2	-0.2	0.0
2024		(64)	(64)		-0.2	-0.2	0.0
2025		(48)	(48)		-0.1	-0.1	0.0
2026							0.0
Total 2017-26	5,328	1,084	6,412	13.9	2.8	16.8	1.6

(a) Calculated by multiplying the MTU as UF6 value by a conversion factor of 0.00261285.
(b) NNSA transfers are in the form of 4.95 w/o EUP and therefore have enrichment content.

Table 3.4 Current and Near-Term DOE Inventory Transfers for Services - Scenario 2

Year	MTU as UF_6			Equivalent Million Pounds of U_3O_8 (a)			SWU (Millions) (b)
	EM Transfers	NNSA Transfers	Total	EM Transfers	NNSA Transfers	Total	NNSA Transfers
2014	2,055	650	2,705	5.4	1.7	7.1	0.7
2015	2,000	534	2,534	5.2	1.4	6.6	0.6
2016	1,600	450	2,050	4.2	1.2	5.4	0.4
2017	2,000	500	2,500	5.2	1.3	6.5	0.5
2018	2,000	500	2,500	5.2	1.3	6.5	0.5
2019	1,328	452	1,780	3.5	1.2	4.7	0.5
2020		(64)	(64)		-0.2	-0.2	0.0
2021		(64)	(64)		-0.2	-0.2	0.0
2022		(64)	(64)		-0.2	-0.2	0.0
2023		(64)	(64)		-0.2	-0.2	0.0
2024		(64)	(64)		-0.2	-0.2	0.0
2025		(48)	(48)		-0.1	-0.1	0.0
2026							0.0
Total 2017-26	5,328	1,084	6,412	13.9	2.8	16.8	1.6

(a) Calculated by multiplying the MTU as UF6 value by a conversion factor of 0.00261285.
(b) NNSA transfers are in the form of 4.95 w/o EUP and therefore have enrichment content.

Table 3.5 Current and Near-Term DOE Inventory Transfers for Services - Scenario 3

The combined EM and NNSA transfers average 641 MTU as UF_6 and 1.7 million pounds U_3O_8 per year between 2017 and 2026 for the Base Scenario, Scenario 2 and Scenario 3. In Scenario 1 the transfers decline to an average of 108 MTU as UF_6 and 0.3 million pounds U_3O_8 per year over the next ten years as there are no further releases by EM, but NNSA transfers continue. Enrichment services contained in NNSA transfers only take place in the near term, as discussed below.

While the average quantities projected to be released by EM and NNSA in the Base Scenario and Scenarios 2 and 3 are the same, the annual quantities released in the near term (2017 to 2019) differ. Transfers average 2,074 MTU as UF_6 and 5.4 million pounds U_3O_8 per year in the near term for the Base Scenario, rising 9% to 2,260 MTU as UF_6 and 5.9 million pounds U_3O_8 per year for Scenario 3. Scenario 2 declines 19% from the Base Scenario in the near term to 1,684 MTU as UF_6 and 4.4 million pounds U_3O_8 per year. Scenario 3 declines significantly (77%) to just 484 MTU as UF_6 and 1.3 million pounds U_3O_8 per year in the near term. Average enrichment services contained in NNSA transfers are the same for all four scenarios at 0.5 million SWU per year in the near term.

3.3 Future DUF_6 and Proposed Off-Spec Inventory Transfers

In November 2016, DOE entered into an agreement with Global Laser Enrichment (GLE), and subject to its terms and conditions, DOE will transfer annually depleted uranium held by the Office of Environmental Management in an amount equal to 2,000 MTU of NU equivalent. GLE will enrich the depleted uranium to NU at a new laser enrichment facility it intends to build near the Paducah site. GLE will compensate DOE with NU. DOE expects to begin transfers of DUF_6 in 2024. It is ERI's understanding that the GLE agreement is subject to terms based on market conditions and therefore the timing of the commercial effects of the DUF_6 transfers could be delayed.

Unallocated DOE excess inventories include a small quantity of off-spec non-UF_6, with product assays ranging between 0.711 w/o and 4.9 w/o and a small quantity of off-spec LEU with an average assay of 1.6 w/o. In 2009, the Portsmouth DOE contractor issued an RFP to sell certain off-spec non-UF_6 material. In November 2013 DOE also announced that it had entered into negotiations with AREVA for the commercialization of the off-spec LEU material. No decision has yet been made as to whether any material will be sold under the 2009 RFP or the 2013 RFO. DOE now expects that the off-spec LEU will enter the market in 2020 while a small amount of the off-spec non-UF_6 will enter the commercial markets in 2021 or 2022. The NU equivalent quantity of the off-spec non-UF_6 affecting the market is just 2 MTU while the off-spec LEU affecting the market totals 456 MTU as NU equivalent.

The material transfers that would result from the future DUF_6 and proposed DOE inventory transfers are summarized in Table 3.6. Note that the enrichment content of the off-spec LEU is lost during blending.

Year	Natural Uranium Equivalent, MTU				Equivalent Million Pounds of U_3O_8 (a)			
	DUF_6	Off-Spec LEU	Off-Spec non-UF_6	Total	DUF_6	Off-Spec LEU	Off-Spec non-UF_6	Total
2014								
2015								
2016								
2017								
2018								
2019								
2020		456		456		1.2		1.2
2021								
2022			2	2			0.0	0.0
2023								
2024	2,000			2,000	5.2			5.2
2025	2,000			2,000	5.2			5.2
2026	2,000			2,000	5.2			5.2
Total 2017-26	6,000	456	2	6,458	15.7	1.2	0.0	16.9

(a) Calculated by multiplying the MTU as UF6 value by a conversion factor of 0.00261285.

(b) The Off-Spec LEU averages 1.6 w/o with an estimated enrichment equivalent of approximately 0.1 million SWU total, but the enrichment content is lost during blending.

Table 3.6 Future DUF_6 and Proposed Off-Spec Inventory Transfers, All Scenarios

3.4 HEU Down Blending to High-Assay LEU

Based on information provided by DOE, DOE plans to down blend HEU to provide high-assay LEU for research reactors between 2017 and 2026. DOE also plans to provide high-assay LEU for certain medical isotope development and production purposes, for which it has separately conducted a market impact analysis and determination.[27] High-assay LEU cannot currently be provided by the commercial markets. Therefore, at this time, DOE's plan to down blend HEU to provide high-assay LEU for research reactors has not been included in this analysis of quantities of DOE inventory entering the commercial LEU markets.

3.5 Summary of All DOE Material Affecting the Commercial Markets

As described in the previous sections, there are three broad categories of material for uranium originally attributable to DOE which are expected to be introduced into the commercial markets. They include (i) historical DOE transfers, the uranium from which will continue to displace commercial supply in the markets, as presented in Table 3.1; current and near-term inventory transfers in exchange for services (transfers for services) for four scenarios, as presented in Tables 3.2, 3.3 3.4 and 3.5; and (iii) planned transfers of additional DUF_6, as well as proposed transfers of off-spec LEU and off-spec non-UF_6 that

[27] *See* 80 Fed Reg 65727 (Oct. 27, 2015) and 81 Fed Reg 1409 (Jan. 12, 2016).

are currently under consideration as presented in Table 3.6. Combining the above categories results in four separate scenarios for DOE inventory affecting the commercial markets.

The schedule and quantities of DOE inventory affecting the commercial uranium and conversion markets is shown in Figure 3.1 for the Base Scenario. Historical transfers continue to affect the market at lower annual rates through 2025 as shown in the figure. The EM and NNSA transfers for services are the primary source of DOE inventory affecting the market over the next three years (through 2019). The proposed transfer of DUF_6 inventory under an agreement with GLE, is the primary source of DOE inventory affecting the market in the longer term (2024 and beyond). The total DOE inventory affecting the commercial uranium market is significantly lower in 2020 to 2023 due to delay between the completion of EM transfers for services and the start up of DUF_6 transfers.

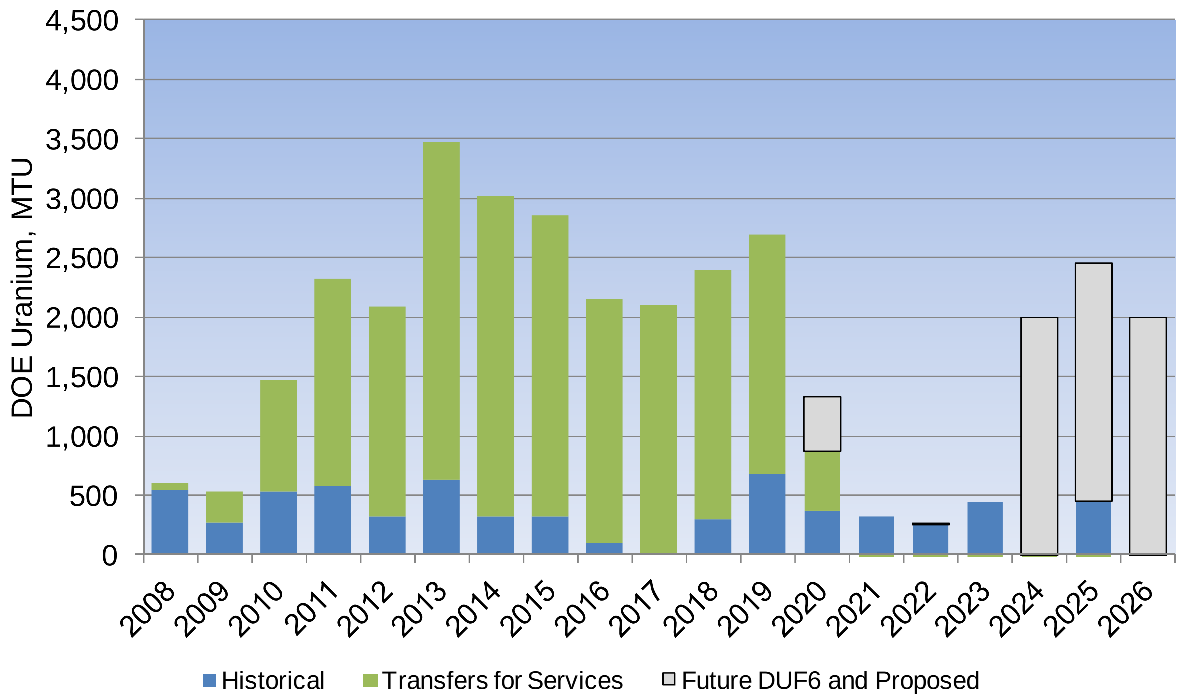


Figure 3.1 DOE Inventory Affecting the Commercial Uranium Market – Base Scenario

The schedule and quantities of DOE inventory affecting the commercial uranium and conversion markets for Scenario 1 are shown in Figure 3.2. Figure 3.2 demonstrates the dramatic reduction in DOE uranium and conversion quantities over the next ten years (2017 to 2026) for Scenario 1 when compared to the Base Scenario due to the assumed immediate cessation of EM transfers for cleanup services in 2017. Historical transfers and NNSA transfers continue to affect the market from 2017 to 2025. Future DUF_6 transfers remain significant in 2024 and later.

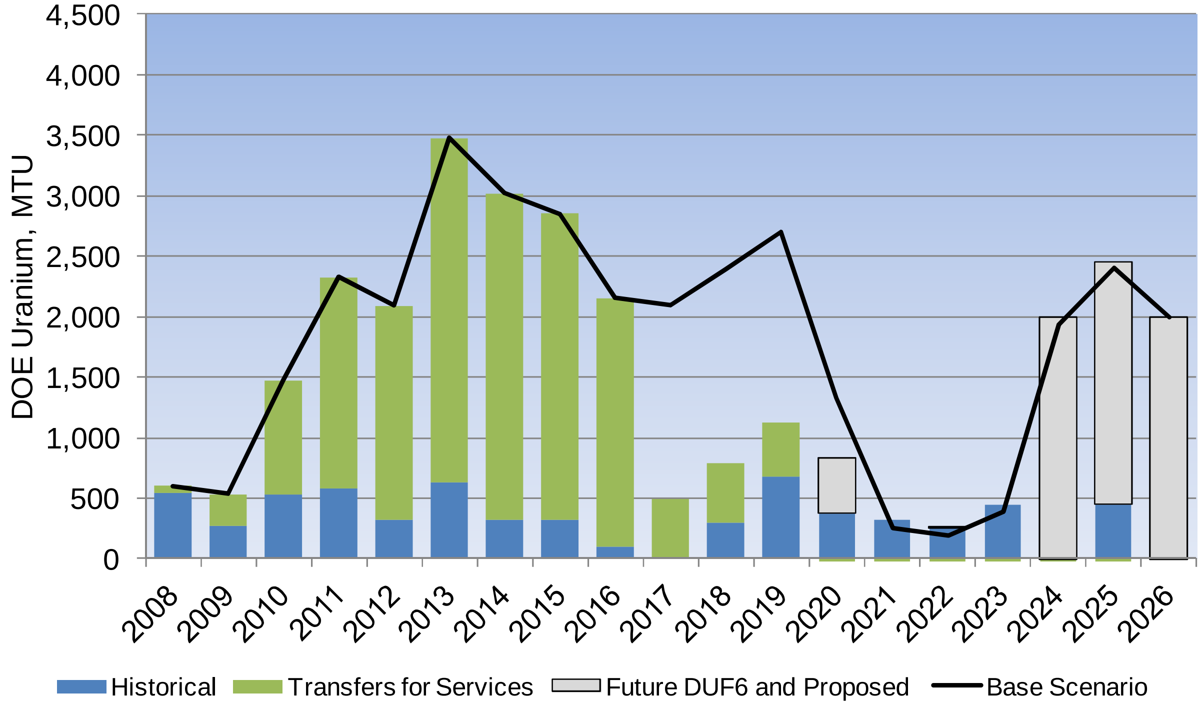


Figure 3.2 DOE Inventory Affecting the Commercial Uranium Market - Scenario 1

The schedule and quantities of DOE inventory affecting the commercial uranium and conversion markets for Scenario 2 are shown in Figure 3.3. Figure 3.3 demonstrates how the DOE uranium and conversion quantities decline in the near term over the years 2017 to 2019 for Scenario 2 when compared to the Base Scenario. However, DOE inventory quantities are higher for Scenario 2 in the years 2020 to 2021, as some of the EM transfers for cleanup services are deferred into those years when compared to the schedule assumed in the Base Scenario. DOE inventory quantities in 2022 to 2026 are the same as those assumed to be released in the Base Scenario.

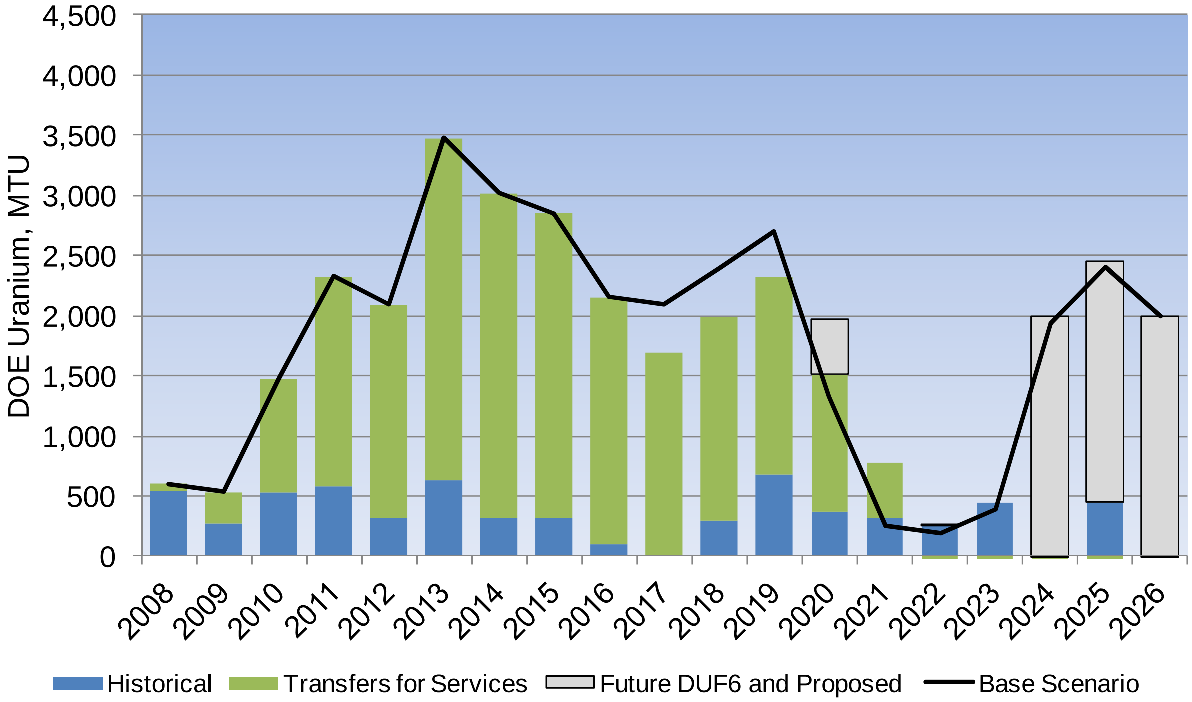


Figure 3.3 DOE Inventory Affecting the Commercial Uranium Market - Scenario 2

The schedule and quantities of DOE inventory affecting the commercial uranium and conversion markets for Scenario 3 are shown in Figure 3.4. Figure 3.4 demonstrates how the DOE uranium and conversion quantities increase in 2017 and 2018 for Scenario 3, but are then lower in 2019 and 2020 when compared to the Base Scenario. The EM transfers for cleanup services are exhausted in 2019 for this Scenario.

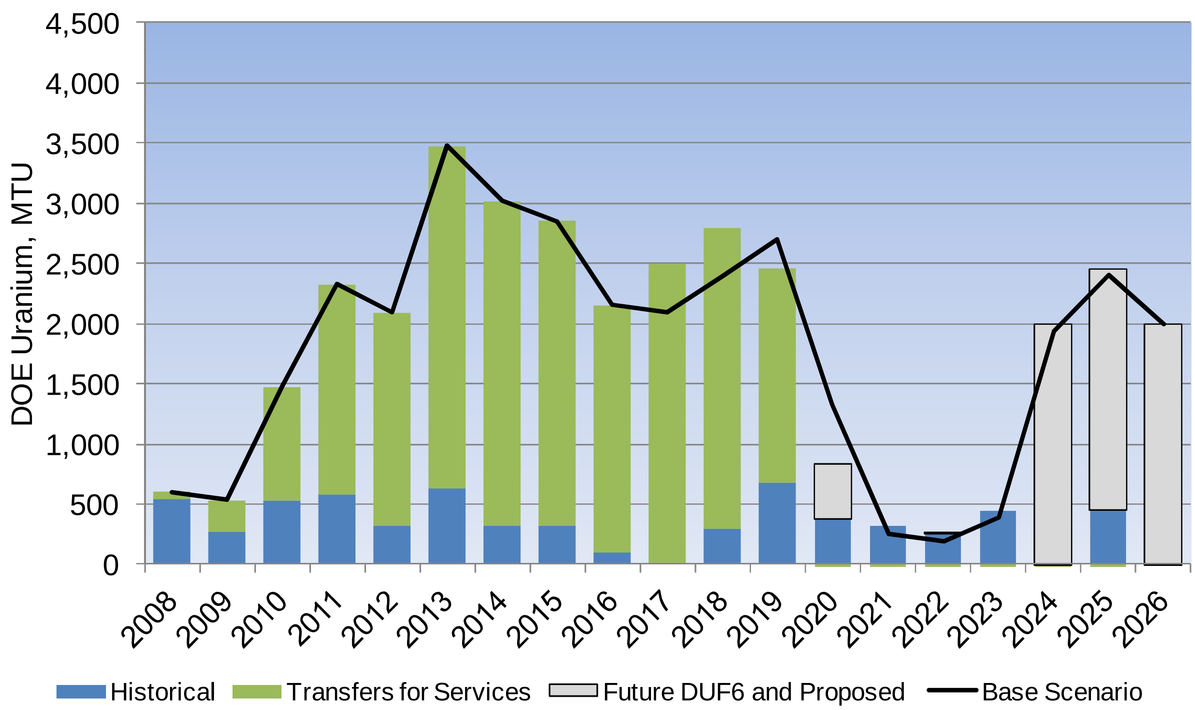


Figure 3.4 DOE Inventory Affecting the Commercial Uranium Market - Scenario 3

Table 3.7 compares the annual and total equivalent net uranium concentrates contained in the uranium attributable to DOE transfers based on when the material supplies the commercial uranium market for the four scenarios. Under the Base Scenario, the total DOE inventory affecting the uranium market is 41 million pounds U_3O_8 over the period 2017 to 2026. During that time period, the total DOE inventory affecting the uranium market could also be as low 27 million pounds U_3O_8 for Scenario 1. When compared to the Base Scenario, the annual quantities of DOE inventory material affecting the uranium market vary for Scenarios 2 and 3 in 2017 to 2021 but the cumulative totals are the same. The quantity of DOE material affecting the commercial uranium market in 2014 through 2016 is also shown for comparison.

Year	Equivalent Million Pounds of U_3O_8			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	7.9	7.9	7.9	7.9
2015	7.5	7.5	7.5	7.5
2016	5.6	5.6	5.6	5.6
2017	5.5	1.3	4.4	6.5
2018	6.3	2.1	5.2	7.3
2019	7.0	2.9	6.1	6.4
2020	3.5	2.0	5.1	2.0
2021	0.7	0.7	2.0	0.7
2022	0.5	0.5	0.5	0.5
2023	1.0	1.0	1.0	1.0
2024	5.1	5.1	5.1	5.1
2025	6.3	6.3	6.3	6.3
2026	5.2	5.2	5.2	5.2
Total 2017-2026:				
	41.0	27.1	41.0	41.0

Table 3.7 Total Equivalent Net Million Pounds of U_3O_8 Affecting the Uranium Market

Table 3.8 compares the annual and total equivalent net natural UF_6 contained in the uranium attributable to DOE transfers based on when the material supplies the commercial conversion market for the four scenarios. During the period 2017 to 2026, the total DOE inventory affecting the conversion market in the Base Scenario is nearly 16,000 MTU. For Scenario 1, the total DOE inventory affecting the conversion market declines to just over 10,000 MTU. The quantity of DOE material affecting the commercial conversion market in 2014 through 2016 is also shown for comparison.

Year	MTU as UF_6			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	3,023	3,023	3,023	3,023
2015	2,852	2,852	2,852	2,852
2016	2,155	2,155	2,155	2,155
2017	2,100	500	1,700	2,500
2018	2,396	796	1,996	2,796
2019	2,698	1,129	2,329	2,457
2020	1,328	769	1,969	769
2021	253	253	781	253
2022	196	196	196	196
2023	386	386	386	386
2024	1,936	1,936	1,936	1,936
2025	2,402	2,402	2,402	2,402
2026	2,000	2,000	2,000	2,000
Total 2017-2026:				
	15,695	10,367	15,695	15,695

Table 3.8 Total Equivalent Net MTU Affecting the Conversion Market

Table 3.9 compares the annual and total equivalent net enrichment services contained in the uranium attributable to DOE transfers based on when the material supplies the commercial enrichment market for the four scenarios. During the period 2017 to 2026, the total DOE inventory affecting the enrichment market in all four scenarios is 4.2 million SWU. The quantity of DOE material affecting the commercial enrichment market in 2014 through 2016 is also shown for comparison.

The enrichment quantities are potentially subject to some offsets when evaluating the effect on industry. The LEU created from DUF_6 transferred to ENW contains 3.2 million SWU, but was offset by the purchase of a combined 4.4 million SWU in 2012 and 2013 from USEC. In order to be conservative, this analysis treats the enrichment content of the ENW LEU created from DUF_6 as a potential market effect when it is used by TVA reactors.

Year	Equivalent SWU (Millions)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	1.3	1.3	1.3	1.3
2015	1.0	1.0	1.0	1.0
2016	0.9	0.9	0.9	0.9
2017	0.8	0.8	0.8	0.8
2018	1.0	1.0	1.0	1.0
2019	0.9	0.9	0.9	0.9
2020	0.3	0.3	0.3	0.3
2021	0.6	0.6	0.6	0.6
2022	0.4	0.4	0.4	0.4
2023	0.3	0.3	0.3	0.3
2024	0.0	0.0	0.0	0.0
2025	0.0	0.0	0.0	0.0
2026	0.0	0.0	0.0	0.0
Total 2017-2026:				
	4.2	4.2	4.2	4.2

Table 3.9 Total Equivalent Net Million SWU Affecting the Enrichment Market

DOE Inventory Material Affecting the Spot Markets

As previously stated, it has been assumed that 50% of the NU that DOE transfers to the contractor(s) via EM transfers is introduced through spot market contracts and 50% through term market contracts. While Traxys has reported that as much as 90% of the conversion supply from EM transfers in 2015 and 2016 had already been sold into forward contracts, ERI has conservatively assumed that 50% of the conversion services contained in the EM transfers is sold on the spot market.[28] It is conservatively assumed that 100% of the NU and SWU content of the NNSA transfers is introduced into the spot market[29]. The historical transfer of high assay DUF_6 and BLEU material from off-spec HEU are used by TVA and ENW under long-term arrangements. Planned future transfer of DUF_6 under agreement with GLE and proposed transfers of DOE inventory currently under negotiation as a result of DOE RFOs, are assumed to be introduced on a 50% spot and 50% term basis. This is considered a conservative assumption, as the uranium created from DUF_6 in the future may well enter the market on a term basis only, as was the case with the first DUF_6 transfer. The total amount of DOE inventory affecting the commercial spot markets is shown in Table 3.10 for the uranium spot market, Table 3.11 for the conversion spot market and Table 3.12 for the enrichment spot market. A comparison of Table 3.7 with Table 3.10 and Table 3.8 with Table 3.11 indicates that 44% of the uranium and conversion components of the DOE inventories delivered into the commercial markets over the next ten years are expected to take place under spot market contracts for the Base Scenario, Scenario 2 and Scenario 3, and declining to 42% for Scenario 1. As indicated in the discussions above, DOE inventory introduced into the spot market is sourced from the EM and NNSA transfers for services and future DUF_6 transfers. A comparison of Table 3.9 with Table 3.12 indicates that 37% of the enrichment component of the DOE inventories delivered into the commercial markets over the next ten years is expected to take place under spot market contracts for all scenarios.

[28] Smith, Kevin P., Traxys North America LLC, Managing Director for Uranium Marketing and Trading, Declaration of Kevin P. Smith, Attachment 6 to Defendant's Opposition to Plaintiff's Motion for Preliminary Injunction, Case No. 1:14-cv-1012-RBW, Document 17-7, Filed July 7, 2014, at 23.

[29] Previous ERI analyses assumed 100% this material was introduced into the spot market. ERI believes that a portion of the NNSA transfers are delivered into the term market, but has assumed 100% into the spot market in order to be conservative.

Year	Equivalent Million Pounds of U_3O_8			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	4.4	4.4	4.4	4.4
2015	4.0	4.0	4.0	4.0
2016	3.3	3.3	3.3	3.3
2017	3.4	1.3	2.9	3.9
2018	3.4	1.3	2.9	3.9
2019	3.2	1.2	2.7	2.9
2020	1.2	0.4	2.0	0.4
2021	(0.2)	(0.2)	0.5	(0.2)
2022	(0.2)	(0.2)	(0.2)	(0.2)
2023	(0.2)	(0.2)	(0.2)	(0.2)
2024	2.4	2.4	2.4	2.4
2025	2.5	2.5	2.5	2.5
2026	2.6	2.6	2.6	2.6
Total 2017-2026:				
	18.2	11.3	18.2	18.2

Table 3.10 Total DOE Inventory Affecting the Uranium Spot Market

Year	MTU as UF_6			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	1,678	1,678	1,678	1,678
2015	1,534	1,534	1,534	1,534
2016	1,250	1,250	1,250	1,250
2017	1,300	500	1,100	1,500
2018	1,300	500	1,100	1,500
2019	1,237	452	1,052	1,116
2020	444	164	764	164
2021	(64)	(64)	200	(64)
2022	(63)	(63)	(63)	(63)
2023	(64)	(64)	(64)	(64)
2024	936	936	936	936
2025	952	952	952	952
2026	1,000	1,000	1,000	1,000
Total 2017-2026:				
	6,977	4,313	6,977	6,977

Table 3.11 Total DOE Inventory Affecting the Conversion Spot Market

Year	Equivalent SWU (Millions)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	0.7	0.7	0.7	0.7
2015	0.6	0.6	0.6	0.6
2016	0.4	0.4	0.4	0.4
2017	0.5	0.5	0.5	0.5
2018	0.5	0.5	0.5	0.5
2019	0.5	0.5	0.5	0.5
2020	0.0	0.0	0.0	0.0
2021	0.0	0.0	0.0	0.0
2022	0.0	0.0	0.0	0.0
2023	0.0	0.0	0.0	0.0
2024	0.0	0.0	0.0	0.0
2025	0.0	0.0	0.0	0.0
2026	0.0	0.0	0.0	0.0
Total 2017-2026:				
	1.6	1.6	1.6	1.6

Table 3.12 Total DOE Inventory Affecting the Enrichment Spot Market

DOE Inventory Material Share of U.S. and World Requirements

The commercial supply displaced by uranium attributable to DOE transfers is expected to average 1,570 MTU as UF_6, equivalent to 4.1 million pounds U_3O_8 per year over the next ten years (2017 through 2026) in the Base Scenario. The quantity of DOE material released has been compared to total U.S. requirements in the past. Given that the uranium, conversion and enrichment markets are global[30], ERI does not find the share of U.S. requirements to be a particularly useful measure of the effect of the DOE transfers on commercial markets. Nonetheless, a summary is provided in Table 3.13 for the four scenarios. The DOE shares are summarized for three periods: recent (2014-2016), near term (2017-2019) and ten year forward (2017-2026). For the Base Scenario, the DOE inventory share of U.S. uranium and conversion requirements is 14% in recent years, declining to 13% in the near term and 9% over the long term. The share of U.S. enrichment requirements is 8% in recent years, declining to 6% in the near term and to 3% over the ten-year term. Scenario 1 demonstrates a significant reduction in the near term and ten-year term for uranium and conversion to 5% to 6% of U.S. requirements. Scenario 2 demonstrates a slight reduction in the DOE inventory share of U.S. uranium and conversion

[30] The uranium, conversion and enrichment markets are global in nature. End-users purchase from suppliers worldwide in each of these industries and suppliers worldwide are generally able to sell into markets in most regions, not just to the region in which the supplier is located.

requirements to 11% in the near term while Scenario 3 demonstrates a small increase to 14% in the near term. The ten-year shares for Scenarios 2 and 3 are unchanged from the Base Scenario, as the same total quantity of uranium is released. The DOE inventory share of enrichment requirements is the same across all four scenarios.

Period	DOE Inventory Share			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
Share of U.S. Uranium Requirements				
Recent: 2014-16	15%	15%	15%	15%
Near Term: 2017-19	13%	5%	11%	14%
Ten Year: 2017-26	9%	6%	9%	9%
Share of U.S. Conversion Requirements				
Recent: 2014-16	14%	14%	14%	14%
Near Term: 2017-19	14%	5%	11%	15%
Ten Year: 2017-26	9%	6%	9%	9%
Share of U.S. Enrichment Requirements				
Recent: 2014-16	8%	8%	8%	8%
Near Term: 2017-19	6%	6%	6%	6%
Ten Year: 2017-26	3%	3%	3%	3%

Table 3.13 DOE Inventory Shares of U.S. Requirements

It is important to realize that the uranium, conversion and enrichment markets are global in nature. End-users purchase from sources globally and suppliers make sales throughout the world.[31] It is therefore more useful to compare DOE inventory quantities to total world requirements rather than just U.S. requirements as has been done in Table 3.14. Unsurprisingly, the DOE inventory shares are lower as the U.S. requirements comprise a fraction of world requirements. For the Base Scenario, the DOE inventory share of world uranium and conversion requirements is 4% in the near term and 2% to 3% over ten years, while the share of U.S. enrichment requirements is 2% in the near term and 1% over ten years. Scenario 1 demonstrates a significant reduction in the near term for the uranium and conversion components to 1% of world requirements in the near term and to less than 2% in the ten-year forward period. The DOE share of enrichment requirements is unchanged for Scenario 1.

[31] There are some exceptions, particularly for conversion and enrichment services, as described in the discussion on the accessible world markets below.

Period	DOE Inventory Share			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
Share of World Uranium Requirements				
Recent: 2014-16	5%	5%	5%	5%
Near Term: 2017-19	4%	1%	3%	4%
Ten Year: 2017-26	2%	2%	2%	2%
Share of World. Conversion Requirements				
Recent: 2014-16	5%	5%	5%	5%
Near Term: 2017-19	4%	1%	4%	5%
Ten Year: 2017-26	3%	2%	3%	3%
Share of World Enrichment Requirements				
Recent: 2014-16	3%	3%	3%	3%
Near Term: 2017-19	2%	2%	2%	2%
Ten Year: 2017-26	1%	1%	1%	1%

Table 3.14 DOE Inventory Shares of World Requirements

As noted in the footnote on the previous page, some markets are not fully open to the domestic industries, in particular China, Russia and most of Eastern Europe are considered by some in the industry to be inaccessible for conversion and enrichment services. To be conservative, China has been assumed to be inaccessible for new conversion and enrichment services contracts, even though AREVA and Rosatom currently supply EUP containing conversion and enrichment services and Urenco supplies a small amount of enrichment services to China. The majority of Chinese conversion and enrichment requirements are filled by indigenous sources and China has long proclaimed its aim to be self-sufficient in this regard. China is considered to be accessible for uranium sales, however, and large contracts exist with AREVA, Cameco and Kazatomprom.

Russia is completely closed to all three front-end markets. Most[32] of Eastern Europe is conservatively assumed to be closed as reactors there use Russian fuel assemblies including EUP supplied under life of plant contracts. Small quantities of uranium mined in Eastern Europe are used when available. While Ukraine used to be closed as well, it has recently diversified and is no longer solely dependent on Russia fuel supply and therefore is considered to be accessible. Table 3.15 compares DOE inventory quantities to total world requirements markets accessible to the domestic industry. The results are similar to the total world shares but 0.3% to 1.0% higher over the next ten years.

[32] The Czech Republic is known to purchase a portion of its enrichment supplies from non-Russian sources and Romania purchases natural uranium from non-Russian sources in addition to limited domestic production.

Period	DOE Inventory Share			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
Share of Accessible World Uranium Requirements				
Recent: 2014-16	5%	5%	5%	5%
Near Term: 2017-19	4%	2%	4%	5%
Ten Year: 2017-26	3%	2%	3%	3%
Share of Accessible World. Conversion Requirements				
Recent: 2014-16	6%	6%	6%	6%
Near Term: 2017-19	6%	2%	5%	6%
Ten Year: 2017-26	4%	2%	4%	4%
Share of Accessible World Enrichment Requirements				
Recent: 2014-16	3%	3%	3%	3%
Near Term: 2017-19	2%	2%	2%	2%
Ten Year: 2017-26	1%	1%	1%	1%

Table 3.15 DOE Inventory Shares of Accessible World Requirements

4. Quantification of the Effect of DOE Material on the Commercial Markets

4.1 Potential Effect of DOE Inventory on Market Prices

ERI continues to believe that attributing a difference in market price to DOE inventory releases provides an important measure of the DOE material's effect on the domestic industry. However, there is no absolute measure of the isolated effect any one particular market factor or event, such as the DOE inventory material, has on market prices. There are many market factors which combine to determine the relationship between supply and demand, and ultimately market prices as found in published price indicators.

By applying the results of ERI's economic market clearing price analysis regarding the predicted effect of an incremental addition of supply on the market clearing price of uranium concentrates, conversion services and enrichment services, respectively, to the equivalent nuclear fuel materials and services contained in DOE's inventory transfers, the effect on market price may be estimated as presented below.

4.1.1 Potential Effect of DOE Inventory on Market Prices Based on Market Clearing Price Analysis

As was done in the February 2015 ERI market analysis, a market clearing price approach has been employed to determine the effect of changes in individual components of supply on market prices. ERI chose the market clearing approach because it assumes an efficient allocation of resources in a competitive market and is consistent with the view that long term prices are determined by production costs and future supply-demand forecasts. Using this approach allows the price impact of any single supply component, such as DOE inventory, to be estimated. This market clearing approach requires the creation of an annual supply curve for each supply component[33], which in the case of uranium concentrates is constructed by stacking individual increments of supply (e.g., individual mines) in ascending order from low to high based on each increment's cost of production. The market clearing price is the total cost of production for the last increment of primary supply that is required to meet demand (less secondary supply and excess inventory) during that year. The primary supply curve created by ERI for the year 2016 is shown in Figure 4.1. Note that the market

[33] The supply curves are constructed from individual supply sources, e.g. individual uranium mines, conversion plants and enrichment plants. ERI gathers available information such as capital costs, capital cost impairments taken, operating costs, disposal costs, tax rates, royalties, interest rates, facility lifetime and production rate, etc. for each supply source. Where possible, discounted cash flow analyses are performed for each supply source to determine the levelized, constant dollar price which will generate a reasonable rate of return, typically assumed to be 15% after taxes. Adjustments are made to account for foreign exchange rates as well as historical inflation. Sources of cost information include company financial reports, regulatory filings such as NI 43-101 technical reports, preliminary economic assessments, presentations at conferences, etc. The quality and timeliness of the available sources of cost information can vary. Information is limited or even non-existent for some individual supply increments.

clearing approach assumes secondary supply is always utilized first, followed by primary production. In over-supplied markets such as the current uranium, conversion and enrichment markets, the amount of primary production required to meet requirements, including normal strategic inventory building, is well below actual production. As a result, excess inventories are built up at suppliers as well as end-users.

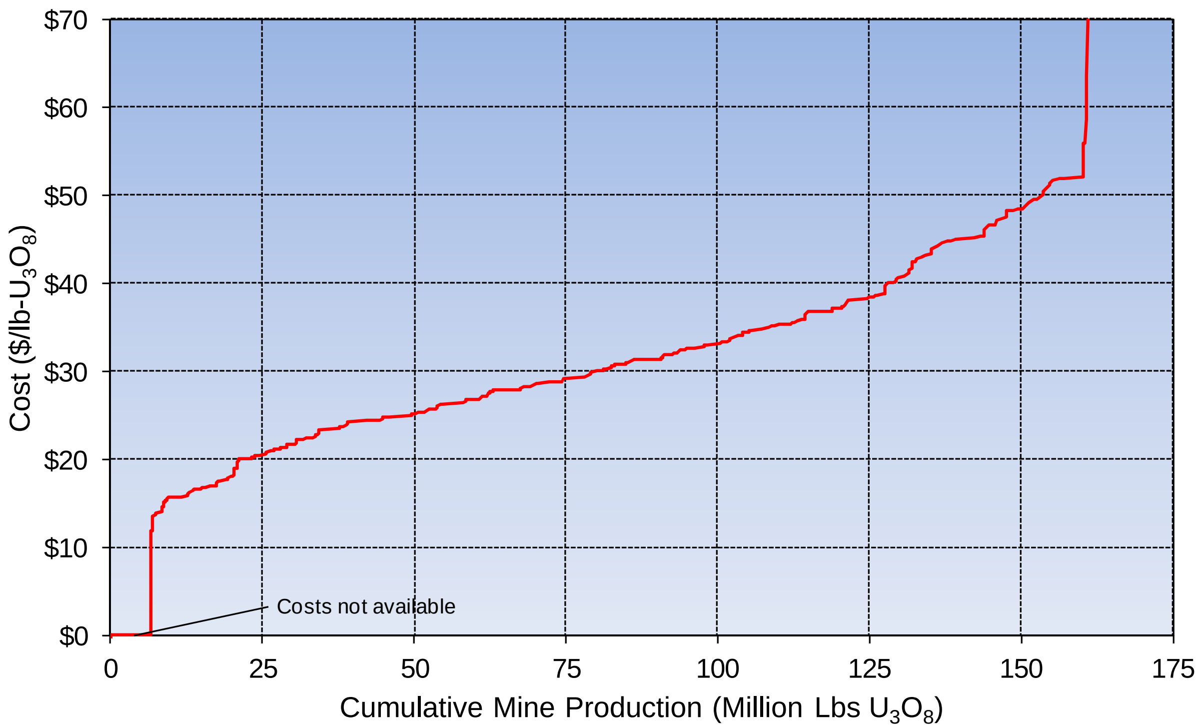


Figure 4.1 ERI Supply Curve for 2016

The change in market clearing price attributed to a particular component of secondary supply, such as the DOE inventory, is found by removing the market component in question from secondary supply. This has the effect of moving the intersection of demand (less secondary supply) to the right, resulting in a higher market clearing price for the same reactor requirements. The difference between the two market clearing prices is the price effect of the DOE inventory.[34] In a market with considerable oversupply as has been observed in recent years, the removal of a particular component of secondary supply does not result in a corresponding amount of new primary supply entering the market in its place, it instead reduces the amount of oversupply. For the analysis summarized herein, ERI has forecast the supply curve for each year in the next ten years, based on production and cost information about existing mines, expected mine developments, and secondary

[34] The relevant slope of the supply curve (i.e., Δ$ per pound / Δ million pounds) can be determined from the difference of two price points on the supply curve (e.g. clearing price with and without DOE inventory) divided by the quantity in question (e.g. the DOE inventory affecting the market).

supply. Matching forecast demand less secondary supply (both with and without DOE inventory) against these supply curves, ERI can forecast the price effect of the DOE inventory.

The supply curve developed by ERI appears to be consistent with the work of other market analysts[35,36,37,38], as shown in Figures 4.2 through 4.6. These supply curves examine production cash cost and global cost. The supply curves are all consistent with a slope which rises as cumulative production approaches the upper end of the supply curve. The supply curve slopes are more modest around the 100 million pound cumulative production point, which is where the clearing price will be set when there is significant inventory overhang as is the current situation. When excess inventory is worked down (reduced), the clearing price point will move closer to the upper end of the supply curve and the steeper slope will be consistent with greater price sensitivity.

Similar production cost analysis coupled with economic market clearing price analysis has been conducted for conversion and enrichment facilities. The supply curves are based on supply sources worldwide, not just in the U.S., as the uranium, conversion and enrichment markets are global in nature.

[35] BMO Capital Markets, "Global Mining Research: Uranium Sector Report", May 16, 2016.

[36] RBC Capital Markets, "Metal Prospects: Uranium Market Outlook – Third Quarter 2014", July 11, 2014.

[37] CRU, "Cost deflation renders the majority of uranium mines cash positive in 2015", March 22, 2016, http://www.crugroup.com/about-cru/cruinsight/Cost_deflation_renders_the_majority_of_uranium_mines_cash_positive_in_2015.

[38] Ux Consulting Company, "Is $35 the New $10: A Case for Production Delays and Cutbacks", NEI International Uranium Fuel Seminar 2013, October 7, 2013.

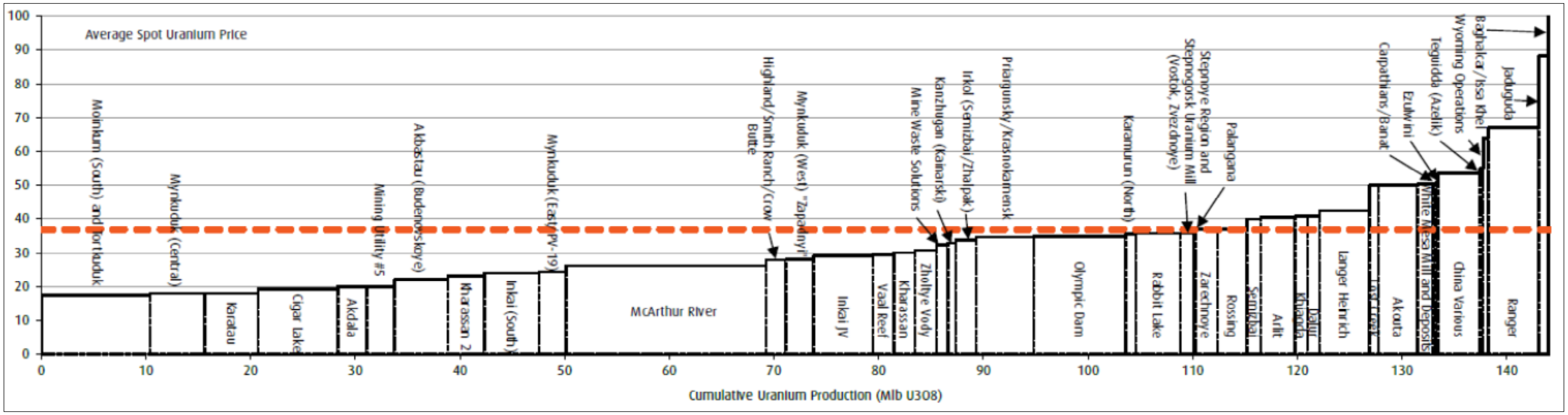


Figure 4.2 BMO Production Cash Cost Curve for 2015

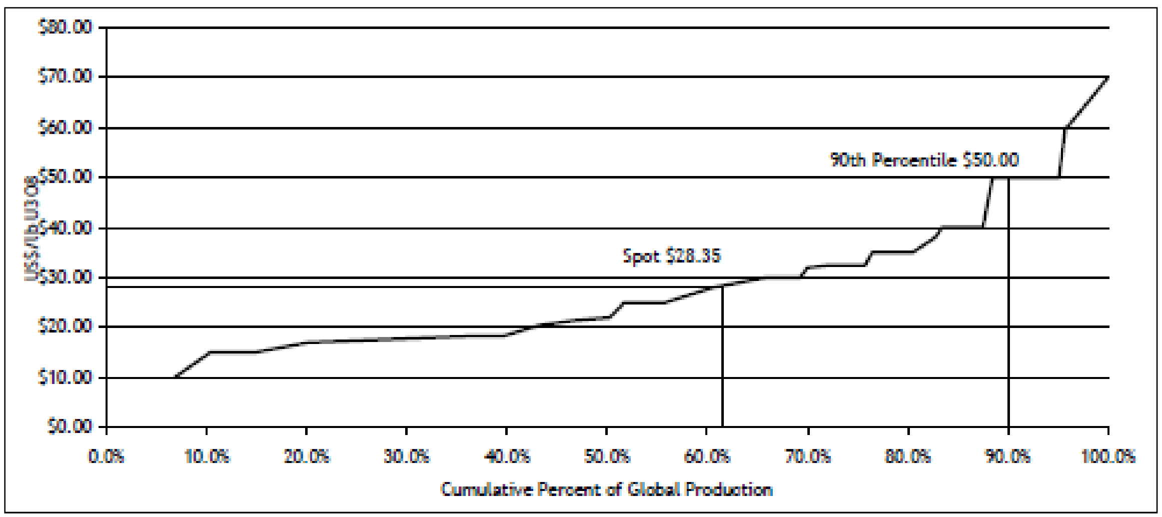


Figure 4.3 RBC Production Cash Cost Curve for 2014

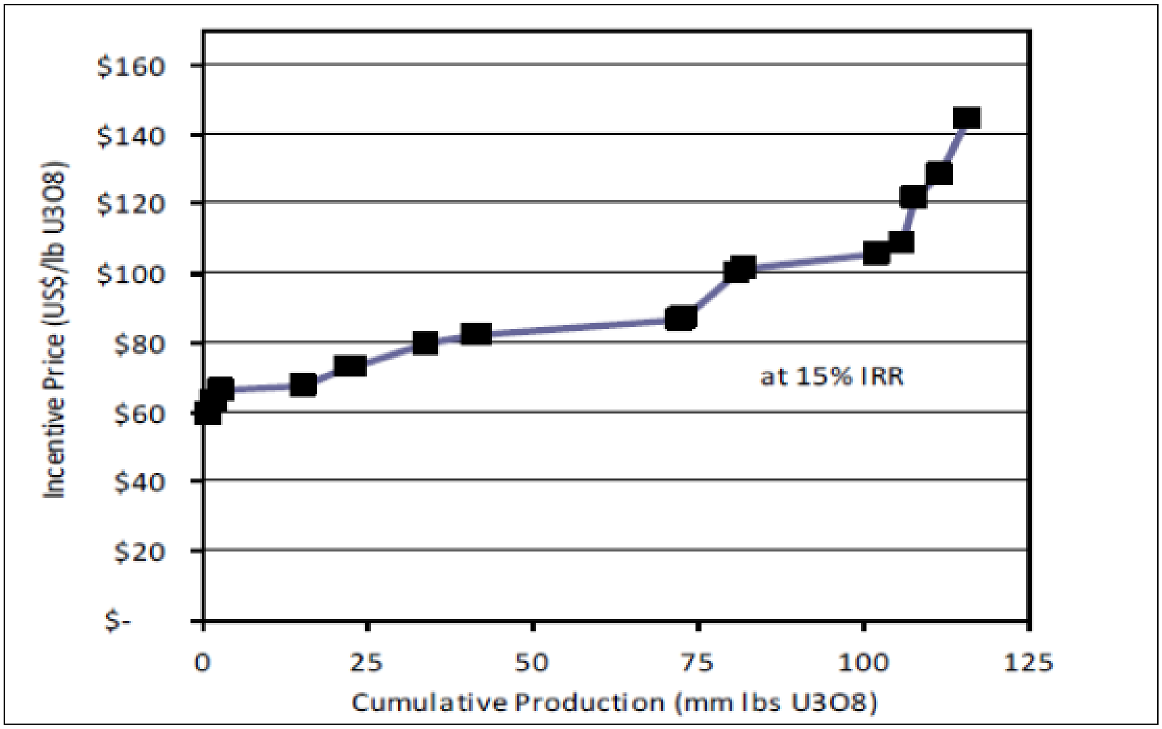


Figure 4.4 RBC Uranium Incentive Pricing Cost Curve

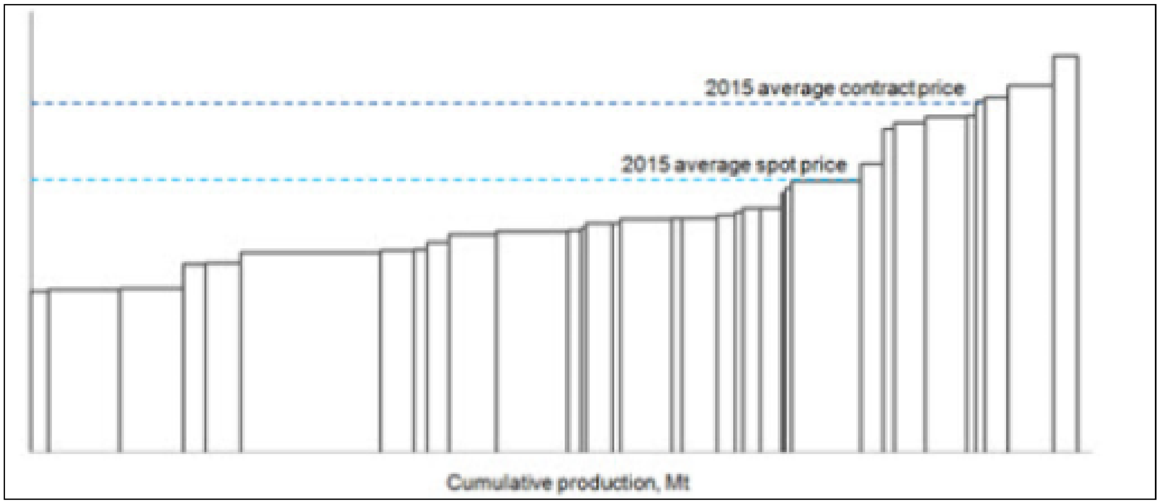


Figure 4.5 CRU 2015 Global Business Cost Curve

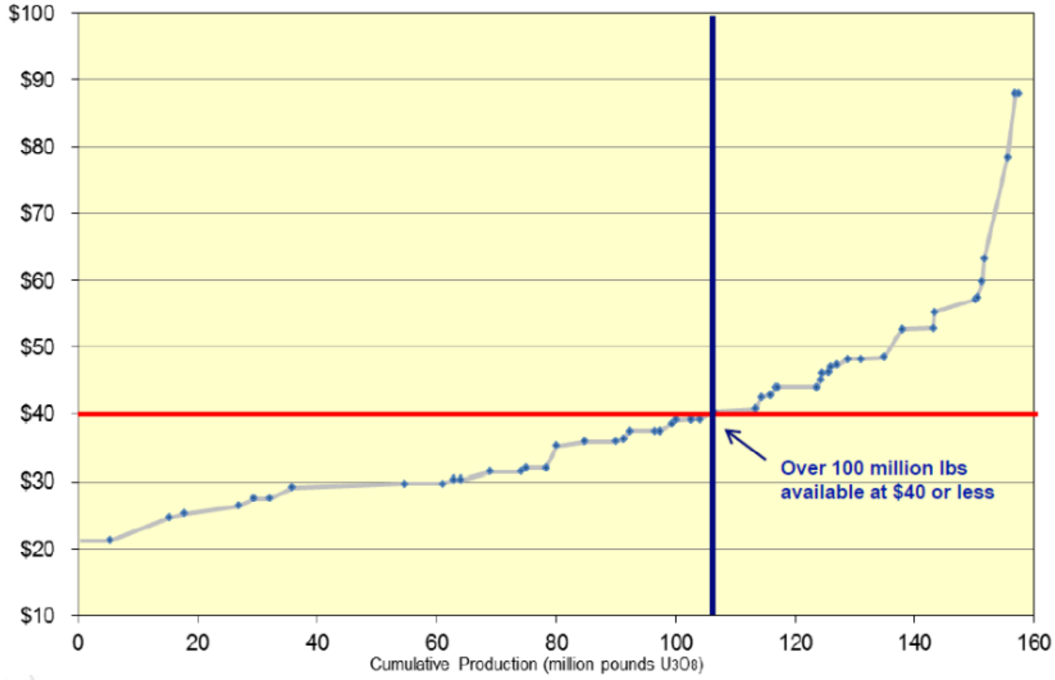


Figure 4.6 UxC Production Cost Curve for 2013

DOE Inventory Price Effects Using an Annual Clearing Price Methodology

The February 2015 ERI market analysis estimated price effects by applying the clearing price methodology on a stand-alone, annual basis. The annual basis assumes that the supply curve in a given year is independent of the DOE inventory releases in prior years.

Using the annual methodology, the supply curves for the uranium concentrates, conversion services, and enrichment services markets have been used to determine clearing prices both with and without the DOE inventory material affecting the commercial markets, which were summarized in Tables 3.11, 3.12 and 3.13 in Section 3. The resulting year-by-year changes in clearing price attributed to the DOE material are presented in Tables 4.1, 4.2 and 4.3 for the four scenarios considered[39]. During the last three years (2014-2016), the change in average clearing price attributed to the DOE inventories is estimated to be $1.5/lb for the uranium market, $0.3/kgU for the conversion market and $1.4/SWU for the enrichment market.

[39] The annual method price effects for uranium and conversion in 2021 is quite low (rounds to $0.0 in most scenarios) due to the very small of quantity of DOE material to be released in that year.

During the next ten years (2017-2026), the change in average clearing price attributed to the DOE inventories using the annual methodology is estimated to be $1.3/lb for the uranium market, $0.3/kgU for the conversion market and $0.9/SWU for the enrichment market under the Base Scenario. Scenarios 2 and 3 provide similar price effects to the Base Scenario, with the uranium and conversion price effects slightly lower for Scenario 2 and slightly higher for Scenario 3. For Scenario 1, where the EM transfers for services are halted in 2017, the future price effects are modestly reduced for uranium and conversion to $1.1/lb and $0.2/kgU, respectively. The Scenario 1 price effect reduction takes place in 2017-2020 and is therefore larger than when averaged over the full ten years study period.

It is important to note that the price effects attributed to DOE inventory are already built into current market prices. If no DOE inventory releases took place, then future market prices would be higher by the amounts stated, e.g. by $1.3 per pound for uranium, by $0.3 per kgU for conversion services, and by $0.9 per SWU for enrichment services under the Base Scenario.

Year	Uranium (\$/lb U_3O_8)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$1.7			
2015	$1.7			
2016	$1.0			
2017	$1.4	$0.3	$1.1	$1.6
2018	$0.8	$0.3	$0.7	$1.0
2019	$1.4	$0.6	$1.2	$1.3
2020	$0.6	$0.4	$0.9	$0.4
2021	$0.8	$0.8	$2.4	$0.8
2022	$1.1	$1.1	$1.1	$1.1
2023	$0.9	$0.9	$0.9	$0.9
2024	$1.7	$1.7	$1.7	$1.7
2025	$2.1	$2.1	$2.1	$2.1
2026	$2.6	$2.6	$2.6	$2.6
Average 2017-2026:				
	$1.3	$1.1	$1.5	$1.3

Table 4.1 Uranium Clearing Price Changes Due to DOE Inventory, Annual Method

Year	Conversion ($/KgU as UF_6)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$0.3			
2015	$0.4			
2016	$0.3			
2017	$0.4	$0.1	$0.3	$0.4
2018	$0.1	$0.0	$0.1	$0.1
2019	$0.6	$0.2	$0.5	$0.5
2020	$0.3	$0.2	$0.4	$0.2
2021	$0.0	$0.0	$0.1	$0.0
2022	$0.1	$0.1	$0.1	$0.1
2023	$0.1	$0.1	$0.1	$0.1
2024	$0.4	$0.4	$0.4	$0.4
2025	$0.5	$0.5	$0.5	$0.5
2026	$0.5	$0.5	$0.5	$0.5
Average 2017-2026:				
	$0.3	$0.2	$0.3	$0.3

Table 4.2 Conversion Clearing Price Changes Due to DOE Inventory, Annual Method

Year	Enrichment ($/SWU)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$0.9			
2015	$1.8			
2016	$1.6			
2017	$1.4	$1.4	$1.4	$1.4
2018	$1.8	$1.8	$1.8	$1.8
2019	$1.7	$1.7	$1.7	$1.7
2020	$0.1	$0.1	$0.1	$0.1
2021	$1.7	$1.7	$1.7	$1.7
2022	$1.7	$1.7	$1.7	$1.7
2023	$0.1	$0.1	$0.1	$0.1
2024	$0.1	$0.1	$0.1	$0.1
2025				
2026				
Average 2017-2026:				
	$0.9	$0.9	$0.9	$0.9

Table 4.3 Enrichment Clearing Price Changes Due to DOE Inventory, Annual Method

DOE Inventory Price Effects Using a Cumulative Clearing Price Methodology

The annual methodology used above assumes that the supply curve in a given year is independent of the DOE inventory releases in prior years. However, the uranium, conversion and enrichment markets are characterized by large quantities of excess inventories which have built up over the last five years. The effect of excess primary production on an annual basis is exacerbated by the excess inventories, or overhang. A cumulative clearing price methodology accounts for the fact that when some inventory is removed in one year (DOE releases for example) then the size of the inventory overhang in the following year is reduced. Over time, the cumulative effect of reduced inventory overhang can have a more pronounced effect than is captured by the annual methodology. The cumulative methodology, particularly when applied to past years, must take into account that the reduction in one supply source does not take place in a vacuum - the behavior of other suppliers can be influenced as well. Specifically, if no DOE releases had taken place from 2009 then a supply source cumulatively totaling 39 million pounds would have been removed[40] by 2016, rising to 61 million pounds by 2020 for the Base Scenario. ERI believes that the lack of supply from DOE would have prevented or delayed a portion of the cutbacks in mine production that actually took place, thereby increasing cumulative mine production by 9 million pounds in 2014-2016 and 23 million pounds by 2020.

Using the cumulative methodology on a forward-looking basis, the supply curves for the uranium concentrates, conversion services, and enrichment services markets have been used to determine clearing prices both with and without the DOE inventory material affecting the commercial markets. The resulting year-by-year changes in clearing price attributed to the DOE material are presented in Tables 4.4, 4.5 and 4.6 for the four scenarios considered. During the last three years (2014-2016), the change in average clearing price attributed to the DOE inventories using a cumulative clearing price methodology is estimated to be $5.1/lb for the uranium market, $0.9/kgU for the conversion market and $6.5/SWU for the enrichment market.

During the next ten years (2017-2026), the change in average clearing price attributed to the DOE inventories using the cumulative methodology is estimated to be $3.0/lb for the uranium market, $0.9/kgU for the conversion market and $8.2/SWU for the enrichment market under the Base Scenario. Scenarios 2 and 3 provide similar price effects to the Base Scenario for uranium and conversion services. For Scenario 1, where EM transfers for services are halted in 2017, the future price effects are reduced to $1.6/lb for uranium and $0.7/kgU for conversion services. The future price effect for enrichment services is the same under all four scenarios.

[40] It was assumed that the BLEU program with TVA would have been maintained.

Year	Uranium ($/lb U_3O_8)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$4.9			
2015	$5.6			
2016	$4.9			
2017	$5.5	$4.4	$5.3	$5.5
2018	$4.7	$3.2	$4.5	$5.3
2019	$5.0	$2.8	$4.3	$5.3
2020	$3.7	$1.1	$3.5	$3.7
2021	$2.7	$0.4	$2.7	$2.7
2022	$1.4	$0.1	$1.4	$1.4
2023	$2.1	$0.0	$2.1	$2.1
2024	$1.7	$1.6	$1.7	$1.7
2025	$2.3	$2.0	$2.3	$2.3
2026	$1.3	$0.7	$1.3	$1.3
Average 2017-2026:				
	$3.0	$1.6	$2.9	$3.1

Table 4.4 Uranium Clearing Price Changes Due to DOE Inventory, Cumulative Method

Year	Conversion ($/KgU as UF_6)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$0.6			
2015	$0.9			
2016	$1.0			
2017	$1.1	$0.9	$1.1	$1.1
2018	$1.1	$1.1	$1.1	$1.2
2019	$2.3	$1.6	$2.1	$2.3
2020	$1.9	$1.5	$1.9	$1.8
2021	$0.7	$0.1	$0.8	$0.7
2022	$0.2	$0.2	$0.2	$0.2
2023	$0.1	$0.1	$0.1	$0.1
2024	$0.4	$0.4	$0.4	$0.4
2025	$0.5	$0.5	$0.5	$0.5
2026	$0.5	$0.5	$0.5	$0.5
Average 2017-2026:				
	$0.9	$0.7	$0.9	$0.9

Table 4.5 Conversion Clearing Price Changes Due to DOE Inventory, Cumulative Method

Year	Enrichment ($/SWU)			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	$5.2			
2015	$6.6			
2016	$7.7			
2017	$9.7	$9.7	$9.7	$9.7
2018	$8.8	$8.8	$8.8	$8.8
2019	$7.3	$7.3	$7.3	$7.3
2020	$8.8	$8.8	$8.8	$8.8
2021	$14.9	$14.9	$14.9	$14.9
2022	$10.5	$10.5	$10.5	$10.5
2023	$10.1	$10.1	$10.1	$10.1
2024	$2.6	$2.6	$2.6	$2.6
2025	$7.5	$7.5	$7.5	$7.5
2026	$1.3	$1.3	$1.3	$1.3
Average 2017-2026:				
	$8.2	$8.2	$8.2	$8.2

Table 4.6 Enrichment Clearing Price Changes Due to DOE Inventory, Cumulative Method

The price effects using the cumulative methodology are also provided in Figures 4.7, 4.8 and 4.9 for each of the four scenarios. The historical price effects for Scenarios 1, 2 and 3 are identical to the Base Scenario in 2014-2016, as the different release rates postulated do not begin until 2017. It is important to note that the price effects attributed to DOE inventory are already built into current market prices. If no DOE inventory releases took place, then future market prices would be higher by the amounts stated.

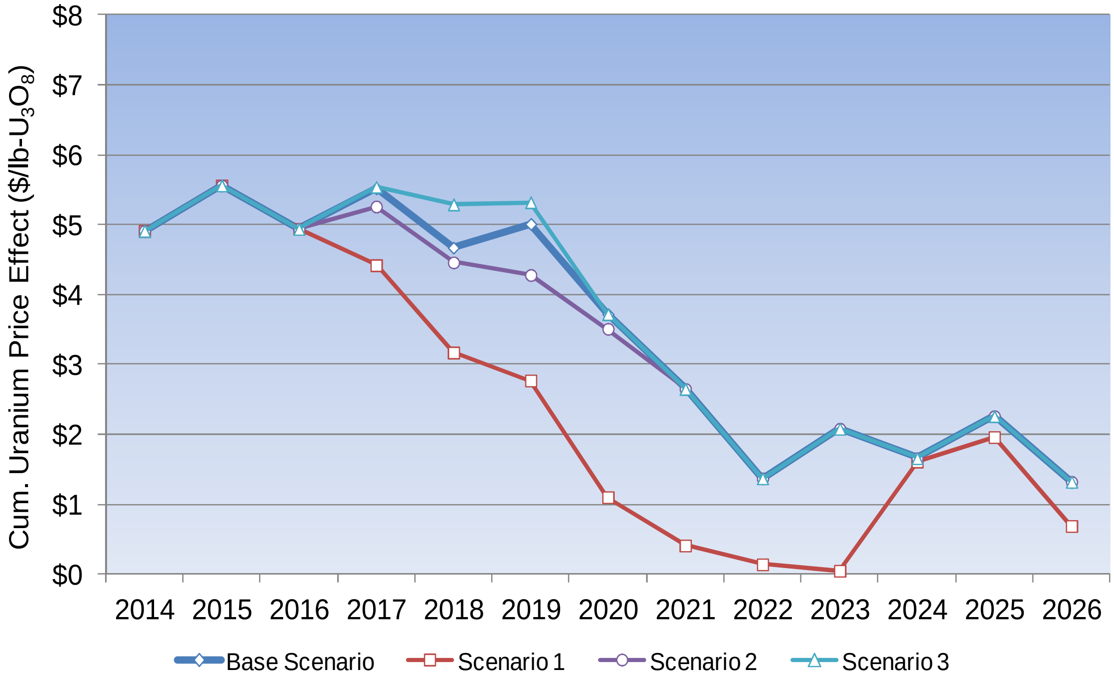


Figure 4.7 Cumulative Uranium Price Effects for All Scenarios

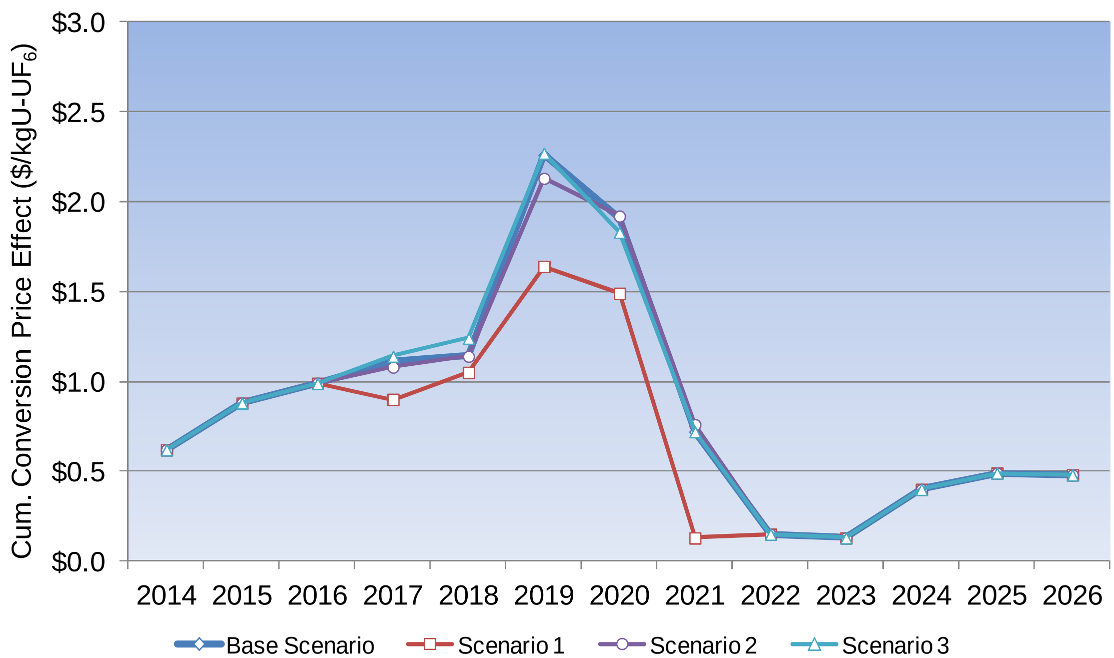


Figure 4.8 Cumulative Conversion Price Effects for All Scenarios

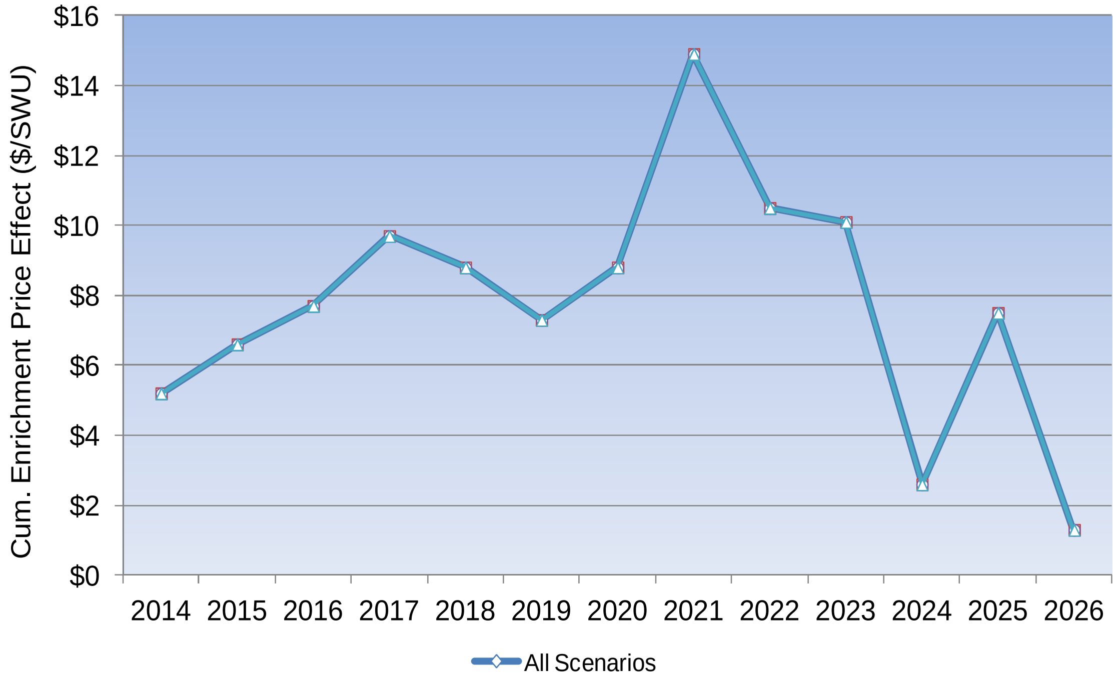


Figure 4.9 Cumulative Enrichment Price Effects for All Scenarios

Comparison of Annual and Cumulative Methodology Clearing Prices

The historical and future price effects on the uranium, conversion and enrichment markets of the Base Scenario are compared for the annual and cumulative methodologies in Figures 4.10, 4.11 and 4.12. For point of reference, the price effects of Scenario 1 (which was the base scenario) from the February 2015 ERI market analysis are also provided. Note that Scenario 1 from February 2015 postulated higher DOE release rates in 2020-2023 due to the earlier start of proposed DU processing.

The annual method shows lower price effects through 2023 for uranium, through 2021 for conversion and through 2026 for enrichment. The larger price effects found when using the cumulative methodology is consistent with importance of excess inventory buildup in the current market. The most recent annual method price effect is lower than found in the February 2015 analysis due to the assumption of greater excess inventory overhang. This causes the market clearing price to occur in an area of the producer supply curves where the slope is not as steep and as a consequence the price effect is lower when the DOE inventory for a given year is removed.

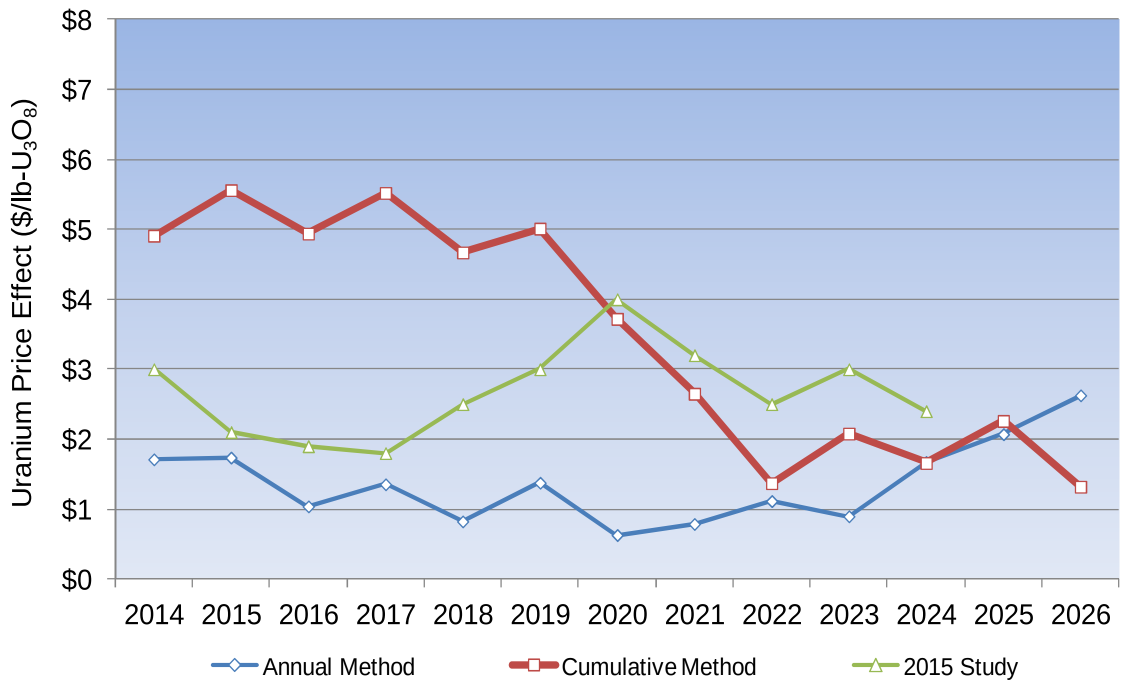


Figure 4.10 Base Scenario Uranium Price Effect for Annual and Cumulative Methods

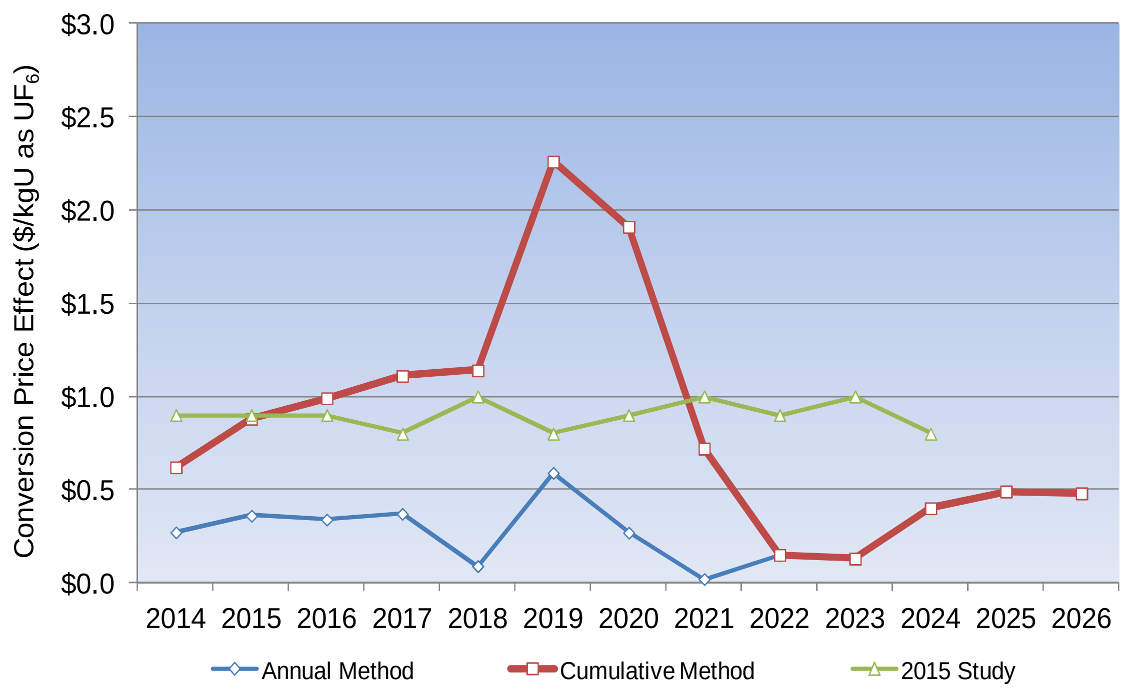


Figure 4.11 Base Scenario Conversion Price Effect for Annual and Cumulative Methods

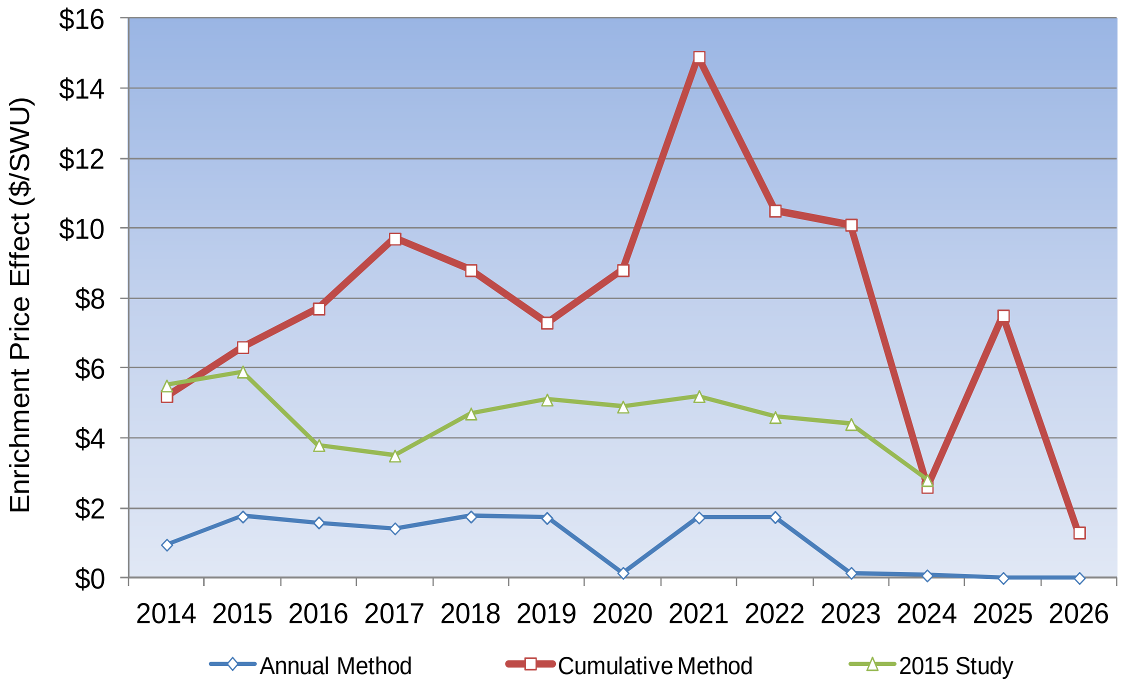


Figure 4.12 Base Scenario Enrichment Price Effect for Annual and Cumulative Methods

Cumulative Clearing Price Effect Relative to "No DOE" Clearing Prices

Tables 4.7, 4.8 and 4.9 restate the changes in clearing price using the cumulative methodology relative to the "No DOE" market clearing price for each of the scenarios in order to provide some additional perspective. The "No DOE" market clearing price assumes that DOE releases from 2009 onward were zero.

During the last three years (2014-2016), the change in clearing price attributed to the DOE inventories relative to the "No DOE" market price averaged approximately 14% lower for the uranium market, 10% lower for the conversion market and 8% lower for the enrichment market. This indicates that actual spot market prices in 2014-2016 could have been 16% higher for the uranium market, 11% higher for the conversion market and 9% higher for the enrichment market if no DOE inventory releases had occurred dating back to 2009.

During the next ten years (2017-2026), the change in clearing price attributed to the DOE inventories relative to the "No DOE" market price averages approximately 7% for the uranium market, 7% for the conversion market and 9% for the enrichment market when the Base Scenario inventory release rates are assumed. That is, clearing prices are 7% to 9% lower due to DOE historical and projected Base Scenario releases. The relative price effects are larger in 2017-2020 than in 2021-2026, particularly for uranium and conversion

(13% for uranium, 15% for conversion, 11% for enrichment), due to the gradual reduction in industry excess inventory as well as the eventual increase in market prices.

For Scenario 1, the price effects decline to 4% and 6% of the "No DOE" prices for uranium and conversion, respectively. This means that under Scenario 1, where EM transfers for services are halted starting in 2017, average uranium prices in 2017-2026 will be 3% higher (7% - 4%) than under the Base Scenario. This difference rounds to 2% for conversion. Over ten years, the differences are minimal (less than 0.5%) for Scenarios 2 and 3. The enrichment price effect is the same across all four scenarios.

Year	Uranium			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	13%			
2015	13%			
2016	16%			
2017	15%	12%	14%	15%
2018	13%	9%	12%	14%
2019	13%	7%	11%	14%
2020	10%	3%	9%	10%
2021	7%	1%	7%	7%
2022	3%	0%	3%	3%
2023	5%	0%	5%	5%
2024	4%	3%	4%	4%
2025	5%	4%	5%	5%
2026	3%	1%	3%	3%
Average 2017-2026:				
	7%	4%	7%	7%

Table 4.7 Cumulative Uranium Price Effect as Percentage of "No DOE" Clearing Price

Year	Conversion			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	8%			
2015	11%			
2016	13%			
2017	12%	10%	12%	13%
2018	12%	11%	12%	13%
2019	19%	14%	18%	19%
2020	15%	12%	15%	14%
2021	6%	1%	6%	6%
2022	1%	1%	1%	1%
2023	1%	1%	1%	1%
2024	3%	3%	3%	3%
2025	4%	4%	4%	4%
2026	4%	4%	4%	4%
Average 2017-2026:				
	7%	6%	7%	7%

Table 4.8 Cumulative Conversion Price Effect as Percentage of "No DOE" Clearing Price

Year	Enrichment			
	Base Scen.	Scenario 1	Scenario 2	Scenario 3
2014	5%			
2015	9%			
2016	12%			
2017	12%	12%	12%	12%
2018	11%	11%	11%	11%
2019	9%	9%	9%	9%
2020	10%	10%	10%	10%
2021	16%	16%	16%	16%
2022	11%	11%	11%	11%
2023	11%	11%	11%	11%
2024	3%	3%	3%	3%
2025	8%	8%	8%	8%
2026	1%	1%	1%	1%
Average 2017-2026:				
	9%	9%	9%	9%

Table 4.9 Cumulative Enrichment Price Effect as Percentage of "No DOE" Clearing Price

4.1.2 Potential Effect of DOE Inventory on Uranium Spot Market Price

ERI has developed a multivariable correlation[41] between the monthly spot market prices for uranium concentrates published by TradeTech and the active spot market supply and active spot market demand, which are also published monthly by TradeTech. Active spot market supply is uranium available for sale and delivery within one year as of the date published. Active spot market demand is based on active inquiries to purchase uranium for delivery within one year as of the date published. Spot market volume (sales) and the spot market price in the preceding month are used in the correlation as well. The active supply and demand over a number of trailing months as well as for just the preceding month are used in the correlation. This correlation covers the period from July 2004 through December 31, 2016 and has an R^2 = 90%, which indicates a reasonable correlation, particularly given the extreme volatility experienced in the spot market price during this period. A comparison of the actual spot market prices with the price "predicted" by the correlation is provided in Figure 4.13

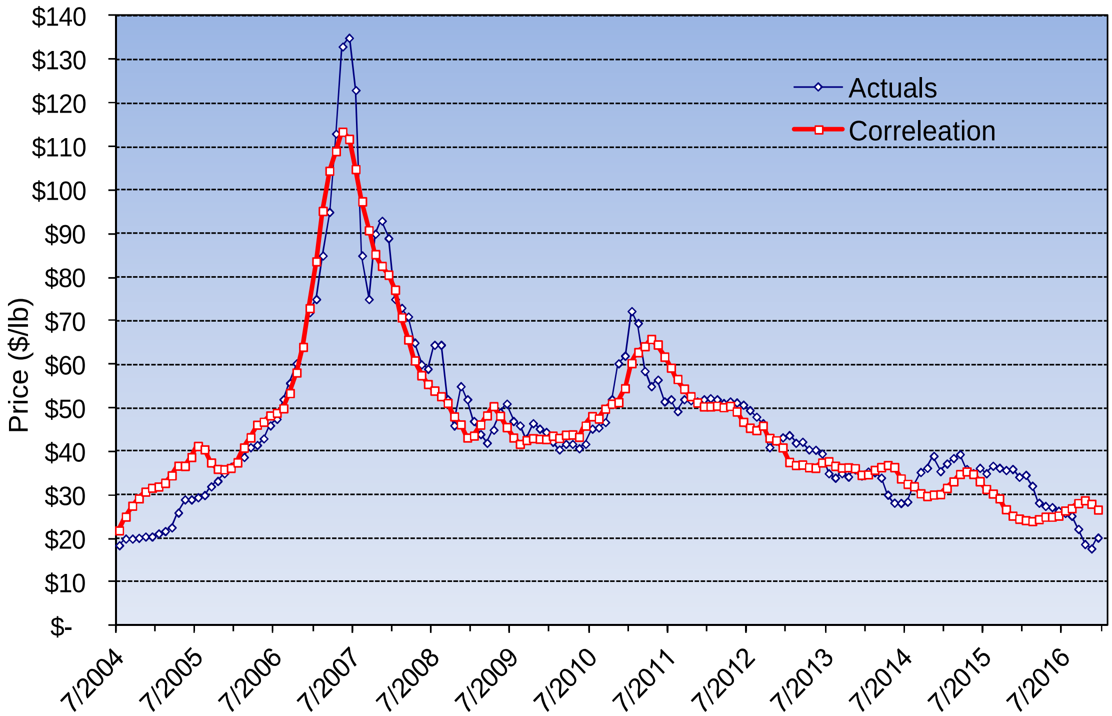


Figure 4.13 Spot Market Prices for Uranium – Actual versus Correlation

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[41] The correlation was developed by using the least squares method to develop a linear curve fit between each of the independent variables and the spot market price. The curve fit is an equation of the form $y = m_1x_1 + m_2x_2 + \ldots + b$ where x_1, x_2, etc. are the values for each of the variables (active supply, active demand, etc.) and m_1, m_2, etc. are the variable coefficients which provide the best fit of the price returned by the correlation to the actual spot price.

This correlation was then used to simulate[42] the 2009 through 2026 spot market price for uranium concentrates with and without the DOE inventory released to the spot market, as shown in Figure 4.14.

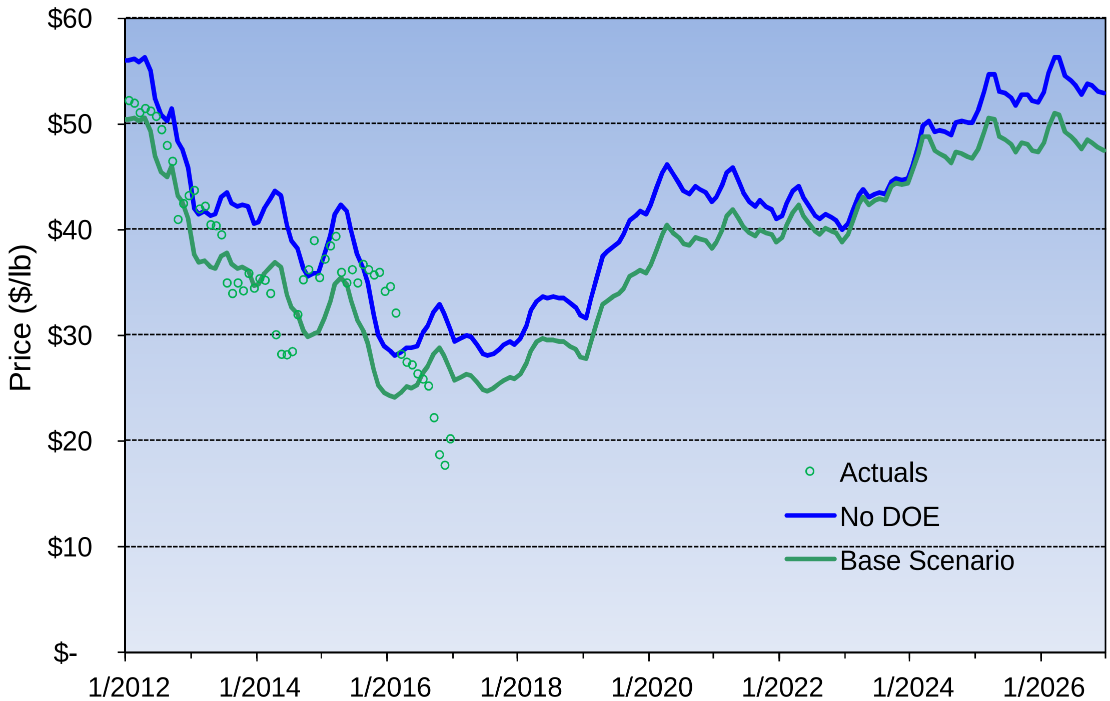

Figure 4.14 Estimate of Uranium Spot Market Price Change Due to Base Scenario DOE Inventory Using Correlation

Historical auctions of DOE material were modeled as they took place. For the uranium that is transferred to EM's contractor and ultimately sold by Traxys, it has not been possible to explicitly identify when and how much of this DOE origin material is introduced into the commercial markets by Traxys at any point in time. For use in the correlation, the DOE inventory is assumed to be released to the spot market evenly through the year, i.e. one-twelfth of the annual amount each month. The quantity of DOE material released to the spot market was developed in Table 3.10 of Section 3.5, which included the conservative assumption that 50% of sales of DOE material by Traxys take place under mid- and long-

[42] Future values of active supply and demand were projected based on historical values. Two projections of spot market price into the future using the correlation equation were then made - one assuming DOE material continues to contribute to active spot market supply and one which assumes DOE material no longer contributes. The difference between the two is the price effect of the DOE material.

term contracts.[43,44] The domestic industry has expressed concern that the DOE transfer material disposed of by Traxys in term contracts is primarily in the form of mid-term contracts which reduce spot market demand in subsequent years. When the correlation is used to estimate the price effect with the DOE releases removed, spot demand is adjusted higher (to reflect the removal of the mid-term price effect) and spot supply is adjusted lower.

Application of the correlation results in an estimated spot market price effect of $5.3 per pound U_3O_8 over the last three years (2014-2016). This indicates an estimated effect that spot market prices were 15% lower over the past three years due to DOE inventory releases compared to no release of DOE inventory. Looking forward and assuming Base Scenario DOE inventory release rates, the correlation results in projected spot market price effects of $3.5 per pound U_3O_8 over the next ten years (2017-2026). This represents an estimated effect of 8% lower spot market prices if Base Scenario DOE inventory releases take place over the next ten years (2017-2026) compared to no release of DOE inventory. The DOE effect is higher in the near term (2017-2020) at $4.4 per pound and 12% lower prices. The price effect is on future spot market prices, which are projected to eventually rise with or without the DOE inventory releases as shown in Figure 4.14. The price effects attributed to past and current DOE inventory releases are already built into current spot market prices. If the past releases had not occurred, then current spot market prices would be higher.

In a 2016 analysis[45] prepared for the Uranium Producers of America, industry consultant TradeTech estimated the effect on spot prices of DOE inventory releases to average $4.2/lb in 2012 through 2015. TradeTech made use of its own econometric model which relates active spot market supply to active spot market demand to estimate the price effect of the DOE inventory releases. The ERI econometric model estimates $5.7/lb over the same time period. The ERI clearing price cumulative methodology described in Section 4.1.1 estimated $5.1/lb over the 2012 to 2015 time period.

4.2 Potential Effect on Domestic Industries

The potential effect of the entry of DOE materials and services into the commercial markets discussed above on each of these domestic industries is discussed further in the following sections.

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[43] Smith, Kevin, Director Uranium Trading and Marketing, Traxys, Commercial View of DOE's 2013 Plan for Natural Uranium Barter Sales, Nuclear Energy Institute, International Uranium Fuel Seminar, October 6-9, 2013, San Antonio, Texas.

[44] Smith, Kevin P., Traxys North America LLC, Managing Director for Uranium Marketing and Trading, Declaration of Kevin P. Smith, Attachment 6 to Defendant's Opposition to Plaintiff's Motion for Preliminary Injunction, Case No. 1:14-cv-1012-RBW, Document 17-7, Filed July 7, 2014, at 7-12.

[45] TradeTech LLC, "UPA: DOE Request for Information Request Response", September 2016, http://www.theupa.org/_resources/news/TradeTech_Report_on_DOE_RFI_September_2016_Final.pdf

4.2.1 Potential Effect on the Domestic Uranium Concentrates Industry

ERI continues to believe that the change in market price provides the best measure of, and is the best singly proxy for, market effect. However, ERI's analysis of potential effects on the domestic uranium industry has been expanded to relate how a change in market price affects key metrics of the domestic uranium industry, in particular, employment and uranium production.

U.S. Uranium Industry Employment

Total U.S. uranium industry employment, as measured by responses to U.S. Energy Information Administration (EIA) Form EIA-858, has ranged between 321 and 1,563 person-years over the past 20 years. As shown in Figure 4.15, employment reached its low point in 2003, but then steadily increased over the following five years, peaking in 2008. The large employment gains in 2007 and 2008 were driven by the rapid run up in uranium prices, which resulted in increased employment at uranium production centers as well as increased exploration employment. Employment declined by 30% in 2009 as there was a sharp reduction in exploration, with reduced mining employment as well. The sudden decline appeared to be the result of the large price declines in 2008 and 2009 from the 2007 price peak. Mining industry employment was fairly steady in 2011 to 2013 but declined sharply (-46%) in the last two years and was reported as 625 person-years for 2015. The 2015 employment level was the lowest since 2004.

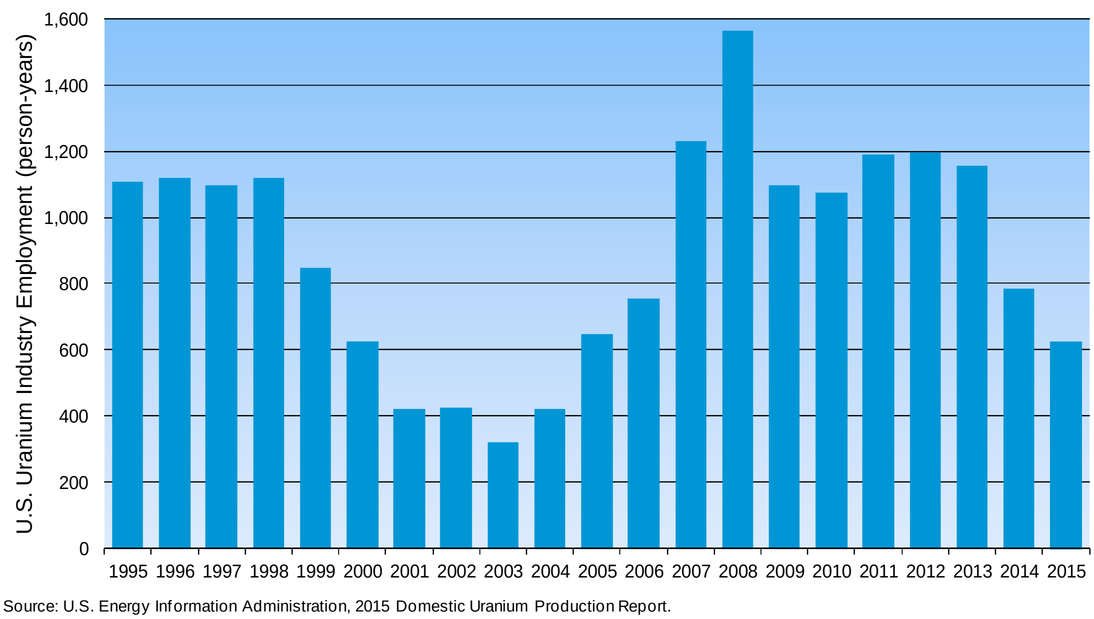

Figure 4.15 U.S. Uranium Industry Employment History

U.S. uranium industry employment over the past dozen years has appeared to respond to changes in uranium spot and term prices, as shown in Figure 4.16. In particular, it was found that changes in industry employment from year-to-year are correlated to the two-year average prices (current and preceding year) in constant dollars. Mining, milling and processing employment was found to be more closely correlated with the term price, while exploration employment was found to be more closely correlated with the spot price. The R^2 (coefficient of determination) for the combined correlations is 0.91, indicating that 91% of the observed changes in employment are consistent with the observed changes in market price.

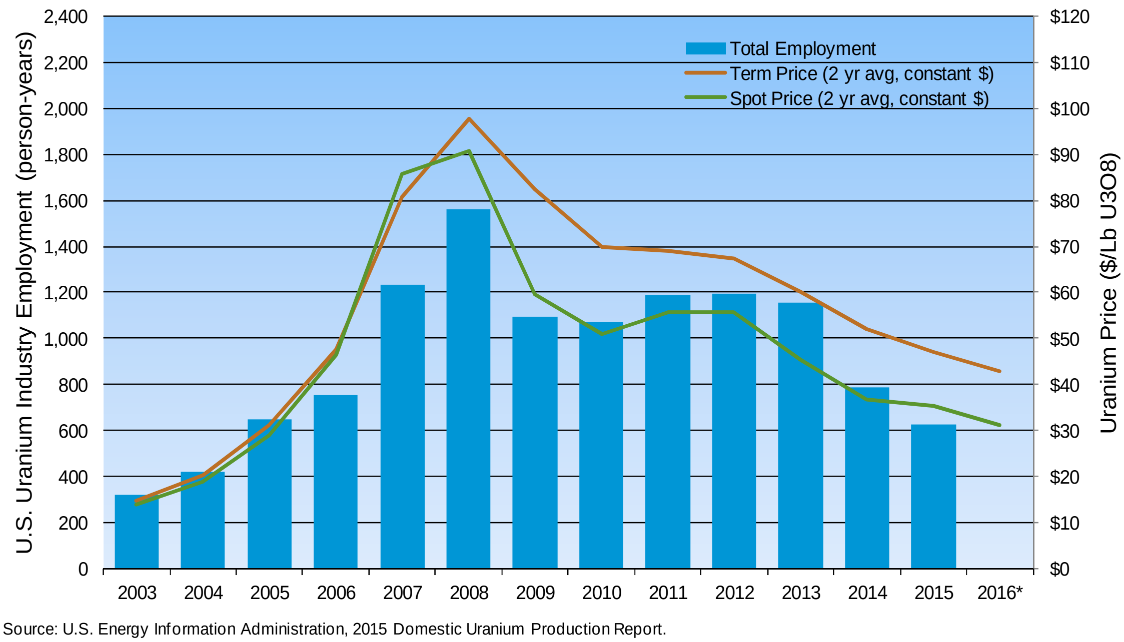

Figure 4.16 U.S. Uranium Industry Employment and Market Prices

As shown in Figure 4.17, the correlations indicate that industry employment in 2017 is expected to decline by an additional 111 person-years from the 2015 value, or 18% as shown in Figure 4.17. This estimation appears consistent with announcements that have been made by domestic industry participants.

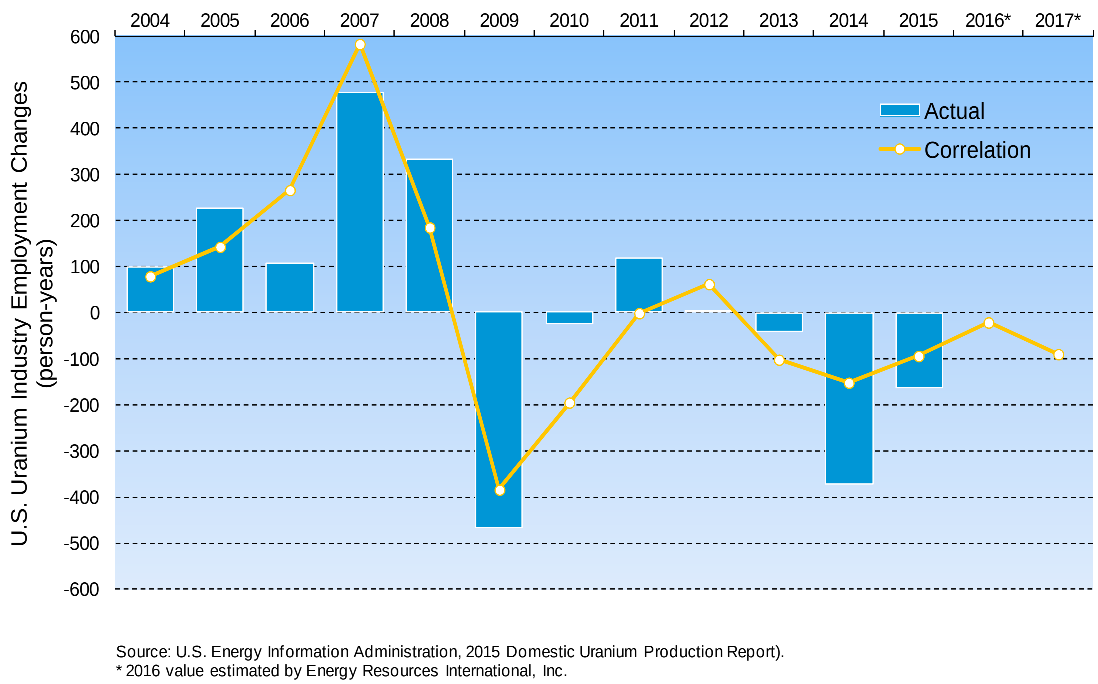

Figure 4.17 Change in U.S. Uranium Industry Employment - Actual and Projected

The price-employment correlations have been used to estimate the effect of the DOE inventory releases on U.S. uranium industry employment. The total price effect of DOE inventory releases is estimated to have averaged $2.1/lb in 2012-2015[46] when a stand-alone annual price effect is estimated (see Table 4.1). The correlations indicate the DOE price effect lowered employment by an average of 30 person-years in 2012-2015. In other words, employment was 3.1%[47] lower in those four years than it would have been if no DOE inventory releases had occurred. Looking forward, the stand-alone annual price effect of DOE uranium inventory on the commercial market is estimated to average $1.3/lb over the next ten years (2017-2026) for the Base Scenario, as was discussed in Section 4.1. This results in an estimated long-term employment loss of 19 person years, meaning that future employment is reduced by 2.9%[48] on average as a result of the DOE inventory releases.

If a cumulative methodology is used, the DOE inventory releases are estimated to be larger and have resulted in a price effect averaging $5.1/lb in 2012-2015. The correlations indicate the cumulative DOE price effect lowered employment by an average of 73 person-years during 2012-2015. In other words using the cumulative methodology, employment

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[46] The correlation is based on average price in the current and preceding year.

[47] Percentage calculated by comparing estimated loss due to DOE (30) with 2012-2015 actual employment (941) plus DOE loss, or 30 / (941+30) = .031 or 3.1%.

[48] Percentage calculated by comparing estimated loss due to DOE (21) with estimated 2017-2026 average employment before DOE loss (662), or 19 / 662 = .029 or 2.9%.

was 7.2%[49] lower in those four years than it would have been if no DOE inventory releases had occurred. Looking forward, the cumulative methodology estimates a price effect averaging $3.0/lb in 2017-2026 for the Base Scenario. The correlations indicate the cumulative DOE price effect lowers employment by an average of 40 person-years, or 6.0%[50], during 2017-2026 when using the cumulative methodology. It is important to note that the cumulative effect of past DOE releases is already in place. If DOE were to halt future EM releases consistent with Scenario 1 then employment would still be lowered by an average of 31 person-years, or 4.7%[51], during 2017-2026. This represents an improvement of 9 person-years (40 - 31) or 1.3% (6.0% - 4.7%) over the Base Scenario using the cumulative methodology.

U.S. Uranium Production

A history of U.S. uranium industry production is provided in Figure 4.18. Production has generally risen since the low of 2 million pounds in 2003. Although DOE uranium inventory transfers started in December 2009, U.S. production rose through 2014, but then declined significantly in 2015. Spurred by the price run-up in 2006 and 2007, five new ISL operations have started production since 2009 - Uranium One's Willow Creek in 2010, Uranium Energy Corporation (UEC)'s Hobson/Palangana in late 2010, Ur-Energy's Lost Creek in 2013, Uranerz's Nichols Ranch in 2014 and Peninsula's Lance in 2015.

[49] Percentage calculated by comparing estimated loss due to DOE (73) with 2012-2015 actual employment (941) plus DOE loss, or 73 / (941+73) = .072 or 7.2%.

[50] Percentage calculated by comparing estimated loss due to DOE (40) with estimated 2017-2026 average employment before DOE loss (662), or 40 / 662 = .0606 or 6.0%.

[51] Percentage calculated by comparing estimated loss due to DOE (31) with estimated 2017-2026 average employment before DOE loss (662), or 31 / 662 = .047 or 4.7%.

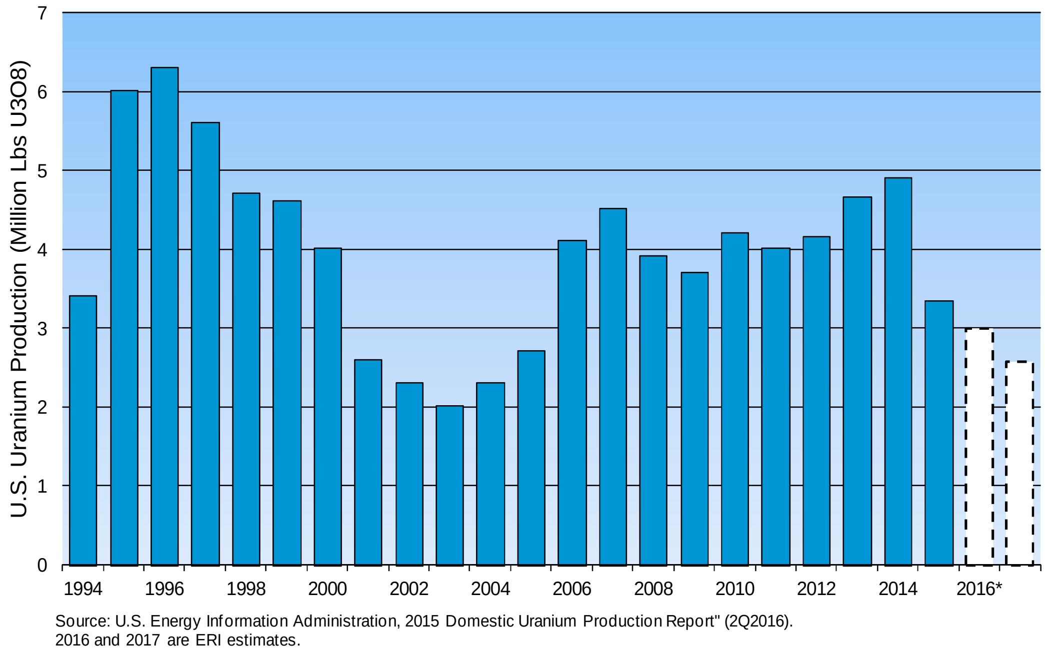


Figure 4.18 U.S. Uranium Industry Production, 1993 - 2017

Despite the startups, the decline in prices has affected the actual and planned production of most U.S. operations. Two of the new operations (Willow Creek and Palangana) subsequently stopped developing new well fields and were effectively place on care and maintenance. In mid-2014 both Ur-Energy and Uranerz announced they would limit production expansion at new ISL facilities at Lost Creek and Nichols Ranch rather than ramp up to originally planned production levels. The two companies decided to match production ramp up to existing term contracts rather than sell additional production at existing spot market prices. Mestena halted well field development at its Alta Mesa ISL facility in Texas[52] in 2013. Alta Mesa was sold to Energy Fuels in 2016 and will remain on standby until market conditions improve. Long-standing U.S. producer Cameco has also stopped new well field development in the U.S. Even though production at the Smith Ranch / Highland center expanded in 2014 with the operation of the North Butte satellite facility, Cameco announced in February 2015 its decision to postpone some well field development due to market conditions. In April 2016 Cameco announced its decision to discontinue well field development at all U.S. sites. Cut backs have also taken place at Energy Fuels conventional mines and the White Mesa mill is placed on standby periodically, although development of the Canyon mine is proceeding.

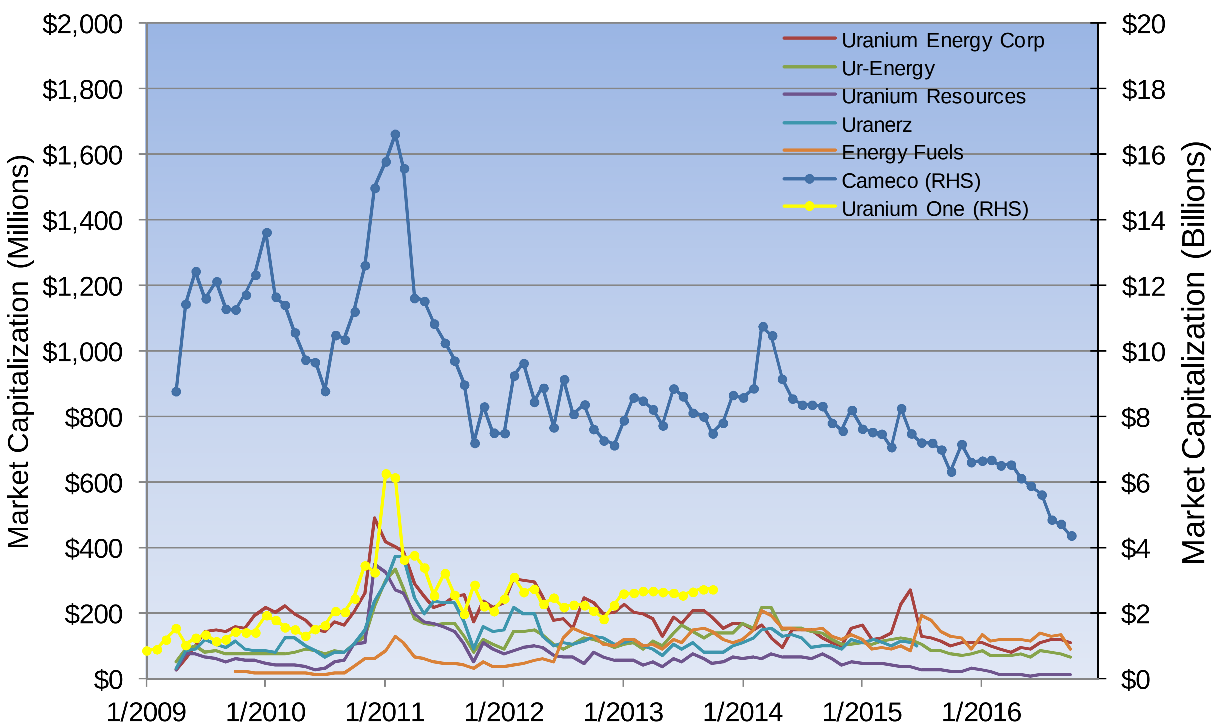
These cut-backs were finally recognized in 2015 U.S. production, which declined 32% to 3.3 million pounds. U.S. Production in 2016 is expected to decline an additional 10% to 3.0 million pounds[53]. The 2015 and 2016 production is the lowest in the ten years dating back

[52] The privatively held Mestena produced a total of 4.6 million pounds at Alta Mesa between 2005 and 2013.
[53] ERI estimate based on U.S. production through 9/30/2016 as provided by the EIA in "Domestic Uranium Product Report 3rd Quarter 2016", November 2016 and company announcements.

to 2005. The expected 2016 production is 39% below the recent 2014 peak. A further 10% - 15% reduction in production is estimated for 2017 based on company announcements. U.S. uranium producers characterize themselves as in "survival mode". The 2016 and 2017 estimates are shown in Figure 4.18 along with the historical data.

Market Capitalization

For the smaller mining companies in the U.S., most of which are publicly traded, market capitalization[54] is an important metric. Figure 4.19 displays the market capitalization history of companies[55] with U.S. production. Two of the companies, Cameco and Uranium One[56], are quite large with market capitalization in the billions, while the remaining companies are smaller with market capitalization in the millions. The majority of Cameco and Uranium One production (and market values) arises from projects in Canada and Kazakhstan. Two scales are therefore provided in the figure, with the larger companies using the right hand scale and the smaller companies using the left hand scale.



Source: www.ycharts.com

Figure 4.19 Market Capitalization of Companies with U.S. Production

54 Share price multiplied by number of outstanding shares.

55 The companies are identified by their ticker symbols and stock market exchange in the figure.

56 Uranium One was taken private in October 2014 when Russian mining company ARMZ completed the acquisition of all outstanding shares.

The data is compared on a relative basis, where each company's market capitalization in December 2009 equals 100, in Figure 4.20. Also provided in the figure are the spot and term market price indicators, which use the right hand scale. It is observed that the market capitalization of the smaller mining companies is sensitive to changes in the spot market price. During 2010, spot price increased from $40 per pound up to $70 per pound, an increase of 75%. The market capitalization of the smaller U.S. miners increased 150% to 600% in response. The response of a large mining company, Cameco, was restrained in comparison, with market capitalization increasing about 75%. Figure 4.20 shows that market capitalization declined just as rapidly following the Fukushima event. Market capitalizations decreased further in early 2014 and again in mid-2015. The most recent market capitalization decrease started in advance of the rapid spot market price decline, which began in early 2016 as the spot price dropped below $30/lb in March 2016, below $25/lb in September 2016 and below $20/lb in October 2016.

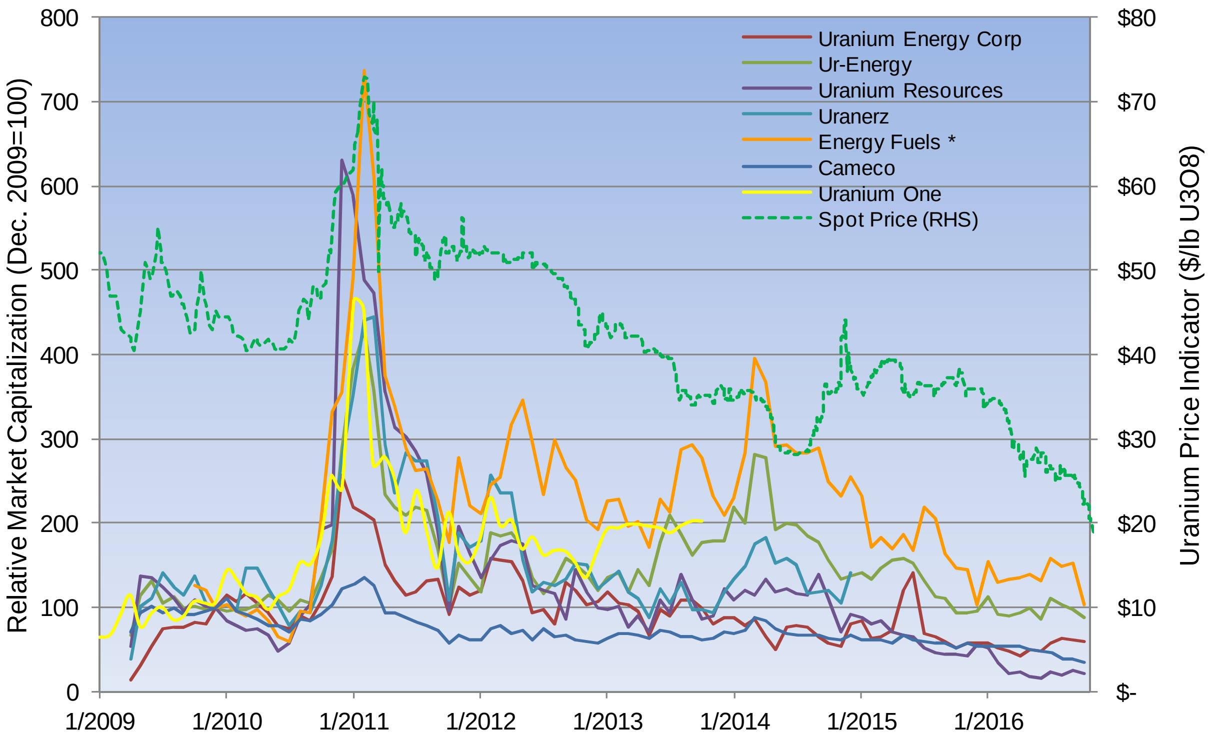


Figure 4.20 Market Capitalization -- Relative to December 2009

Market capitalization is an important metric for the smaller, publicly traded mining companies in the U.S. because it is representative of the ability of these companies to raise funds needed to move projects through the licensing process, which can take many years, as well as initial project development in some cases. The smaller companies generally do not have easy access to debt financing and are more dependent on equity financing. While the effect of large changes in the spot market price is obvious, the effect on market capitalization from the smaller price changes attributed to DOE inventory (See section 4.1) is not as clear. Figure 4.21 provides the total market capitalization for five select U.S.

companies[57] representative of the smaller U.S. miners. The spot uranium price is shown in the figure as well. Total capitalization for these companies declined rapidly in mid-2015 in advance of the spot market price decline observed during much of 2016.

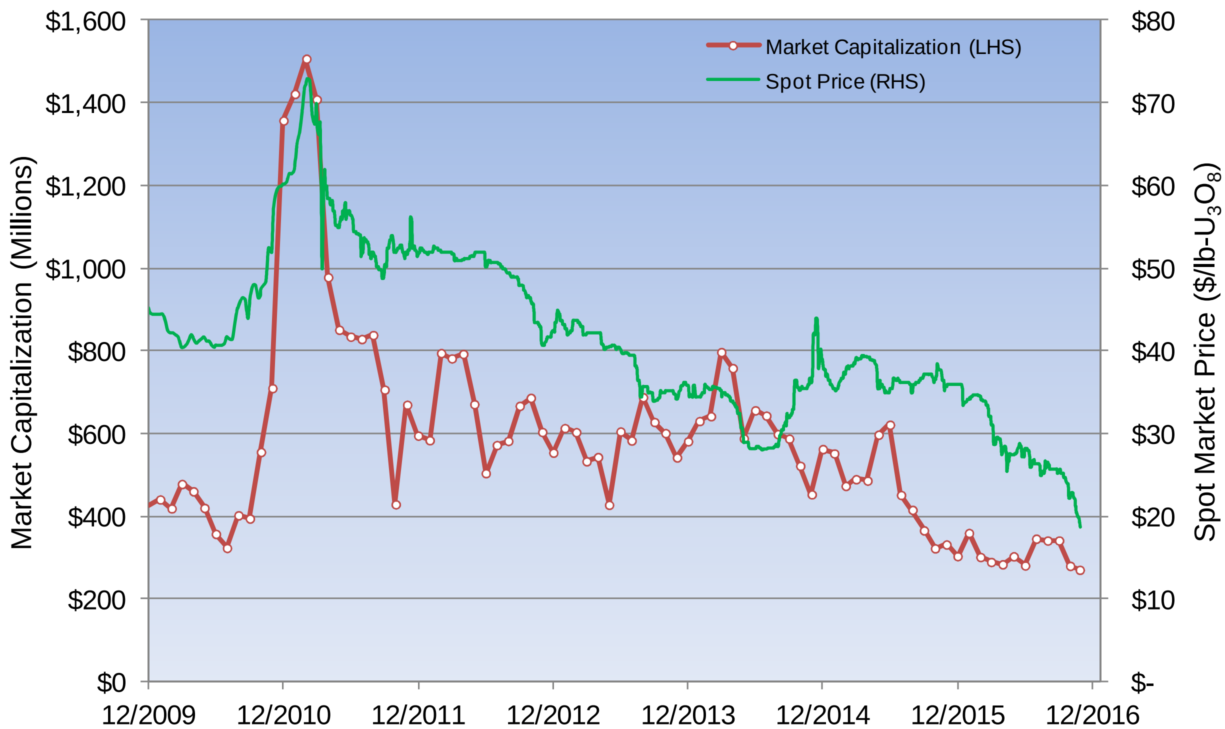


Figure 4.21 Total Market Capitalization of Select U.S. Companies

Realized Prices, Production Costs and Margins

Revenues from U.S. uranium sales are obtained under a mix of term and spot market price based contracts. This is demonstrated by Figure 4.22, which compares the EIA's average delivered price in the U.S. with historical market prices. The EIA average delivered price in the U.S. is representative of realized prices for the uranium industry on a global basis. Figure 4.22 shows that for U.S. end-users, the average price of all delivered uranium increased steadily between 2006 and 2011/2012 but has slowly declined since that time. The average delivered price for U.S. end-users was $44/lb-$U_3O_8$ in 2015 or 21% below the 2011 peak. Additional decline is expected by ERI for 2016, although floor prices in many market-related contracts are preventing end-users from reaping the full benefit of the 2016 spot market price decline.

The average price of U.S. origin uranium delivered by U.S. producers is also provided by the EIA and has been somewhat lower than the end-user delivered price since 2008. The

[57] Uranium Energy Corp, Ur-Energy, Uranium Resources Inc, Uranerz, Energy Fuels Corp

producer price has also been in general decline since 2011 and was \$43/lb-U_3O_8 in 2015 or 18% below the 2011 peak. Additional decline is expected by ERI for 2016, although floor prices in market-related contracts are providing producers with some protection from the 2016 spot market price decline. Also, U.S. producer spot market sales are low as producers with "unhedged" sales strategies have cut back their production.

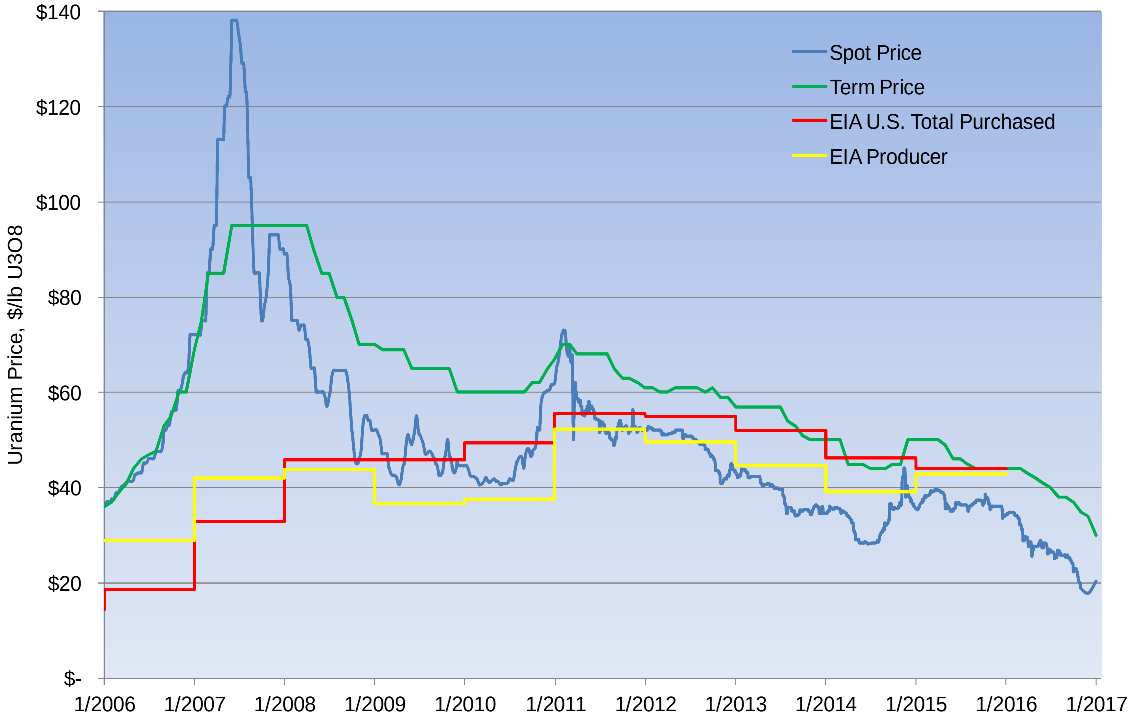


Figure 4.22 Market Prices and Average Delivered Price in the U.S.

Realized prices for the U.S. uranium supply industry varies from one company to another, as demonstrated by Figure 4.23 which presents the realized prices for companies with U.S. production during the period 2011 through the first three quarters of 2016. The prices are drawn from company public filings[58], and are compared to the average spot market price for each year. The companies providing price data represent approximately 90% of U.S. production in 2015. It is apparent that some mining companies have chosen to sell on a spot market price basis, while others have hedged their exposure to spot market prices by locking in prices using a base price escalated approach for a portion of their portfolio. For example, Cameco - the largest U.S. producer - has reported that it usually includes in its contracts a mix of fixed-price and market-price components, which reflect a target of 40% fixed-price and 60% market-price. Cameco's most recent estimate of the price sensitivity of its current contract portfolio through 2020 indicates that the projected change in realized

[58] Note that Cameco's prices are for all production, not just the U.S. based production.

price is about 55% of the change for increases in the spot market price.[59] The share of U.S. production coming from companies that are effectively unhedged (no long-term contracts with higher fixed prices)[60] has declined from about 25% in 2012 and 2013 to just 3% in 2015 and 2016.

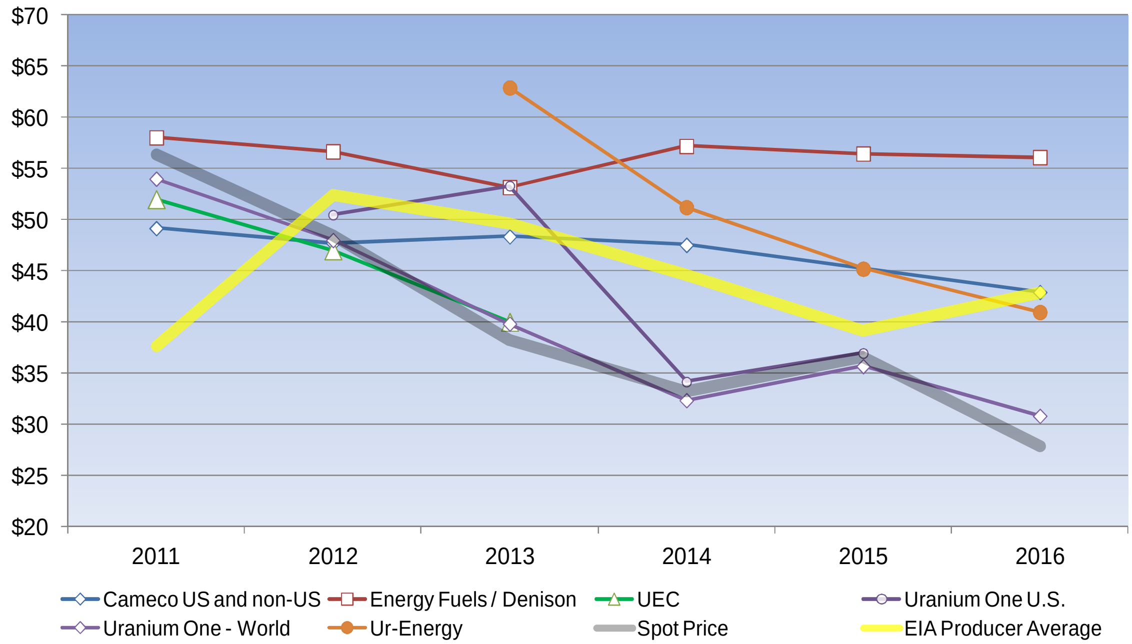


Figure 4.23 Realized Uranium Prices of Companies with U.S. Production

It is apparent that new U.S. uranium producers that have recently begun production have used fixed price term contracts to support the startup of their operations. Figure 4.24 shows that most of these companies agreed to such contracts when long-term prices were in the $55 to $70 per pound range. One producer has been willing to enter into contracts when long-term prices were in the $45 to $50 per pound range in late 2014 to early 2016. These contracts allowed the new operations to follow through on facility development even as prices have declined over the past two years. At least one of these companies has stated that the project would not have been able to proceed if the initial contracts had been made at then-current price levels ($45 to $50 per pound long-term). Owners of proposed new conventional mines outside the U.S. have typically stated that an incentive price of $60 per pound or more is required to move forward with development[61].

[59] Cameco Corporation, "Management's discussion and analysis for the quarter ended September 30, 2016", November 2016. Cameco's portfolio is less sensitive to spot price declines through 2020 due to contract floor prices.
[60] Note that while Uranium One's realized price for U.S. production in 2013 was high, the realized prices for 2012 and 2014 are consistent with spot prices as are the prices for the company as whole, consistent with the stated policy to ensure that realized prices are highly correlated to the spot market price.
[61] An exception is Berkeley Energia which is moving the Salamanca mine in Spain into development with one fixed off-take agreement at $44 per pound.

It does not appear that removing the DOE inventory from the market and adding back the $5/lb per pound cumulative price effect attributed to the DOE inventory material in 2016 (shown in Table 4.4) in the Base Scenario would necessarily increase current prices enough to change the situation regarding the viability of new production centers in the U.S., that is, current spot prices would remain less than $30 per pound and current term prices would still be less than $40 per pound. Higher price signals appear to be required to move forward with the development of new conventional mines in the U.S. Lower cost ISL projects may still be able to move forward at current term prices (which include the DOE inventory price effect). For example, in early 2016 Peninsula announced a new term contract with a major European utility for its proposed Lance project, which began production in late 2015.

Figure 4.24 Market Prices and U.S. Industry Contracting and Production Events

Figure 4.24 also shows the price levels when announcements of cutbacks were made by some U.S. suppliers. Energy Fuels put its conventional mines in Utah on standby when spot prices dropped below $45 per pound in 2012. Uranium One and UEC cut back production activity at their ISL facilities when spot prices dropped below $40 per pound in 2013. Both of these suppliers were effectively unhedged and fully exposed to spot market prices. With spot prices in the $35 range, Energy Fuels announced its decision to place its remaining conventional mines still in operation and the White Mesa mill on standby for a year in 2013. Energy Fuels has long term contracts, some of which do not require the uranium to be sourced from Energy Fuels' mines, enabling the use of uranium purchased on the spot market at prices below production costs of Energy Fuels' conventional mines. As prices declined rapidly from $35/lb to less than $30/lb in early 2016, Cameco halted all new U.S. well field development. Cameco also put the Key Lake mine on standby as it moved to limit production to its three large tier 1 mines in Canada and Kazakhstan.

The EIA reports total industry expenditures for U.S. uranium production, including facility expense, in its annual Domestic Uranium Production Report. The total for 2015 was $118.5 million, or an average of $35 per pound when spread across 2015 uranium production of 3.34 million pounds. SEC Industry Guide 7 requires the establishment of proven and probable reserves before the capitalization of mining development costs may begin. As a result, many U.S. ISR mines expense mine and well field development costs as they are incurred. This results in higher initial production costs than would be obtained by depreciation of these assets over time. Figure 4.25 presents EIA production costs using a three year average to smooth them out. For example, the 2014 cost was obtained by dividing the sum of EIA production costs in 2013-2015 by the sum of EIA production over the same three year period).

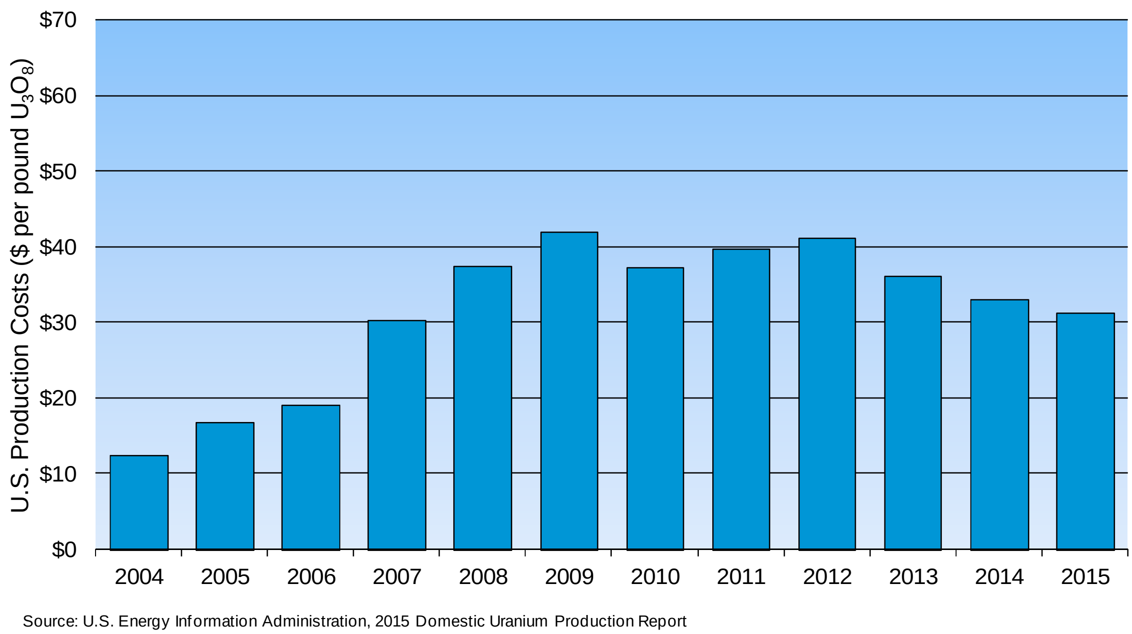


Figure 4.25 Three Year Average Production Costs for U.S. Uranium Industry

Figure 4.25 indicates three-year average production costs rose steadily between 2004 and 2009, and were then fairly level between 2009 and 2012 at about $40/lb. The $40/lb U.S. production cost was consistent with the $40/lb global average production cost mentioned by other market analysts[64,65] at the time. The EIA average production costs have steadily

[64] Ux Consulting, Presentation by Nick Carter at the IAEA International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle, June 27, 2014. 2013 production cost curve graphic stating "Over 120 million lbs available at $40 or less",

[65] Cantor Fitzgerald, Commodity Price Update, January 3, 2014. "... the spot price of US$34.50/lb is below the current marginal cost of production of US$40/lb..."

declined since 2012, however. While some new lower cost supply was added, U.S. producers have cut costs in response to lower market prices including curtailed operations at higher cost mines, resulting in a three-year average production cost of $31/lb in 2015. For comparison, the spot uranium price averaged $36.76/lb in 2015 but averaged less than $26/lb in 2016 and was just $20.25/lb at the end of December 2016.

The EIA also reports exploration and development drilling costs. An estimate of the drilling costs devoted to development, based on feet drilled, indicates development drilling costs averaging $7/lb produced between 2009 and 2015. Since maintaining production at ISL projects requires continual development drilling, it is appropriate to look at average production plus development drilling costs, as is done in Figure 4.26. The figure shows that ongoing costs have declined from $49/lb in 2012 to $37/lb in 2015. Production plus development costs for U.S. facilities are expected by ERI to average about $35/lb in 2016.

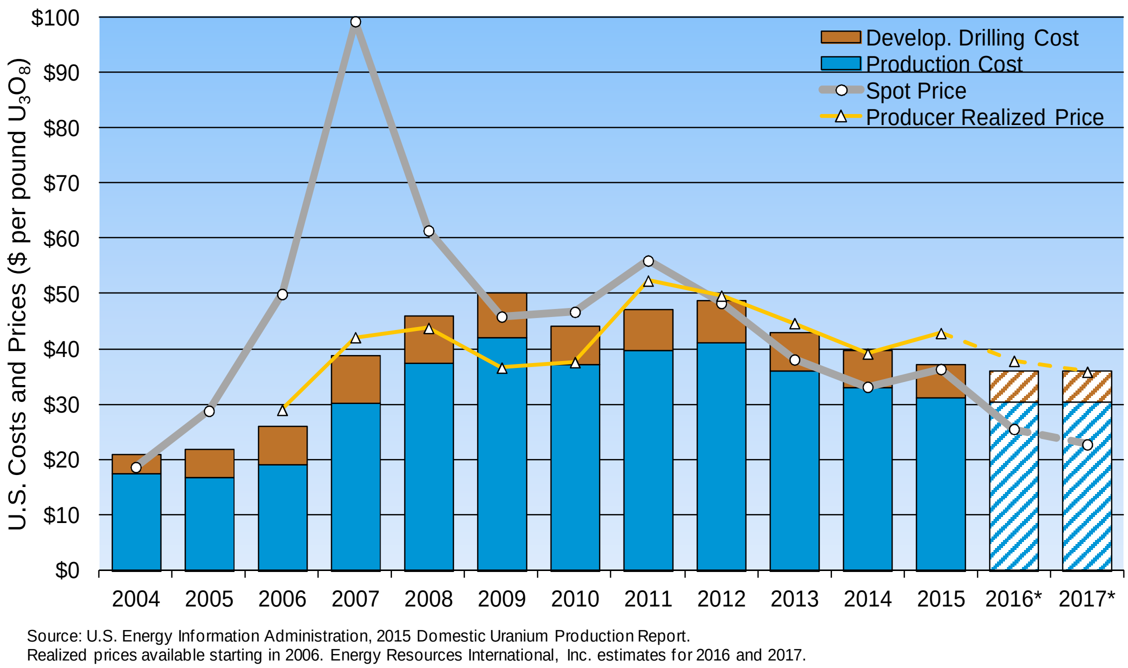


Figure 4.26 Average Production + Development Drilling Costs for U.S. Uranium Industry

Some of the U.S. facilities employ contracting strategies which are immediately sensitive to changes in spot price. As a result, operations were cut back as prices declined to $40 per pound and below, which is consistent with the timing of decisions to cut back as shown in Figure 4.24.

The pattern of mine cutbacks shown earlier in Figure 4.24 as well as the domestic industry production costs just discussed seem to indicate that adding back the $5 per pound price effect attributed to all DOE inventory material for the Base Scenario in 2014-2016 (shown in Table 4.4 for the cumulative methodology) would not have prevented the cutbacks by U.S. producers, although it might have delayed the cutbacks at some facilities. The difference in future DOE price effects between the Base Scenario and Scenario 1 is only $1.4/lb as shown in Table 4.4. This is not enough to cause producers to ramp well field development and production activities back up.

Figure 4.26 also provides the spot market price and average U.S. producer realized price, which allows the average U.S. producer margin to be calculated. Figure 4.27 shown the average margin (price less production and development costs per pound produced) at the actual realized prices and at the then current spot price since 2004. Note that the realized prices and margins are only available starting in 2006. The large spot price margins available in 2006 and 2007 show why there was a rush to bring new properties into production. Despite the cost cutting efforts by the U.S. industry, the spot margins have been negative since 2013, and this is why "unhedged" producers selling at the spot price ramped down their operations at that time. The average realized price margins for the U.S. uranium industry have been mixed at best over the last ten years, and have been minimally positive since 2011. Producers with hedged sales portfolios which include contracts with fixed base prices have maintained a positive realized price margin, but as those contracts roll off they can only be replaced by new contracts at lower prices. As a result the realized price margin may be eliminated or go negative in 2017.

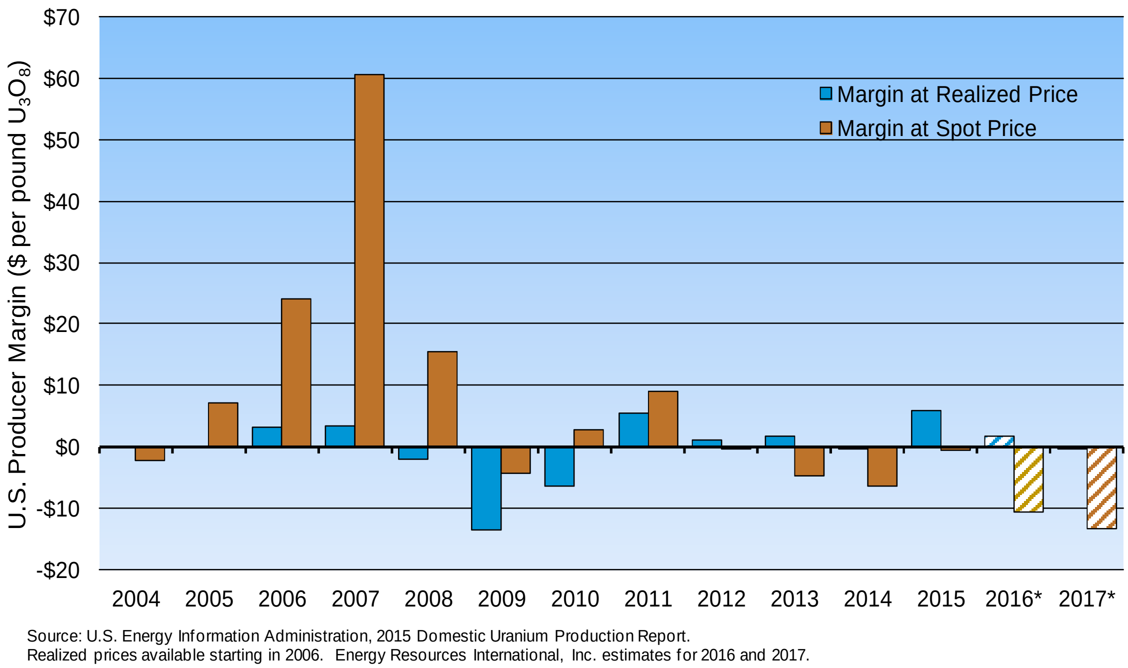


Figure 4.27 U.S. Producer Production + Development Drilling Cost Margins

The effect on realized margins of the DOE releases is estimated in Figure 4.28. The margins have been recalculated by assuming the average realized price is increased by the historical DOE price effect as calculated by both the annual and cumulative clearing price methodologies. As would be expected the removal of DOE inventory releases leads to higher margins. The realized margins would not actually have increased as much as shown since older fixed-price contracts would not have been able to take advantage. As has been noted previously, the price effect of DOE releases to date is built into current prices. The difference between the Base Scenario and Scenario 1 price effects (found in Table 4.4) is only about $1.4/lb going forward. Thus, while Figure 4.28 shows the estimated 2017 realized and spot margins if no DOE releases had taken place since 2008, the Scenario 1 margins would only improve the Base Scenario margins by about $1/lb in 2017 and later.

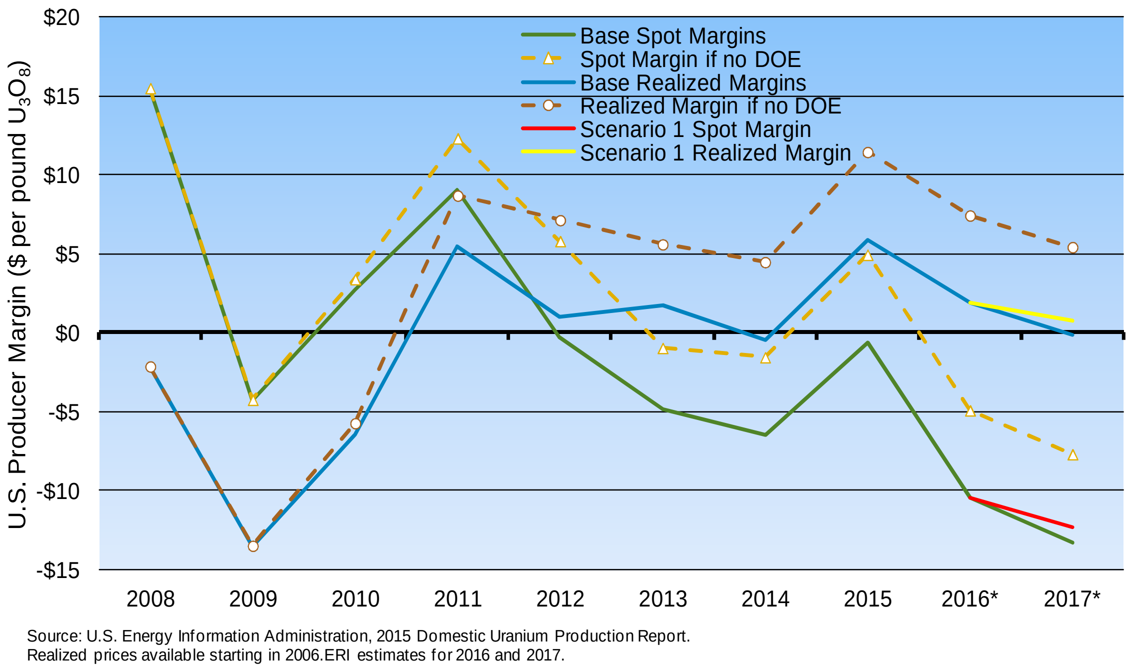


Figure 4.28 Effect on Margins of DOE Releases

4.2.2 Potential Effect on the Domestic Conversion Services Industry

As noted in Section 2.2, world requirements for uranium as UF_6 for ERI's November 2016 Reference forecast are projected to rise gradually from 57 million in 2016 to 68 million kgU by 2024. ERI projects that U.S. requirements for conversion services will remain essentially unchanged from 2016 through 2024, averaging 17 million kgU per year.

Comparing ERI's November 2016 forecast to its forecast from June 2011 shows the worldwide decline in projected requirements since the March 2011 accident at Fukushima Daiichi as shown in Figure 4.29. ERI's June 2011 forecast estimated that conversion services requirements for the period 2017 and 2018 would be approximately 74 million kgU annually, increasing to approximately 85 million kgU by 2024. In comparison, ERI's November 2016 forecast estimates that conversion requirements in 2017 and 2018 will be 59 million kgU, a decrease of 21% over ERI's 2011 forecast. While projected requirements are expected to increase in requirements to 68 million kgU by 2024, this is still 20% lower than projected in 2011, following the March 2011 Fukushima accident in Japan.

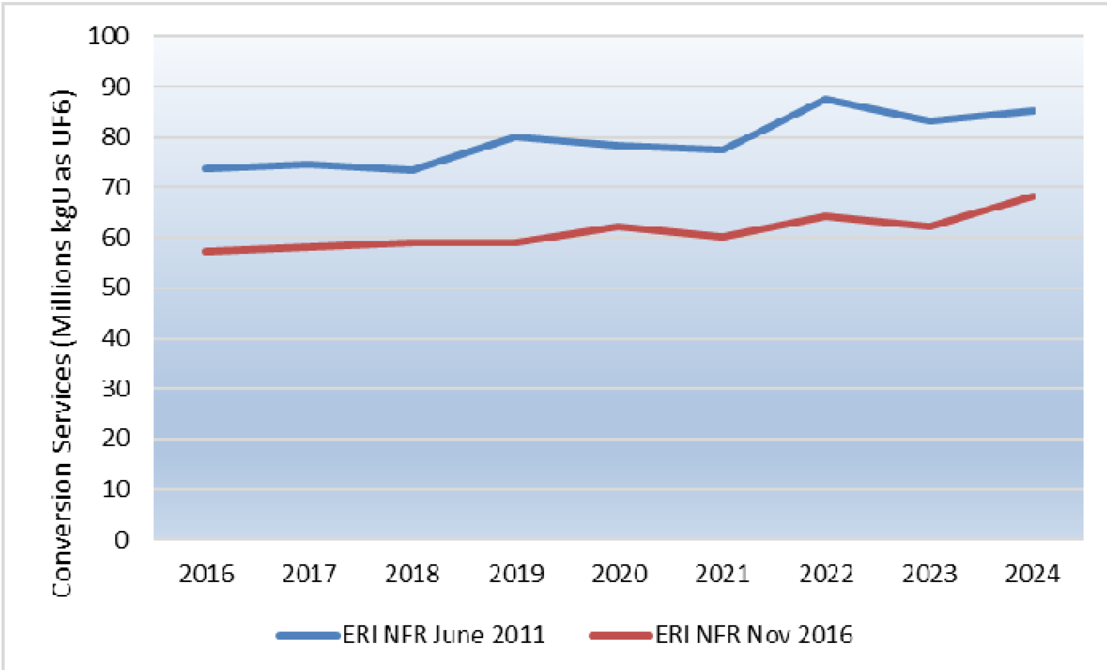


Figure 4.29 Comparison of ERI Forecast of Conversion Services, June 2011 to November 2016

The loss of conversion sales volume due to lower demand following the shutdown of nuclear reactors in Japan and Germany is estimated to be 9.5 million kgU of UF_6, meaning 2016 world conversion requirements were 14% lower than they would have been without the shutdowns. Even with the restart of several Japanese reactors over the past year, demand for conversion services in Japan is not expected to increase in the near term since Japanese utilities have substantial inventories that have built up over the period that plants have be shut down. In the U.S., six units (5 GWe) were retired in 2013-2016, representing approximately 0.9 million kgU in requirements. An additional nine units, including the already planned early shut down of Oyster Creek, are expected to shutdown prematurely in the U.S. by 2025 although a number of additional plants are considered to be at risk. The additional U.S. retirements are due to unfavorable economics, driven by natural gas prices, subsidies for wind power and capacity price structure in some deregulated markets. These additional early closures will be offset somewhat by four new units (4.4 GWe) being commissioned between 2019 and 2021.

As noted in the February 2015 ERI market analysis, it is also recognized that the greater the amount of secondary supply that is available to owners and operators of nuclear power plants to meet their operating requirements, particularly at the lower spot market prices, would have the potential of reducing contracting volumes under the higher-priced term contracts. In addition to changes in world requirements for conversion services, there has been a marked change in contracting for conversion services over the past five years, with lower volumes of contracting under both long-term and spot market purchases. This was demonstrated in a recent presentation at an industry conference by an official from Cameco, who noted changes in contracting volumes from 2005 through 2016.[66] During the past four years, contracting for conversion under either spot-market or long-term contracts was less than 20 million kgU as UF_6, or only 35% of world requirements. In contrast, during the prior four years (2009 to 2012), contracting volumes were approximately 48 million kgU, or 85% of world requirements. Thus, primary converters, including ConverDyn, continue to be unable to maintain contracted backlog, as new sales have been well below annual deliveries during the past four years.

In response to a 2016 DOE Request for Information, ConverDyn officials have noted that continued DOE transfers would "continue to depress prices and, more importantly, displace sales… DOE transfer will displace a substantial percentage of ConverDyn's sales. This results in lost sales proceeds, underutilization of MTW [Metropolis Works], and increased unit production costs."[67] As analyzed in more detail below, ERI examines the potential loss of sales/production volume for ConverDyn and increased unit production costs associated with loss of production volume, which is associated with the entry of DOE material into the conversion market under the four scenarios described in Section 3.

Analysis of Sales Volume Effect

Conversion services (or UF_6) from the four primary world producers, as well as secondary market material from brokers and traders, make up U.S. supply. The conversion component may also be provided as part of enriched uranium product (EUP), whether from a fully integrated enricher or from an enricher underfeeding.

ConverDyn does not publish its annual production volumes of UF_6. However, in a declaration by a ConverDyn official in support of litigation against DOE (*ConverDyn v. U.S. DOE*) regarding the release of DOE inventory into the U.S. market,[68] ConverDyn noted that over the past five years, its sales have ranged between 6.5 and 11 million kgU annually and Metropolis Works' production has been between 4.5 million and 11 million kgU annually.

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[66] Gabruch, Tim, Vice President, Marketing, Cameco, Unique Challenges in a Unique Market, NEI International Uranium Fuel Seminar, Naples, FL, October 19, 2016, Slide 4. http://www.nei.org/Conferences/Conference-Archives/International-Uranium-Fuel-Seminar-Archives

[67] Critchley, Malcolm, President and CEO, ConverDyn, to Cheryl Moss Herman, U.S. DOE, Subject: Excess Uranium Management: Effects of DOE Transfers of Excess Uranium on Domestic Uranium Mining, Conversion and Enrichment Industries; Request for Information – 81 Fed. Reg. 46917 (July 19, 2016), dated September 19, 2016, (Critchley 2016) at Enclosure 1, p. 4.

[68] Critchley, Malcolm, President and CEO, ConverDyn, Supplemental Declaration of Malcolm Critchley, ConverDyn, Plaintiff, v. Ernest J. Moniz, in his official capacity as Secretary of the U.S. Department of Energy and U.S. Department of Energy, Defendants, Case No. 1:14-cv-1012-RBW, United States District Court for the District of Columbia, Document 21-2, Filed July 14, 2014 (Critchley Declaration).

Based on information presented in the redacted version of DOE's May 1, 2015 analysis that supported the 2015 Secretarial Determination, ERI is able to estimate that ConverDyn's production volume in 2015 was approximately 10 million kgU.[69] This is also consistent with an estimate of 2016 conversion production from a recent presentation at an industry conference by an official from Cameco, who estimated 2016 production volumes from the primary converters.[70] In this presentation, total 2016 production was estimated to be approximately 39 million kgU with ConverDyn production estimated at approximately 10 million kgU. This estimated Metropolis Works annual production of 10 million kgU is higher than assumed in ERI's February 2015 report, in which ERI assumed a post-Fukushima production volume of 8.5 million kgU. As noted by DOE in its May 1, 2015 analysis regarding ERI's 8.5 million kgU production volume at Metropolis Works, DOE stated that "based on other available information, DOE believes that both sales and production at MTW are significantly higher."[71] While the nameplate capacity of Metropolis Works is 15 million kgU as UF_6,[72] for the purposes of analyzing the potential loss of sales volume to ConverDyn associated with the introduction of DOE inventory into the market, ERI utilizes an estimated production volume of 10 million kgU at Metropolis Works based the new information described above.

In order to illustrate the effect on the conversion market associated with entry of DOE inventory, ERI analyzes the effect of the entry of planned DOE inventories into the market under four scenarios previously described in Table 3.8, Total Equivalent Net MTU Affecting the Conversion Market. As the volume of DOE material entering the market in 2018 is somewhat higher than that expected to enter the market in 2017 (due to previously released material associated with ENW DUF_6) ERI analyses the effect on the conversion market associated with the DOE inventory entering the market in 2018 as these effects will bound those associated with DOE inventory entering the market in 2017.

Specifically, in 2018:

- Base Scenario: 2.4 million kgU
- Scenario 1: 0.8 million kgU
- Scenario 2: 2.0 million kgU
- Scenario 3: 2.8 million kgU

[69] U.S. DOE, Analysis of Potential Impacts of Uranium Transfers on the Domestic Uranium Mining, Conversion, and Enrichment Industries, May 1, 2015 (DOE 2015), at pp. 82-83.

[70] Gabruch, Tim, Vice President, Marketing, Cameco, Unique Challenges in a Unique Market, NEI International Uranium Fuel Seminar, Naples, FL, October 19, 2016, Slide 7. http://www.nei.org/Conferences/Conference-Archives/International-Uranium-Fuel-Seminar-Archives

[71] DOE 2015, at p. 82.

[72] Mani, Ganpat, ConverDyn, President and CEO, ConverDyn and Uranium Conversion, presented to the U.S. Nuclear Infrastructure Council, April 20, 2010; http://www.converdyn.com/press_room/pdf/presentations/US%20NIC%20Intro%20to%20CvD%20and%20Conv%20April%202010%20Final%20pdf.pdf

In all four scenarios, the quantities of DOE inventory affecting the conversion market in 2018 bound the average DOE quantities in 2019 to 2026. Under the Base Scenario, the DOE inventory that will enter the market in 2018 includes: 0.50 million kgU from allocated down blended HEU by NNSA, 1.6 million kgU associated with EM transfer material to support GDP cleanup, and 0.3 million kgU associated with UF_6 from prior transfer of DUF_6 to ENW by DOE, as shown in Table 4.10. Under Scenario 1, the DOE inventory that will enter the market in 2018 includes: 0.5 million kgU from allocated down blended HEU and 0.3 million kgU associated with UF_6 from prior transfer of DUF_6 to ENW by DOE. Under Scenario 2, the DOE inventory that will enter the market in 2018 includes: 0.5 million kgU from allocated down blended HEU, 1.2 million kgU associated with EM transfer material to support GDP cleanup, and 0.3 million kgU associated with UF_6 from prior transfer of DUF_6 to ENW by DOE. Under Scenario 3, the DOE inventory that will enter the market in 2018 includes: 0.5 million kgU from allocated down blended HEU, 2.0 million kgU associated with EM transfer material to support GDP cleanup, and 0.3 million kgU associated with UF_6 from prior transfer of DUF_6 to ENW by DOE. For the purpose of this analysis, ERI assumes that 100% of the allocated down blended HEU, and 100% of the UF_6 associated with prior transfer of DUF_6 to ENW will enter the U.S. market.

As noted in Section 3.2, Traxys has a contract with FBP to purchase UF_6 transferred to FBP by EM (EM Transfer material). The Traxys goal in the sale of the EM Transfer material it to sell at least 50% of the material to non-U.S. customers. It should be noted that Traxys has reported that in 2013, an estimated 1 million kgU of the conversion component of the EM Transfer material was delivered to U.S. utilities, or approximately 42% of conversion component in the EM Transfer material.[73] ERI is not aware of any more recent data from Traxys regarding sales figures into the U.S. market in 2014 or 2015. Since there is no guarantee that this same percentage of sales of EM Transfer material will be made in 2017 or later, in this analysis, ERI conservatively assumes that 50% of the EM Transfer material enters the U.S. market and 50% enters the remaining world market in 2017 and beyond, as stated by Traxys as its goal. Under the Base Scenario, out of the total of 2.4 million kgU of DOE inventory expected to affect the market in 2018, an estimated 1.6 million kgU, or 67% is expected to be sold into the U.S. market and 0.8 million kgU, or 33% is expected to be sold into the remaining world market as summarized in Table 4.10.

[73] Smith, Kevin P., Traxys North America LLC, Managing Director for Uranium Marketing and Trading, Declaration of Kevin P. Smith, Attachment 6 to Defendant's Opposition to Plaintiff's Motion for Preliminary Injunction, Case No. 1:14-cv-1012-RBW, Document 17-7, Filed July 7, 2014, at 7-12.

Material Description	Base Scenario				
	2018 Annual Quantity (Million kgU)	Volume to U.S. Market		Remaining Volume to World Market	
		%	Quantity	%	Quantity
Allocated HEU Downblend	0.50	100%	0.50	0%	0.00
EM Transfers for GDP Cleanup Services	1.60	50%	0.80	50%	0.80
Off-Spec HEU Downblend - TVA	0.00	100%	0.00	0%	0.00
ENW DUF6	0.30	100%	0.30	0%	0.00
Total	2.40	67%	1.60	33%	0.80
	Scenario 1				
Allocated HEU Downblend	0.50	100%	0.50	0%	0.00
EM Transfers for GDP Cleanup Services	0.00	50%	0.00	50%	0.00
Off-Spec HEU Downblend - TVA	0.00	100%	0.00	0%	0.00
ENW DUF6	0.30	100%	0.30	0%	0.00
Total	0.80	100%	0.80	0%	0.00
	Scenario 2				
Allocated HEU Downblend	0.50	100%	0.50	0%	0.00
EM Transfers for GDP Cleanup Services	1.20	50%	0.60	50%	0.60
Off-Spec HEU Downblend - TVA	0.00	100%	0.00	0%	0.00
ENW DUF6	0.30	100%	0.30	0%	0.00
Total	2.00	70%	1.40	30%	0.60
	Scenario 3				
Allocated HEU Downblend	0.50	100%	0.50	0%	0.00
EM Transfers for GDP Cleanup Services	2.00	50%	1.00	50%	1.00
Off-Spec HEU Downblend - TVA	0.00	100%	0.00	0%	0.00
ENW DUF6	0.30	100%	0.30	0%	0.00
Total	2.80	64%	1.80	36%	1.00

NOTE: Numbers may not add exactly due to rounding.

Table 4.10 Summary of DOE Inventory Expected to Affect the Conversion Market in 2018

As shown in Table 4.11, world requirements for conversion services as UF_6 in 2010, prior to the 2011 accident at Fukushima Daiichi in Japan, were approximately 60.3 million kgU.

Under Scenario 1, a total of 0.8 million kgU (100%) is expected to affect the U.S. market in 2018. Under Scenario 2, a total of 1.40 million kgU (68%) is expected to affect the U.S. market and 0.60 million kgU, or 32% is expected to be sold into the remaining world market. Under Scenario 3, a total of 1.80 million kgU (66%) is expected to affect the U.S. market and 0.95 million kgU, or 34% is expected to be sold into the remaining world market.

In 2010, U.S. requirements were 19.2 million kgU and requirements in Japan and Germany were 7 million kgU and 2.5 million kgU, respectively. Requirements in China and Russia in 2010 were 3.9 million kgU and 6.7 million kgU respectively. According to ConverDyn statements, it does not have access to the markets in Russia and China. If conversion services requirements for CIS/Eastern Europe (EE)[74] and China are removed from total world requirements[75], the remaining world requirements in 2010 were 49.7 million kgU. Total annual world demand for conversion services in 2017 and 2018 is estimated to average 58.7 million kgU annually. Taking into account the reduced demand for uranium in Germany (1.2 million kgU) and Japan (2.4 million kgU) and the increased demand for China (8.3 million kgU) and CIS/EE (8.8 million kgU), the remaining world requirements are estimated to be an average of 41.6 million kgU annually in 2017 and 2018. U.S. requirements in 2017 and 2018 are estimated to average 17.4 million kgU annually.

Regional Market	2010	2017-2018 Average Annual Requirements
World	60.3	58.7
U.S.	19.2	17.4
Japan	7.0	2.4
Germany	2.5	1.2
China	3.9	8.3
CIS/Eastern Europe (EE)	6.7	8.8
Remaining World (World less CIS/EE and China)	49.7	41.6

Table 4.11 World and Regional Requirements for Conversion Services (Million kgU as UF_6) in 2010 and 2017-2018

ConverDyn does not publish information regarding its share of the world market for conversion services (U.S., Europe, Asia, etc.) In a declaration in *ConverDyn v. U.S. DOE*,

[74] CIS is the Commonwealth of Independent States. Russia, Ukraine and Armenia are among its members. EE is Eastern Europe and includes Bulgaria, Czech Republic, Hungary, Romania and Slovakia.

[75] To be conservative demand from Ukraine and the Czech Republic was removed even though those markets now appear to be accessible.

ConverDyn noted that its share of U.S. demand was 25%.[76] In this analysis ERI will utilize ConverDyn's stated U.S. market share of 25%. Assuming a 25% ConverDyn share in U.S. market results in a U.S. sales volume of 4.35 million kgU (17.4 million kgU * 25%) in 2017/2018. If ConverDyn's 2017/2018 sales volume is 10 million kgU, this means that 5.7 million kgU are allocated to the remaining world market minus the U.S. market (41.6 million kgU – 17.4 million kgU), or an estimated 24% market share as shown in Table 4.12.

ConverDyn Market Share Assumption	ConverDyn Share of Market Share		Market Volume Impact to ConverDyn (million kgU)			ConverDyn Volume (million kgU)	
	US	Remaining World (1)	US	Remaining World	Total	With DOE Inventory	Without DOE Inventory
	%	%					
Base Scenario	25.0%	23.6%	0.4	0.2	0.6	10.0	10.6
Scenario 1	26.1%	24.4%	0.2	0.0	0.2	10.4	10.6
Scenario 2	25.3%	23.8%	0.4	0.1	0.5	10.1	10.6
Scenario 3	24.7%	23.4%	0.4	0.2	0.7	9.9	10.6

Note (1): For purposes of the calculation of ConverDyn's share of World market, ERI assumes World Market of 41.2 million kgU as UF6 (World market minus CIS/EE and China)

Note (2) : In the Base Scenario, U.S. market share of 25% is based on prior statements by ConverDyn officials. Calculations assume 2016 production volume of 10 million kgU. Remaining World Market Share (minus CIS/EE and China requirements) =[10 -(4.35 m kgU: US market)] / [41.3 (World Market - CIS/EE/China) - 17.4 (US market)]

Note (3): In Scenario 1, due to removal of DOE inventory in the U.S. and/or World markets compared to the volumes assumed in the Base Scenario, ConverDyn's percent of US and Remaining World markets is somewhat higher than in the Base Scenario. The analysis assumes that ConverDyn secures a portion of sales associated with the lower DOE inventory volumes entering the market in Scenario 1.

Note (4): In Scenario 2, due to removal of DOE inventory in the U.S. and/or World markets compared to the volumes assumed in the Base Scenario, ConverDyn's percent of US and Remaining World markets is slightly higher than in the Base Scenario. The analysis assumes that ConverDyn secures a portion of sales associated with the lower DOE inventory volumes entering the market in Scenario 2.

Note (5): In Scenarios 3, due to additional of DOE inventory in the U.S. market compared to the volumes assumed in the Base Scenario, ConverDyn's percent of US and Remaining World markets is slightly lower than in the Base Scenario. This assumes an additional market volume impact compared to the Base Scenario.

Note (6): Totals may not add exactly due to rounding.

Table 4.12 Effect on ConverDyn Market Volume Associated with Introduction of DOE Inventory into the Market in 2018, Assuming Pre-Fukushima Sales Volume of 11 Million kgU as UF_6

Applying ConverDyn's U.S. market share of 25% and the remaining world market share of 24% to the volume of DOE inventory expected to be introduced into the market in 2018 from Table 4.11, results in a volume effect of 0.4 million kgU in the U.S. market and 0.2

[76] Critchley, Malcolm, President and CEO, ConverDyn, Declaration of Malcolm Critchley, ConverDyn, Plaintiff, v. Ernest J. Moniz, in his official capacity as Secretary of the U.S. Department of Energy and U.S. Department of Energy, Defendants, Case No. 1:14-cv-1012-RBW, United States District Court for the District of Columbia, Document 7-3, Filed June 23, 2014.

million kgU effect in the remaining world market for a total of 0.6 million kgU, under the Base Scenario. As discussed above, assuming that ConverDyn's production volume is 10 million kgU, ConverDyn's market volume without the introduction of DOE inventory to the market would be 10.6 million kgU as UF_6 as shown in Table 4.12. This analysis assumes that the Base Scenario "ConverDyn Volume, Without DOE Inventory", or 10.6 million kgU annually, is the baseline ConverDyn Volume for the purpose of calculating ConverDyn Volumes "With DOE Inventory" for Scenarios 1, 2 and 3. The DOE inventory volumes that would enter the 2018 market in Scenarios 1 and 2 are lower than that for the Base Scenario, therefore, ConverDyn's sales volume With DOE Inventory would be higher than the Base Scenario volume, as shown in Table 4.12. Likewise because DOE inventory volumes that would enter the market in Scenario 3 are higher than that for the Base Scenario, ConverDyn's sales volume With DOE Inventory is lower than the Base Scenario volume.

In Scenario 1, DOE inventory entering the market is 1.6 million kgU less than the Base Scenario (0.8 million kgU less in the U.S. market and 0.8 million kgU less in the remaining world market). Assuming that ConverDyn captures similar market share of this material (25% of additional U.S. material and 24% of additional Remaining World material), results in a 26% U.S. market share and a 24% Remaining World market share), as shown in Table 4.12. Applying the Scenario 1 ConverDyn U.S. market share (26%) and the Remaining World market share (24%) to the volume of DOE inventory expected to be introduced into the market in 2018 from Table 4.10, results in a volume effect of 0.2 million kgU in the U.S. market. As discussed above, assuming that ConverDyn's sales volume Without DOE Inventory is 10.6 million kgU, results in a calculated ConverDyn sales volume With DOE Inventory of 10.4 million kgU for Scenario 1.

In Scenario 2, DOE inventory entering the market is 0.4 million kgU less than the Base Scenario (0.2 million kgU less in the U.S. market and 0.2 million kgU less in the remaining world market). Assuming that ConverDyn captures similar market share of this additional material as assumed in the Base Scenario, results in no real change in ConverDyn's U.S. market share (25%) and Remaining World market share (24%). Applying the Scenario 2 ConverDyn U.S. market share (25%) and the Remaining World market share (24%) to the volume of DOE inventory expected to be introduced into the market in 2018 from Table 4.10, results in a volume effect of 0.4 million kgU in the U.S. market and 0.1 million kgU effect in the remaining world market for a total of 0.5 million kgU. As discussed above, assuming that ConverDyn's sales volume Without DOE Inventory is 10.6 million kgU, results in a calculated ConverDyn sales volume With DOE Inventory of 10.1 million kgU for Scenario 2.

A similar calculation was conducted for the volumes of DOE material entering the market in 2018 under Scenario 3 in order to calculate ConverDyn's slightly higher effective market shares – 25% of U.S. market and 23% of Remaining World market. Applying these percentages to the volume of DOE inventory expected to be introduced into the market in 2018 for Scenario 3 from Table 4.10, results in a volume effect of 0.4 million kgU in the

U.S. market and 0.2 million kgU in the remaining world market for a total of 0.7 million kgU[77]. As discussed above, assuming that ConverDyn's sales volume Without DOE Inventory is 10.6 million kgU, results in a calculated ConverDyn sales volume With DOE Inventory of 9.9 million kgU for Scenario 3.

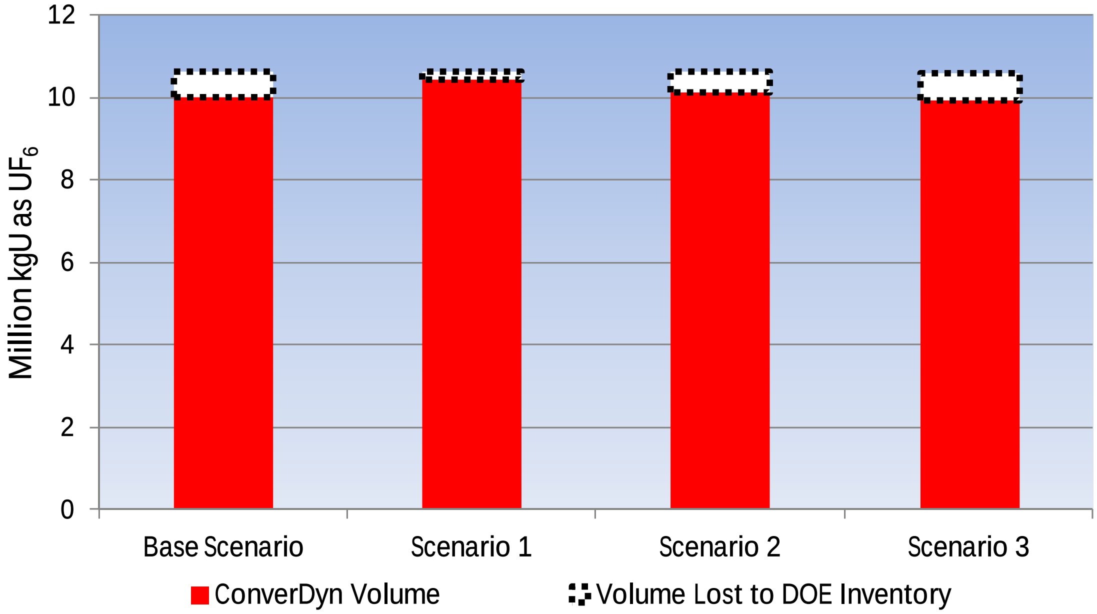

Figure 4.30 Estimated ConverDyn Sales Volume and DOE Effect in 2018

As shown in Figure 4.30 in the Base Scenario, assuming that ConverDyn's U.S. market share is 25%, the introduction of DOE inventory into the conversion market results in a volume effect of 5.6%. In Scenario 1, in which UF_6 associated with prior releases of DUF_6 to ENW enter the market, assuming a ConverDyn U.S. market share of 26%, the introduction of DOE inventory results in a volume effect of just 2.0%. The introduction of DOE inventory into the conversion market results in a volume effect of 4.7% in Scenario 2 and 6.4% in Scenario 3.

As shown in Table 4.10, the quantity of DOE inventory expected to affect the commercial market in 2018 is 2.4 million kgU under the Base Scenario. Total secondary market supplies in 2018 are expected to be approximately 15 million kgU. As discussed in more detail in Section 4.3.2, ConverDyn's sales volume is also affected by the presence of these other market factors, including other secondary market supply sources. However, this report only assesses the effect of DOE inventory on U.S. conversion sales volume.

[77] Sum of U.S. and remaining world volume effects differ from total due to rounding.

Analysis of Effect on Production Cost for Conversion Services

As analyzed above, ERI calculates that the volume effect to ConverDyn would be 0.6 million kgU under the Base Scenario, 0.2 million kgU under Scenario 1, 0.5 million kgU under Scenario 2, and 0.7 million kgU under Scenario 3, assuming a ConverDyn production volume of 10 million kgU. In order to analyze the effect of this decrease in sales volume on the unit cost of production, it is necessary to make assumptions regarding the percent of production costs that are fixed and variable. Conversion facilities have high fixed costs, so ERI conservatively assumed 80% are fixed in order to determine the effect on production costs on a $/kgU basis.

As shown in Table 4.12, assuming that ConverDyn's production volume is 10 million kgU, if DOE inventory was not introduced into the market, the volume in 2018 would be 10.6 million kgU. If the effective production cost to produce 10.6 million kgU is $15.0 per kgU, with a sales price of $14.0/kgU (because the Metropolis Works is operating at a loss), the total sales revenue would be $148 million and production costs would be $159 million - a loss of $11 million for a ConverDyn sales volume of 10.6 million kgU.

As shown in Table 4.13, under the Base Scenario, if fixed costs were 80% of the cost of production, a reduction of production volume from 10.6 to 10 million kgU would result in an increased cost of production of $0.7 per kgU as UF_6. A production volume of 10.6 million kgU would have fixed costs of $127.2 million and variable costs of $31.8 million, with total costs of $159 million or $15.0 per kgU. A production volume of 10 million kgU would have fixed costs of $127.2 million (the same as the 10.6 million kgU production) and variable costs of $30 million for total production costs of $157.2 million or $15.7 per kgU. Thus there would be an approximate $0.7/kgU or 5% increase in production costs.

Similarly, under Scenario 1, a reduction in sales volume from 10.6 million kgU to 10.4 million kgU would result in increased production costs of $0.2/kgU or a 1% increase. Under Scenario 2, a reduction in sales volume from 10.6 million kgU to 10.1 million kgU would result in increased production costs of $0.6/kgU or a 4% increase. Under Scenario 3, a reduction in sales volume from 10.6 million kgU to 9.9 million kgU would result in increased production costs of $0.8/kgU or a 5% increase as shown in Table 4.13.

		Fixed Cost	Variable Cost	Total Cost of Production	Unit Cost ($/kgU)
Base Scenario					
		80%	20%		
Production Cost Components		$ 12.00	$ 3.00		$ 15.00
Production Volume		Production Costs ($ Millions)			
- without DOE sales	10.6	$ 127.2	$ 31.8	$ 159.0	$ 15.00
- with DOE sales	10.0	$ 127.2	$ 30.0	$ 157.2	$ 15.70
Increased production cost					$ 0.70
Scenario 1					
		80%	20%		
Production Cost Components		$ 12.00	$ 3.00		$ 15.00
Production Volume		Production Costs ($ Millions)			
- without DOE sales	10.6	$ 127.2	$ 31.8	$ 159.0	$ 15.00
- with DOE sales	10.4	$ 127.2	$ 31.2	$ 158.4	$ 15.20
Increased production cost					$ 0.20
Scenario 2					
		80%	20%		
Production Cost Components		$ 12.00	$ 3.00		$ 15.00
Production Volume		Production Costs ($ Millions)			
- without DOE sales	10.6	$ 127.2	$ 31.8	$ 158.9	$ 15.00
- with DOE sales	10.1	$ 127.2	$ 30.3	$ 157.5	$ 15.60
Increased production cost					$ 0.60
Scenario 3					
		80%	20%		
Production Cost Components		$ 12.00	$ 3.00		$ 15.00
Production Volume		Production Costs ($ Millions)			
- without DOE sales	10.6	$ 126.9	$ 31.7	$ 158.7	$ 15.00
- with DOE sales	9.9	$ 126.9	$ 29.7	$ 156.6	$ 15.80
Increased production cost					$ 0.80

Note: Numbers may not add exactly due to rounding.

Table 4.13 Change in Production Cost for UF_6 Due to Decreased ConverDyn Sales Volume Associated with Introduction of DOE Inventory into Market

Summarizing, under the Base Scenario, production costs would increase by 5% (80% fixed costs; Scenario 1 production costs would increase by 1%; Scenario 2 production costs would increase by 4%; and Scenario 3 production costs would increase by 5%. The production cost increase of an estimated 1% to 5% would be in addition to the decrease in market clearing prices associated with the introduction of the DOE inventory into the market as discussed in Section 4.1.

Reduction in Workforce Associated with Volume Reduction

In the February 2015 ERI market analysis, ERI utilized staffing levels that were announced at Metropolis works when the plant restarted in Summer 2013 after an extended shutdown - with total staffing of approximately 270 employees.[78] According to Metropolis Works management, following the 2013 startup, the staffing levels would be lower than in the past to reflect "current market demand and UF_6 volumes required by our customers." Prior to the 2012-2013 temporary shutdown of Metropolis Works for seismic upgrades, the work force was approximately 334.[79] Therefore, the 270 employees that would staff the plant after it returned to production in 2013 were 80% of the pre-shutdown workforce. Based on these figures, there is some correlation of work force size to long-term production volume – thus it is unlikely that 100% of the cost of production at Metropolis Works is fixed. The cost of fluorine is variable as well.

In January 2017, Honeywell announced a planned staffing reduction through layoffs of 22 full-time equivalent (FTE) employees as well as reduction of contractor staffing. Certain news stories included a summary of Metropolis works staffing levels in January 2017 prior to the announced staffing reduction – a total of 106 hourly FTE, 136 salaried FTE and 133 contractor FTE. This results in 242 FTE in 2017 compared to the 270 FTE following the 2013 restart, a reduction of 28 FTE. However, it should be noted that some of this reduction may have been offset by an increase in contractor FTE. Because the number of 2013 contractor FTE is not known to ERI, ERI will rely on the 242 FTE for Metropolis works staffing in 2017.

Using this new employee information, ERI assumes that the staffing levels remain at 242 employees with an annual production rate of 10 million kgU. If one assumes that staffing is proportional to the annual production rate (which is unlikely), then for every 100,000 kgU reduction in annual production, there would be a 2.4 full-time equivalent (FTE) loss in staff. Thus, under the Base Case there is a reduction of 0.6 million kgU of production volume attributed to DOE sales, which results in a 14 FTE loss. Under Scenario 1, a 0.2 million reduction in production volume results in a 5 FTE loss; under Scenario 2, the 0.5 million kgU reduction would result in a 12 FTE loss; and a 0.7 million kgU reduction in production under Scenario 3 would result in a 17 FTE loss. As noted above, it is unlikely that staffing is directly proportional to production volume, thus, the staffing reductions estimated above are conservative. Still, a portion of the reduction in work force at ConverDyn may be associated with the introduction of DOE inventory into the market. However, reductions in reactor demand in Japan, Europe and the U.S., and other secondary supply sources such as enricher underfeeding, upgrade of tails in Russia, and Russian HEU

[78] Smith, Larry, Plant Manager, Metropolis Works, Honeywell, Letter to Employees, April 15, 2013. http://www.honeywell-metropolisworks.com/?document=apr-15-2013-letter-to-employees-3&download=1

[79] Smith, Larry, Plant Manager, Metropolis Works, Honeywell, Letter to Employees, July 19, 2012. http://www.honeywell-metropolisworks.com/?document=jul-19-2012-letter-to-employees&download=1

feed would also be factors that impact ConverDyn's market share, production volumes and staffing levels.

4.2.3 Potential Effect on the Domestic Enrichment Services Industry

As discussed in Section 2, the enrichment market remains in an oversupply situation. There are two U.S.-based enrichment suppliers – Urenco USA and Centrus (formerly USEC Inc.). As shown in Table 3.9, the total equivalent net million SWU that will enter the market due to transfers of DOE inventory average 0.4 million SWU per year over the period 2017 to 2026 under the Base Scenario, 0.26 million SWU per year under Scenario 1, 0.4 million SWU per year under Scenario 2 and 0.4 million SWU per year under Scenario 3. SWU requirements in the U.S. over the period 2017 - 2026 average 15.3 million SWU per year. DOE inventory that will enter the U.S. enrichment market during this period represents 3% of total U.S. requirements under the Base Scenario and Scenarios 2 and 3, and 2% under Scenario 1. DOE inventory would be 1% of world requirements under the Base Scenario and Scenarios 2 and 3 and 0.5% under Scenario 1 during the period 2017 to 2026.

As noted in Section 2.3, world requirements for expected to rise from 45 million SWU in 2016 to an average of 52 million SWU per year between 2018 and 2020, 58 million SWU per year between 2021 and 2025, 64 million SWU per year between 2026 and 2030, and 71 million SWU per year between 2031 and 2035. U.S. requirements are projected to be essentially flat, averaging almost 15 million SWU per year between 2016 and 2035.

Comparing ERI's November 2016 forecast to its January 2011 pre-Fukushima forecast shows the worldwide decline in projected requirements since the March 2011 accident at Fukushima Daiichi as shown in Figure 4.31. ERI's pre-Fukushima forecast estimated that enrichment services requirements for the period 2017-2019 would be approximately 56 million SWU annually, increasing to an average of 66 million SWU in 2024-2026. In comparison, ERI's November 2016 forecast estimates that enrichment requirements in 2017-2019 will average 51 million SWU, a decrease of 9% from ERI's pre-Fukushima forecast. While projected requirements are expected to increase to an average of 60 million SWU in 2024-2026, this remains 9% lower than projected prior to the March 2011 accident in Japan. The decrease in enrichment requirements has not been as large as ERI's projected decrease in conversion requirements due to changes in tails assay assumptions, which result in lower uranium feed requirements and somewhat higher enrichment requirements.

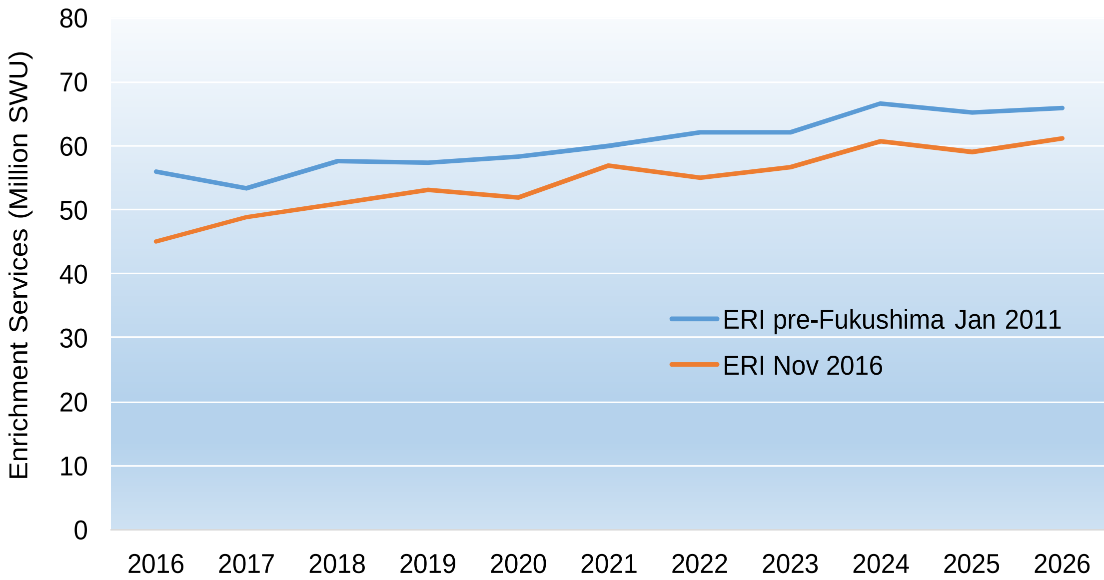

Figure 4.31 Comparison of Current and pre-Fukushima Forecasts of Enrichment Services

U.S. Enrichment Services Suppliers

Centrus does not produce enriched uranium - its sales come from current inventory, SWU purchased from other suppliers and SWU purchased under a Transitional Supply Contract (TSC) between Centrus and TENEX. Centrus is only able to deliver limited quantities of the SWU purchased from Russia into the U.S. market – the rest must be delivered to non-U.S. customers. In its 2013 10-K report[80], USEC noted that due to its fixed commitment to purchase Russian LEU under the Transitional Supply Agreement with TENEX, any reduction in purchases by the customers below the level required for the company to resell both its inventory and the Russian material could adversely affect revenues, cash flows and results of operations. In December 2015 the TSC was amended allowing Centrus to reduce its annual purchases from TENEX in exchange for extending the term of the Agreement. In its 2015 10-K[81], Centrus noted that its order book, as of December 31, 2015, was $2.3 billion compared to $2.7 billion at December 31, 2014.

In its June 30, 2016 Interim Financial Statements Urenco characterized its long-term sales backlog as €15.8 ($17.5[82]) billion, approximately €5.4 billion less than the end of 2010 peak. The actual forward volume of SWU under contract continues to decline as contracting activity has been limited in the last three years.

[80] USEC, Form 10-K, Annual Report For the fiscal year ended December 31, 2013.

[81] Centrus, Form 10-K, Annual Report for the fiscal year ended December 31, 2015.

[82] An exchange rate of 1.11$/€ was assumed by Urenco.

As with both uranium and conversion services contracting, contracting for new enrichment services has been below historical averages since 2011 following active contracting by nuclear operators to lock in long-term contracts for enrichment services in 2010 and earlier. During the period 2007 to 2010, average new commitments for enrichment services were approximately 85 million SWU per year (more than two times annual requirements). Contracting for enrichment services has been limited during the period 2011 to 2015, averaging only 23 million SWU per year (50% of annual requirements). Primary suppliers in general continue to be unable to maintain backlog, as new sales were well below deliveries made during the year and at lower prices as well.

Effects of DOE Inventory of Enrichment Market

As noted in Section 2.3, and shown in Figure 2.9, total world enrichment supply significantly exceeds projected requirements through 2026. Introduction of DOE inventory into the SWU market is estimated to have lowered market clearing prices by 8% in 2014-2016, rising to 9% in 2017-2026 for all four scenarios. While the current market is one of oversupply due to reduced near-term demand, 95% or more of enrichment services and/or EUP are typically delivered under long-term contracts. However, as discussed in Section 2.3, with the current over-supplied enrichment market both the term and spot market prices have declined considerably. The price decline in the nearly six years following Fukushima has been considerable at –66% in the term market and 71% in the spot market.

In the past, the Paducah Gaseous Diffusion Plant operated for an additional 12 months in order to enrich the higher assay depleted UF_6 that was transferred to ENW. The enrichment content of the resulting LEU is being used by TVA under a term contract with ENW. The historic DOE transfers of BLEU materials containing equivalent enrichment services to TVA have been known to the market for many years and are long-term contracts in nature.

The enrichment industry has the ability to lessen the effect of oversupply by underfeeding its plants to make use of the excess supply. Urenco has estimated that it is now using 10% to 15% of its capacity for underfeeding or re-enriching DUF_6.[83] The revenue generated by the subsequent sales of natural UF_6 can be significant when such a large fraction of capacity is used for underfeeding, although still less than normal commercial sales of enrichment services (if the customer demand was present).

[83] Presentation by Paul Harding at World Nuclear Fuel Market conference, Istanbul, June 11, 2013.

4.3 Additional Nuclear Fuel Market Considerations

4.3.1 Price Volatility

The level of price volatility in the uranium, conversion and enrichment markets may be useful when judging the importance of the price effects attributed to DOE material. Figure 4.32 examines the historical price volatility in each of the spot markets as measured by change in market price on a rolling 12-month basis. For example, the 12-month change in uranium spot market price for December 31, 2016 is -41%, found by comparing the December 31, 2016 price of $20.25/lb to the December 31, 2015 price of $34.20/lb. Figure 4.32 demonstrates the considerable price variation which has occurred in the rolling 12-month uranium and conversion spot prices since 2004. Rolling 12-month spot enrichment price changes have been smaller over the long run, but consistently negative since 2010. During the last three years (2014-2016), the rolling 12-month changes have averaged -10%, -12% and -20% for uranium, conversion and enrichment spot prices, respectively.

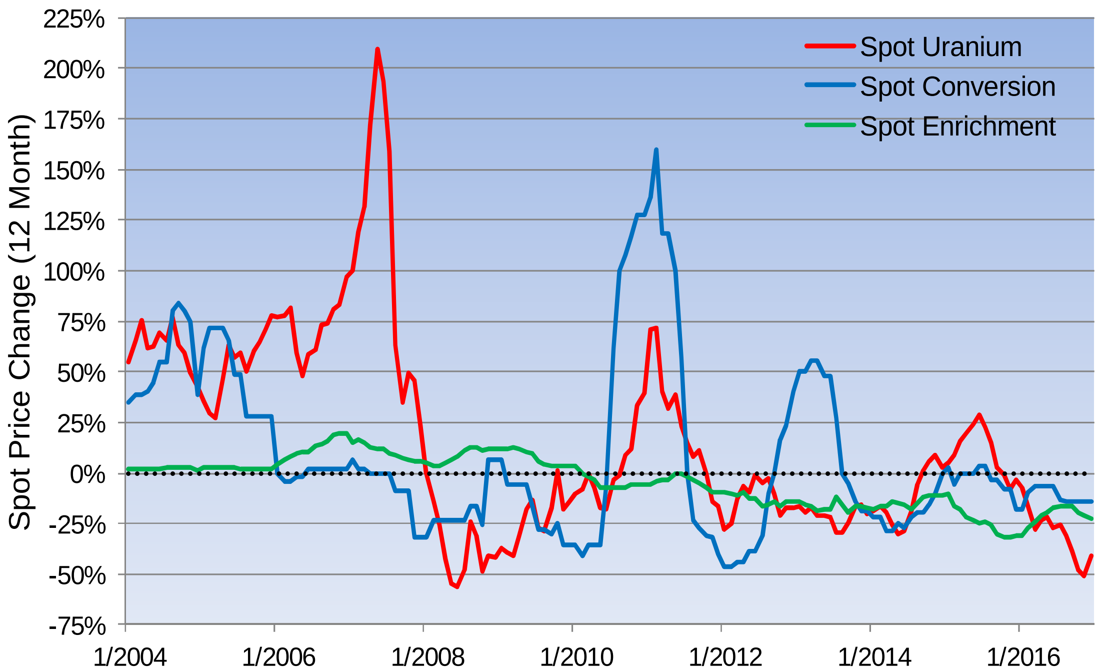

Figure 4.32 Spot Market 12 Month Price Changes

Figure 4.33 examines the historical price volatility in each of the term markets as measured by change in market price on a rolling 12-month basis. A comparison of Figures 4.32 and 4.33 shows that the term markets demonstrated much smaller rolling price changes through 2013 than did the spot markets, but are comparable over the last three years (2014-2016). As was the case with the spot market prices, the uranium and conversion term markets have demonstrated more volatility than the enrichment term market over the long term, but the three components are comparable over the past three years. During the last three years the rolling 12-month changes have averaged -10%, -8% and -19% for uranium, conversion and enrichment term prices, respectively.

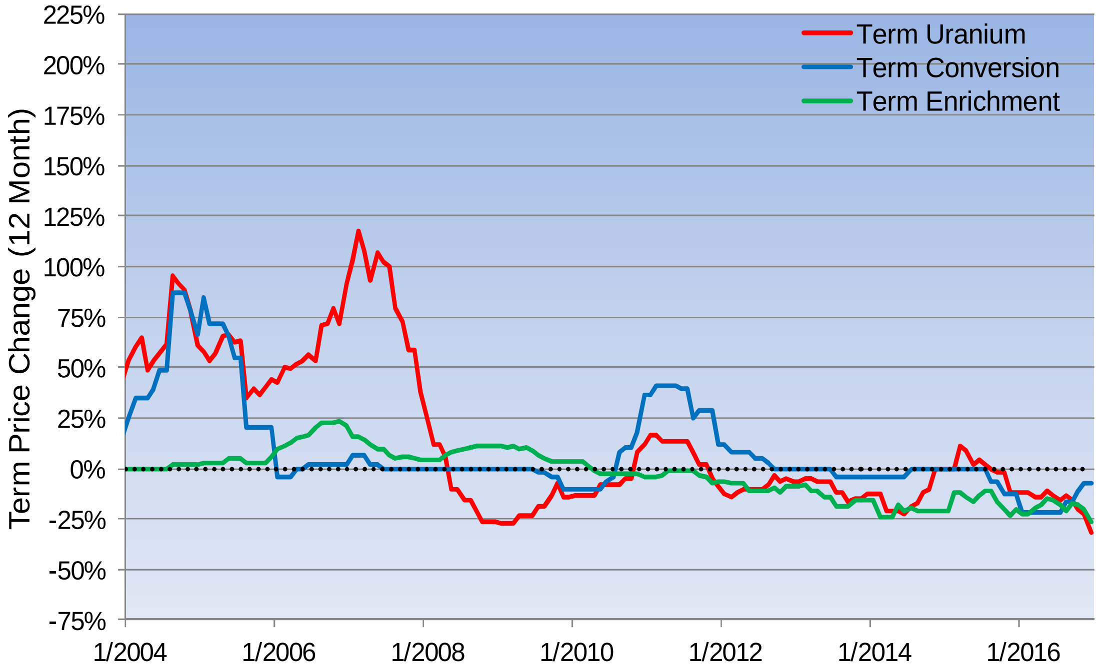

Figure 4.33 Term Market 12 Month Price Changes

The statistical measure of price volatility[86] on an annualized basis is provided for each of the spot markets in Figure 4.34 and for each of the term markets in Figure 4.35. The same general conclusions are reached: historical price volatility is noticeably higher for the uranium and conversion markets than for the enrichment market over the long term, although enrichment term price volatility has been higher and conversion term price volatility has been lower in recent years.

[86] Based on the financial definition of volatility as a measure of variability in price over time (e.g. stock price volatility). Calculated from the annualized standard deviation of monthly changes in price.

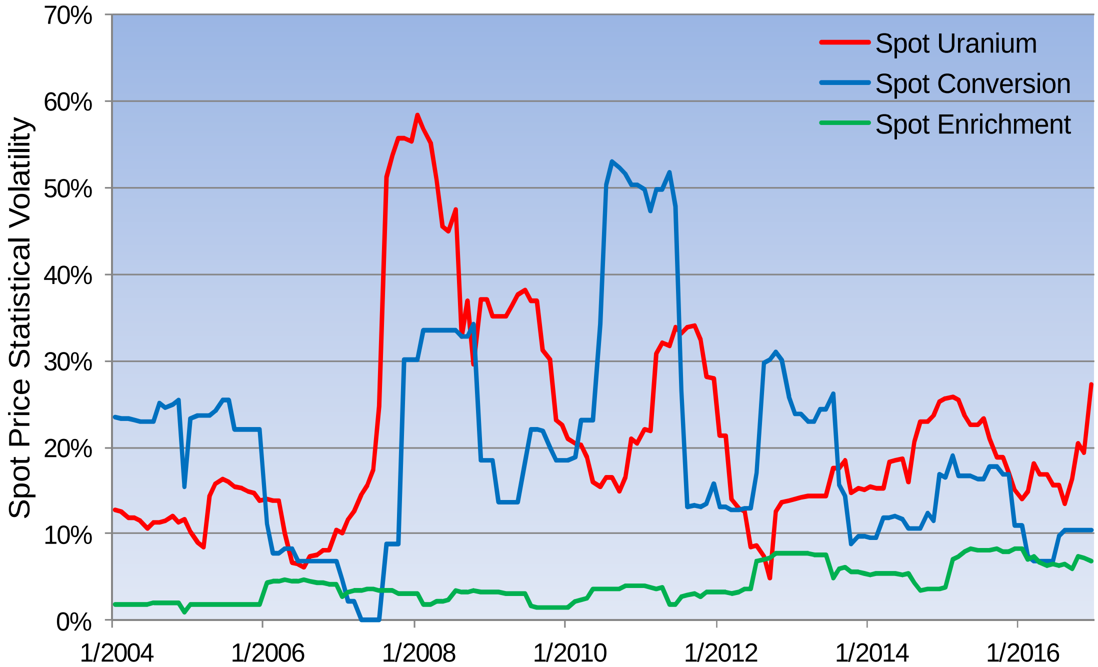

Figure 4.34 Spot Market Statistical Price Volatility

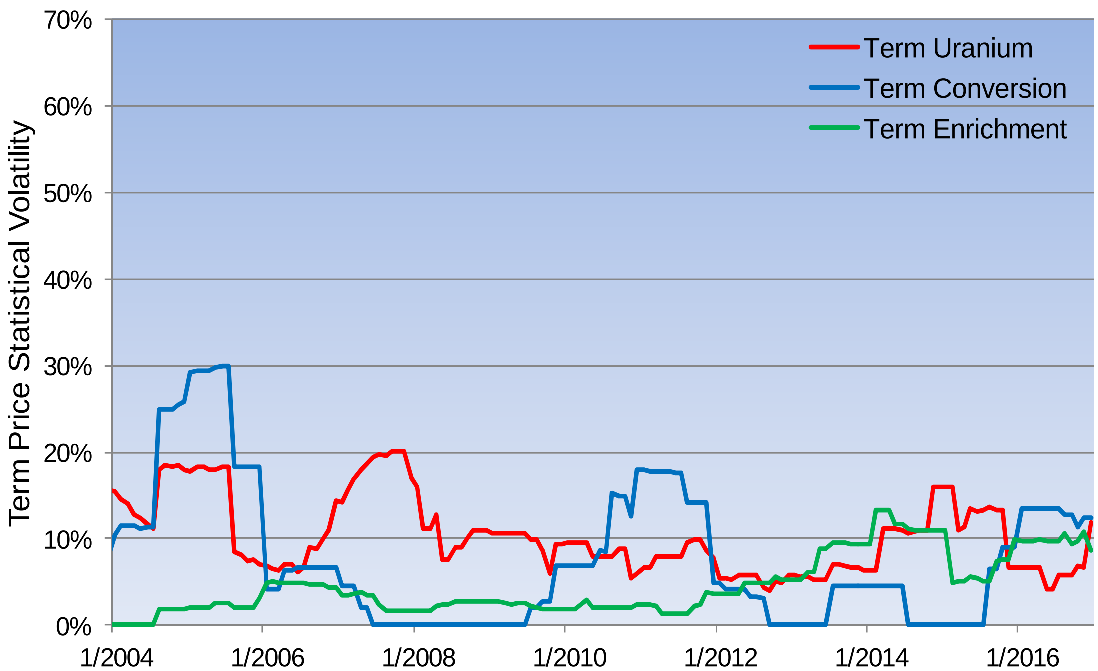

Figure 4.35 Term Market Statistical Price Volatility

4.3.2 DOE Inventory Relative to Other Market Factors

DOE Inventory Relative to Total Market Supply

To help judge the DOE inventories role in the total uranium market, Figure 4.36 compares the Base Scenario DOE quantities that have or are expected to affect the uranium market to total uranium market supply, where the supply is broken down between primary production and secondary supply. Total market supply, including the DOE material, averaged 189 million pounds U_3O_8 in 2014-2016, is expected to decrease to 183 million pounds U_3O_8 in 2017-2021, and then gradually increase to 206 million pounds U_3O_8 by 2026.

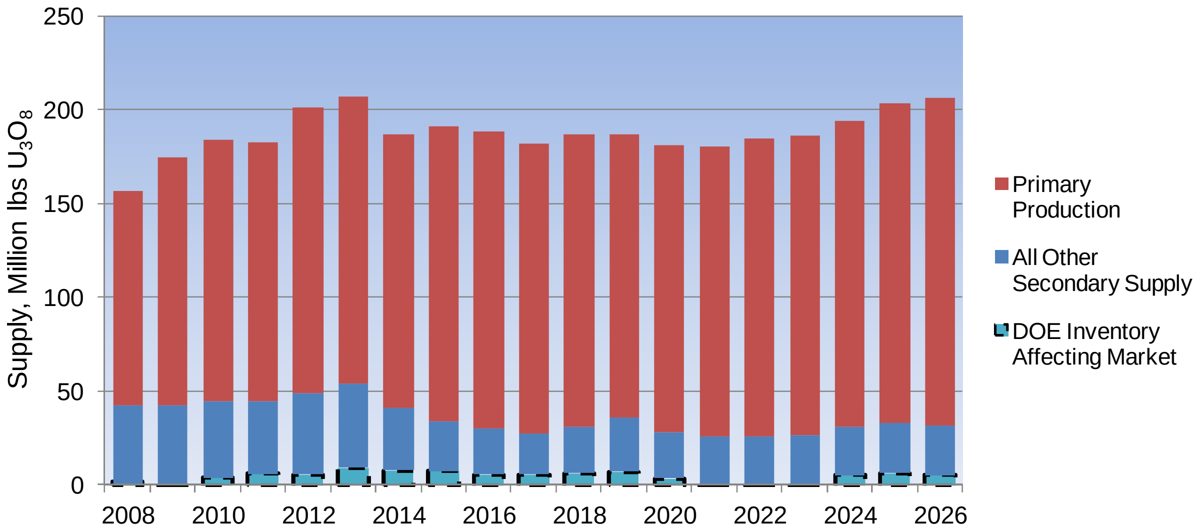

Figure 4.36 Base Scenario DOE Inventory Relative to Total Uranium Market Supply

Figure 4.36 indicates that DOE inventory is small share of total uranium market supply for the Base Scenario. Figure 4.37 compares the DOE inventory's share of total uranium market supply on a percentage basis for all four scenarios. The DOE inventory's share of total uranium market supply grew from about 1% in 2008 and 2009 to a peak of 4.4% in 2013, but has declined to 3.0% in 2016 as a result of the 2015 Secretarial Determination's decision to reduce the transfer quantities. The DOE inventory share is expected to average 3.4% over the next three years (2017-2019) for the Base Scenario, but then drop to 0.4% in 2021-2023 before returning to an average of 2.7% in 2024-2026 based on the assumed onset of DUF_6 processing. The Base Scenario average over the next ten years is 2.2%. For Scenario 1, the DOE inventory share declines to 1.4% over the next ten years (2017-2026), Scenarios 2 and 3 are similar to the Base Scenario as the total amount of material transferred is the same, although Scenario 2 has a smaller share in 2017-2019 while Scenario 3's share is larger.

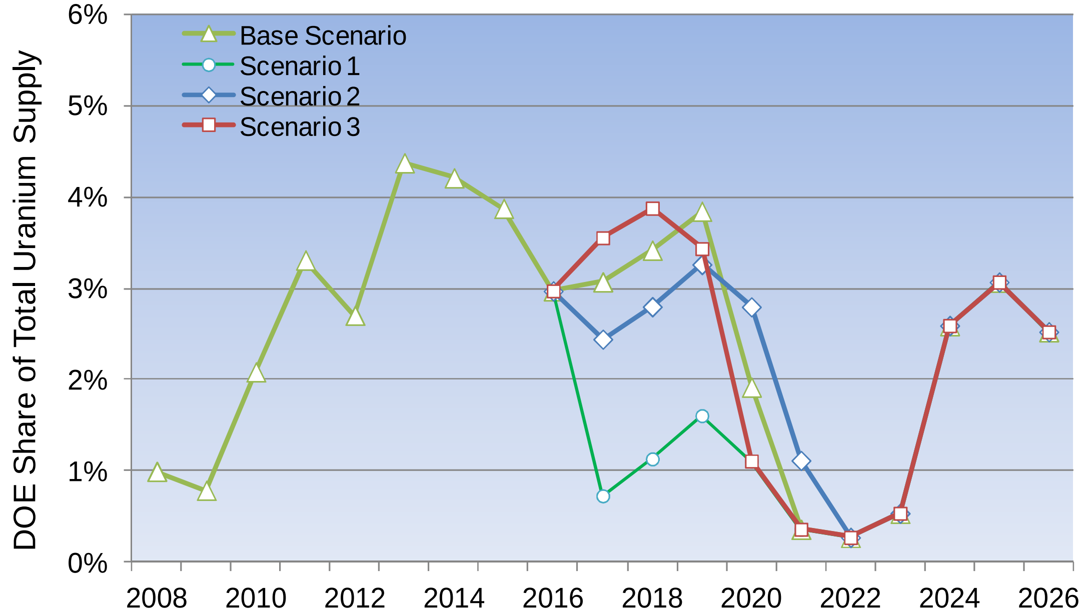

Figure 4.37 DOE Inventory Share of Total Uranium Market Supply for Each Scenario

Figure 4.38 compares the DOE inventory relative to total secondary supply between 2008 and 2026. The DOE inventory grew from 4% of secondary supply in 2008 to a peak of 22% in 2015. Note that total secondary supply declined in 2014 with the end of the HEU Agreement. The total secondary supply and DOE's share under the Base Scenario remain relatively constant over the next three years at 20%, but then declines to 3% during 2021-2021 and then recovers to 17% during 2024-2026. The decline is due to gap between the elimination of EM natural UF_6 inventories in 2020 and the start of DUF_6 processing in 2024.

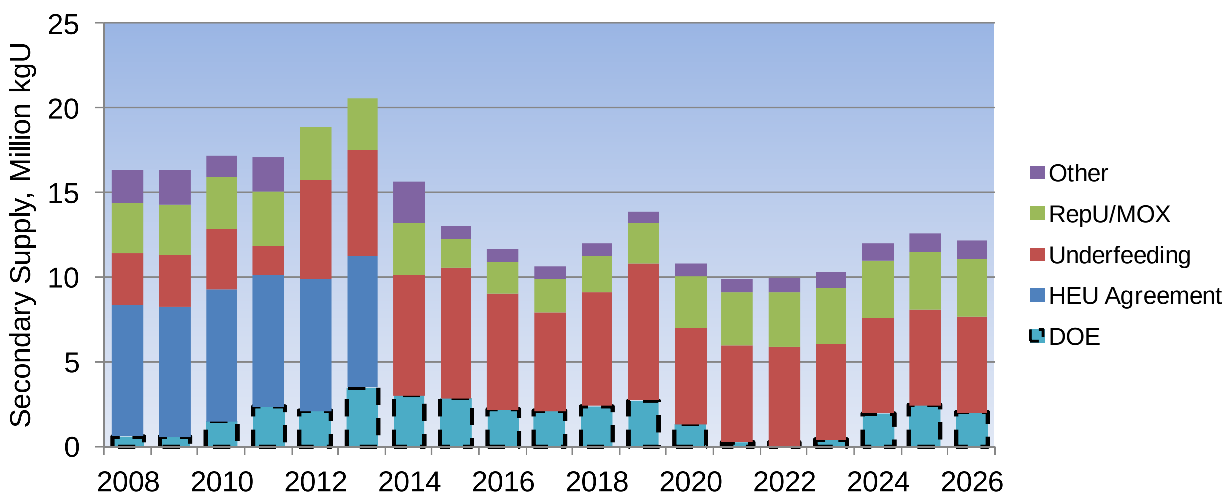

Figure 4.38 Base Scenario DOE Inventory Relative to Total Secondary Supply

Since there is significant industry concern over the effect of DOE inventory on the spot market for uranium, DOE inventory released to the spot market (see Table 3.10) is compared against total spot market volume in Figure 4.39. The total spot market volume is primarily taken from Cameco company filings.[87] It is apparent that the DOE material sold on the spot market constitutes just a fraction of total spot market volume. The DOE share of spot volume averaged 5% in 2004-2007 and declined to 1% in 2008 and 2009 but then increased to an average of 9% in 2013-2015 and 7% in 2016. The DOE material sold on the spot market for the Base Scenario and as a share of 2016 spot market volume is expected to remain at 7% during 2017-2019, but then decline to less than 1% in 2020-2023 before climbing back to 5% in 2024-2026. About 40% less DOE inventory material would be released to the uranium spot market over the next ten years under Scenario 1.

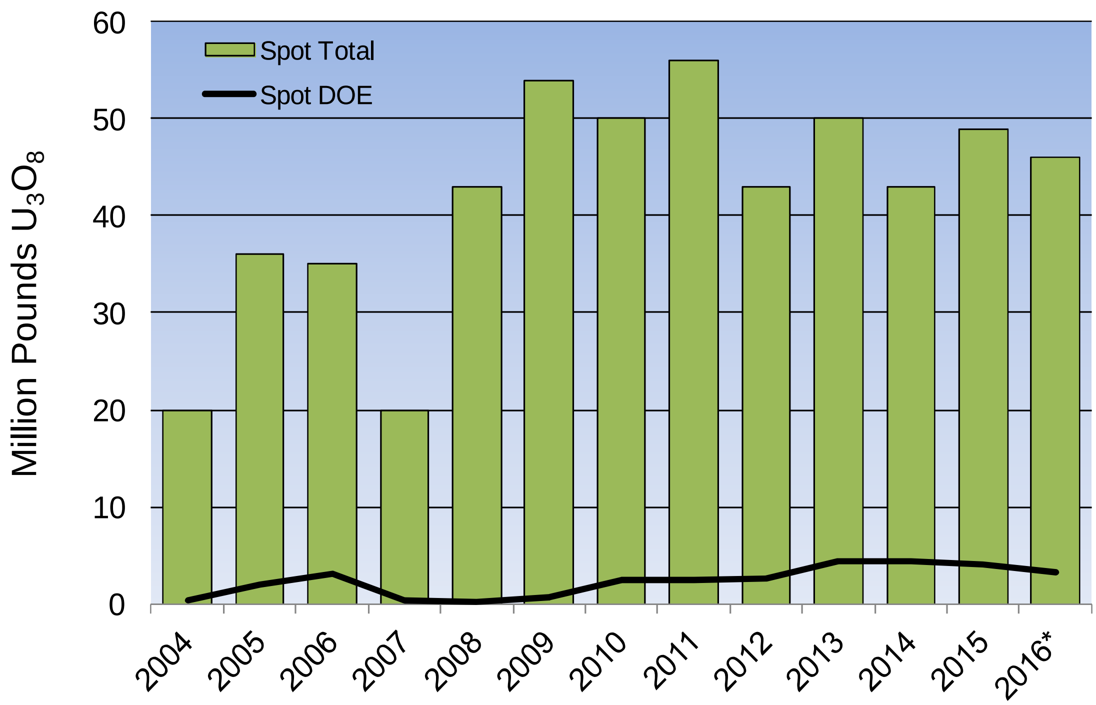

Figure 4.39 DOE Spot Inventory Relative to Spot Uranium Market

Given the industry concern that EM Transfer material disposed of by Traxys in term contracts is primarily in the form of mid-term contracts which "scavenge" spot market demand in subsequent years, Figure 4.40 compares total DOE releases to the spot uranium market. Under this assumption the DOE share of spot volume averaged 3% in 2008-2009 but then steadily increased to a peak of 18% in 2013-2014 before declining back to 12% in 2016. The average annual release of all DOE material to the market for the Base Scenario

[87] Cameco Corporation, “Management’s discussion and analysis" for the year ended December 31, 2015, February 5, 2016 and similar filings for prior years.

over the next ten years is equivalent to 9% of the 2016 spot market volume. The total relative to the 2016 spot volume is higher in 2017-2019 (14%) and 2024-2026 (12%), but lower in 2020-2023 (3%),

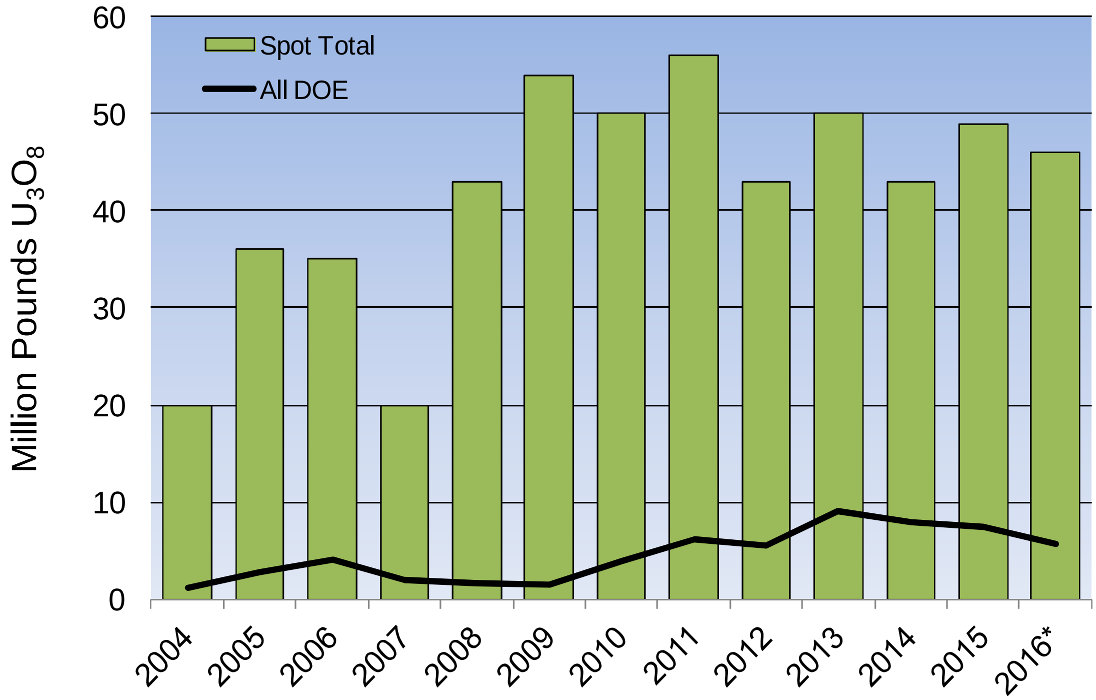

Figure 4.40 DOE Total Inventory Relative to Spot Uranium Market

DOE Inventory Relative to Other Market Factors

There are many market factors which combine to determine the relationship between supply and demand, and ultimately market prices as found in published price indicators. DOE inventory releases are certainly one of the market factors, but a determination of the DOE inventory's effect can also be judged in the context of its relative contribution when compared to other market factors. A reasonable judgment on the specific contribution of DOE inventories to observed market price changes can then be made.

There have been a number of important market factors influencing the markets since DOE inventory affecting the commercial markets began to increase with the first transfers in December 2009. These factors have affected both supply and demand as the markets have gone from balanced in 2008, with little or no excess supply capacity, to highly over-supplied with considerable excess supply capacity at present. Important factors in addition to the DOE inventory releases to be compared are listed below:

- Demand losses in Japan resulting from the March 2011 accident at Fukushima Daiichi
- Demand losses in Germany resulting from changes in Germany energy policy
- Increased uranium production in Kazakhstan (compared to 2008)
- Increased secondary supply (other than DOE inventory) from underfeeding by enrichers and upgrades of DUF_6 in Russia
- Ramp up in supply from the Russian Suspension Agreement (SA) as amended
- Ramp up and subsequent end of U.S.- Russian HEU Agreement in 2013

Note that these market factors do not necessarily apply to all of the markets. Figure 4.41 compares the Base Scenario DOE inventory relative to the other uranium market factors. The uranium equivalent included in the EUP delivered to the U.S. under the Russian SA is not included as a uranium market factor as the uranium content would be delivered to other markets if not delivered to the U.S. under the SA. The DOE inventory was equivalent to about 6% of all the uranium market factors (including DOE) in 2012, rising to 9% in 2013-2014 before declining back to 7% in 2016. The total of all the non-DOE uranium market factors is expected to remain fairly constant over the next decade as the slow increase in Japanese reactor restarts is offset by additional retirements in Germany. The Base Scenario DOE share averages 8% in 2017-2019, but then drops to 1% in 2021-2023 before returning to 7% in 2024-2026. If Scenario 1 DOE inventory is assumed, the DOE share declines to 3% in 2017-2020 but is similar to the Base Scenario thereafter. Scenarios 2 and 3 are similar to the Base Scenario.

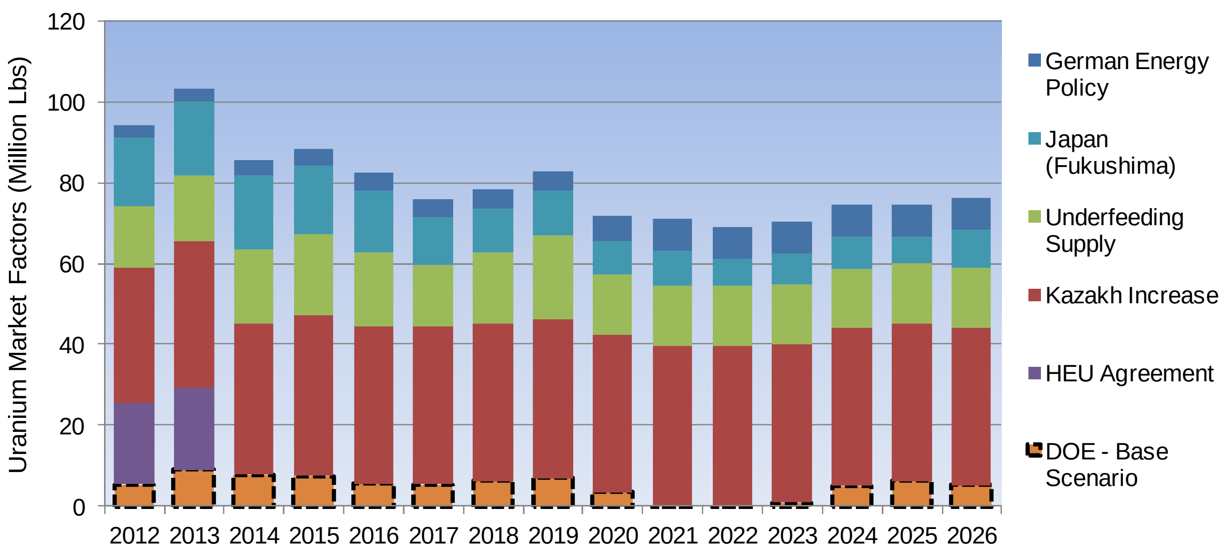

Figure 4.41 DOE Inventory Relative to Other Uranium Market Factors

Figure 4.42 compares the Base Scenario DOE inventory relative to other conversion market factors. A major difference from Figure 4.41 is that increased uranium production in Kazakhstan does not affect the conversion market and so is not shown as a conversion market factor. Another difference is that the ramp up of supply under the Russian Suspension Agreement can affect the conversion market. It is assumed that 80% of the material supplied under the SA is in the form of EUP sales which include a conversion component. Rosatom would not have a market for these included conversion sales if the SA deliveries were not allowed, so it is included as a conversion market factor. The DOE inventory was equivalent to about 10% of all the conversion market factors (including DOE) in 2012, rising to 15% in 2013-2015 before declining back to 12% in 2016. The total of all the non-DOE conversion market factors is expected to decline slightly over the next decade. The Base Scenario DOE share averages 15% in 2017-2019, but then drops to 2% in 2021-2023 before returning to 15% in 2024-2026. If Scenario 1 DOE inventory is assumed, the DOE share declines to 6% in 2017-2020 but is similar to the Base Scenario thereafter. Scenarios 2 and 3 are similar to the Base Scenario.

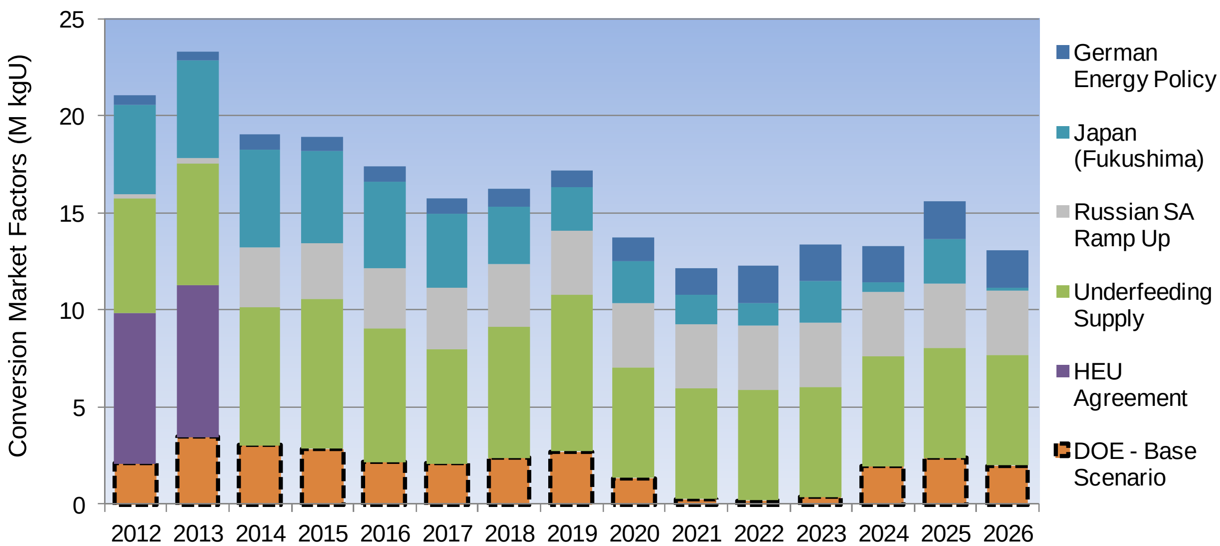

Figure 4.42 DOE Inventory Relative to Other Conversion Market Factors

Figure 4.43 compares the Base Scenario DOE inventory relative to other enrichment market factors. Increased uranium production in Kazakhstan does not affect the enrichment market and so is not shown as a market factor. The DOE inventory was equivalent to about 8% of all the enrichment market factors (including DOE) in 2012, rising to 13% in 2013 before declining back to 10% by 2016. The total of all the non-DOE enrichment market factors is expected to decline modestly over the next decade. The Base Scenario DOE share remains about 10% in 2017-2019 but then declines to an average of 5% in 2020-2023 and is 0% by 2025. The release of DOE enrichment services is the same for all four scenarios.

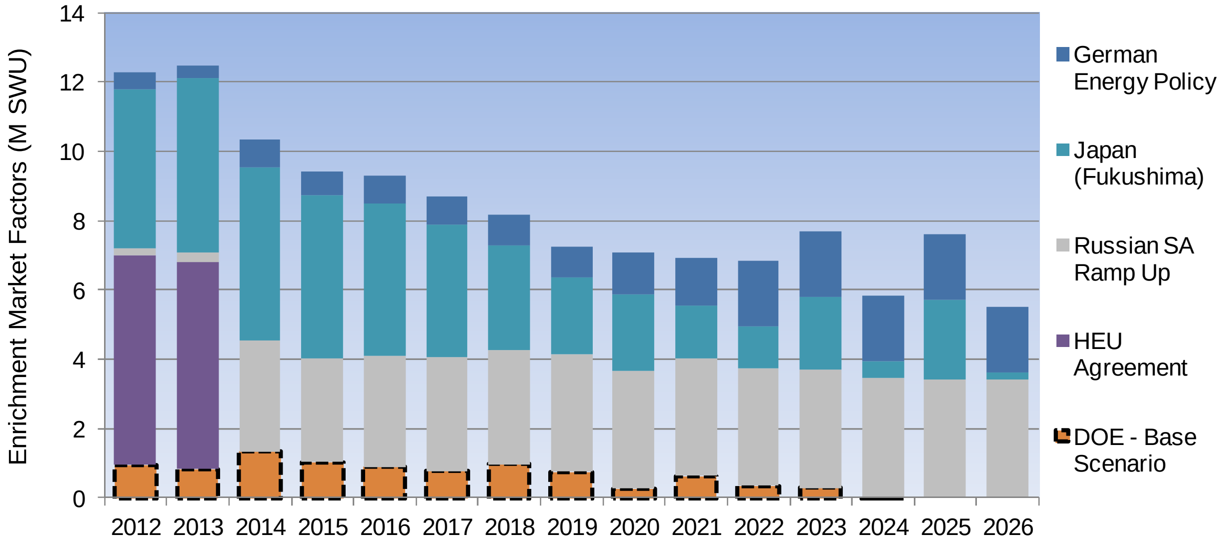

Figure 4.43 DOE Inventory Relative to Other Enrichment Market Factors

An observation which can be drawn from the discussion above is that the increased supply from the DOE inventory does not appear to be a primary driver of the current excess supply condition. In 2016, the DOE inventory is responsible for about 7% of the total of all uranium market factors, 12% of conversion market factors and 10% of enrichment market factors. The relative importance of the DOE inventory, compared to other market factors, indicates that the DOE inventory can only be considered responsible for a portion of the decline in market prices observed since the Fukushima event. This conclusion is consistent with the effects on market price developed in Section 4.1.

4.3.3 Price Effects of Individual DOE Inventory Categories

The price effects of all DOE inventory releases on each of the markets were examined in Section 4.1. The total DOE inventory releases are composed of several individual programs which have been combined into three categories as discussed in Section 3. DOE requested that ERI compare the relative importance of each of these individual programs and categories relative to the total overall effect of all DOE inventory as has been discussed throughout Section 4 of this analysis. Therefore, the clearing price effect using the cumulative clearing price methodology has been estimated for each of the following components of DOE inventory:

- Historic transfers of Blended Low-Enriched Uranium (BLEU) to TVA and of high-assay depleted uranium tails (DUF_6) to Energy Northwest (ENW)
- EM transfers of natural UF_6 inventory and NNSA transfers of LEU from HEU down blending
- Proposed transfers of DOE excess uranium currently under negotiation

The price effect break downs for the Base Scenario and Scenario 1 are provided by category in Table 4.14 for the uranium market, Table 4.15 for the conversion market and Table 4.16 for the enrichment market.

Year	Uranium Price Effect ($/lb U_3O_8)		
	Base Scenario		
	Historic	EM and NNSA Transfers	Proposed DUF_6 and Off-Spec
2014	$1.0	$3.9	$0.0
2015	$1.0	$4.5	$0.0
2016	$0.8	$4.1	$0.0
2017	$0.8	$4.7	$0.0
2018	$0.7	$4.0	$0.0
2019	$0.8	$4.2	$0.0
2020	$0.6	$3.0	$0.1
2021	$0.5	$2.1	$0.0
2022	$0.3	$1.1	$0.0
2023	$0.4	$1.6	$0.0
2024	$0.3	$1.2	$0.1
2025	$0.4	$1.5	$0.3
2026	$0.2	$0.8	$0.3
Average 2017-2026:			
	$0.5	$2.4	$0.1

Year	Uranium Price Effect ($/lb U_3O_8)		
	Scenario 1		
	Historic	EM and NNSA Transfers	Proposed DUF_6 and Off-Spec
2014	$1.0	$3.9	$0.0
2015	$1.0	$4.5	$0.0
2016	$0.8	$4.1	$0.0
2017	$0.7	$3.7	$0.0
2018	$0.6	$2.6	$0.0
2019	$0.6	$2.2	$0.0
2020	$0.2	$0.8	$0.0
2021	$0.1	$0.3	$0.0
2022	$0.0	$0.1	$0.0
2023	$0.0	$0.0	$0.0
2024	$0.4	$1.1	$0.2
2025	$0.4	$1.2	$0.3
2026	$0.1	$0.4	$0.2
Average 2017-2026:			
	$0.3	$1.2	$0.1

Table 4.14 Uranium Price Effect by DOE Inventory Category for Base and Scenario 1

Year	Conversion Price Effect ($/kgU as UF_6)		
	Base Scenario		
	Historic	EM and NNSA Transfers	Proposed DUF_6 and Off-Spec
2014	$0.1	$0.5	$0.0
2015	$0.2	$0.7	$0.0
2016	$0.2	$0.8	$0.0
2017	$0.2	$0.9	$0.0
2018	$0.2	$1.0	$0.0
2019	$0.4	$1.9	$0.0
2020	$0.3	$1.6	$0.0
2021	$0.1	$0.6	$0.0
2022	$0.0	$0.1	$0.0
2023	$0.0	$0.1	$0.0
2024	$0.1	$0.3	$0.0
2025	$0.1	$0.3	$0.1
2026	$0.1	$0.3	$0.1
Total 2017-2026:			
	$0.1	$0.7	$0.0

Year	Conversion Price Effect ($/kgU as UF_6)		
	Scenario 1		
	Historic	EM and NNSA Transfers	Proposed DUF_6 and Off-Spec
2014	$0.1	$0.5	$0.0
2015	$0.2	$0.7	$0.0
2016	$0.2	$0.8	$0.0
2017	$0.1	$0.8	$0.0
2018	$0.2	$0.9	$0.0
2019	$0.3	$1.3	$0.0
2020	$0.3	$1.1	$0.0
2021	$0.0	$0.1	$0.0
2022	$0.0	$0.1	$0.0
2023	$0.0	$0.1	$0.0
2024	$0.1	$0.3	$0.0
2025	$0.1	$0.3	$0.1
2026	$0.1	$0.3	$0.1
Total 2017-2026:			
	$0.1	$0.5	$0.0

Table 4.15 Conversion Price Effect by DOE Inventory Category for Base and Scenario 1

Year	Enrichment Price Effect ($/SWU)		
	All Scenarios		
	Historic	EM and NNSA Transfers	Proposed DUF_6 and Off-Spec
2014	$2.8	$2.4	$0.0
2015	$3.4	$3.2	$0.0
2016	$4.0	$3.7	$0.0
2017	$4.9	$4.8	$0.0
2018	$4.4	$4.4	$0.0
2019	$3.6	$3.7	$0.0
2020	$4.4	$4.4	$0.0
2021	$7.9	$7.0	$0.0
2022	$5.7	$4.8	$0.0
2023	$5.7	$4.4	$0.0
2024	$1.5	$1.1	$0.0
2025	$4.2	$3.3	$0.0
2026	$0.7	$0.6	$0.0
Total 2017-2026:			
	$4.3	$3.9	$0.0

Table 4.16 Enrichment Price Effect by DOE Inventory Category for Base and Scenario 1

The relative contribution to the price effect using the cumulative clearing price methodology of each of the categories over the next ten years (2017-2026) has been summarized across the three scenarios on a percentage basis in Table 4.17.

The relative effects of each category are similar across the four scenarios for the uranium and conversion industries as expected since none of the DOE inventory is in the form of uranium concentrates, but rather contained as uranium equivalent in natural UF_6 or the natural UF_6 component of LEU. The EM and NNSA transfers for services are the largest contributor, comprising 76% to 81% of the total DOE price effect across the four scenarios for uranium and conversion. The historic inventory transfers (TVA BLEU and ENW DUF_6) are smaller, comprising 16% to 20% of the DOE price effect for uranium and conversion across the four scenarios. The additional proposed inventory releases of DUF_6 to GLE are the least significant, comprising 3% to 4% of the average total DOE price effect for uranium and conversion over the next ten years across the four scenarios.

All of the enrichment price effect is due to the first two categories - historic inventory transfers or EM and NNSA transfers for services. At 53% across the four scenarios, the historic transfers contribute more to the enrichment price effect than was seen for uranium and conversion. The EM and NNSA transfers contribute 47% across the four scenarios.

	Share of DOE Price Effect (2017-2026)		
	Historic	EM+NNSA Transfers	Proposed DUF6 and Off-Spec
Uranium			
Base Scenario	17%	80%	3%
Scenario 1	19%	76%	4%
Scenario 2	17%	80%	3%
Scenario 3	17%	81%	3%
Conversion			
Base Scenario	17%	81%	3%
Scenario 1	20%	76%	4%
Scenario 2	17%	80%	3%
Scenario 3	16%	81%	3%
Enrichment			
Base Scenario	53%	47%	0%
Scenario 1	53%	47%	0%
Scenario 2	53%	47%	0%
Scenario 3	53%	47%	0%

Table 4.17 Relative Price Effect Summary by DOE Inventory Category

4.3.4 Commercial Inventories and Discretionary Purchasing

Uranium inventory that is held by owners and operators of nuclear power plants may be broadly categorized as either (i) pipeline inventory—material in processing, (ii) strategic inventory—material held as a hedge against supply interruptions, or (iii) excess inventory—material that is surplus to either of the first two categories. Typically the processing pipeline is about 12 months in the U.S. and 18 months in Asia, although these may decline by a few months. Commercial inventories have been increasing over the past five years. The 2015 Uranium Marketing Annual Report published by the DOE EIA shows a 48% increase in uranium inventories – all forms – held by owners and operators of U.S. nuclear power plants between 2008 and 2015. A small increase took place in 2015, when U.S. uranium inventories increased by 6%. The U.S. commercial inventory levels are depicted in Figure 4.44. The Euratom Supply Agency (ESA) reports a 19% increase in uranium inventories in the EU-28 between 2008 and 2015. The EU inventory decreased 2% in 2015, similar to the small decrease in 2014, as German utilities draw down inventory. The past inventory buildup was initially driven by industry concerns regarding supply vulnerability and later by excess commitments attributed to premature reactor shutdowns. Some of the more recent inventory buildup may also be due to discretionary buying. Given current low prices one might think that discretionary buying would increase dramatically. However end users, particularly in the U.S., are under significant cost pressures themselves and often do not have the budget to make discretionary purchases. End user perception is that low prices and plentiful supply will remain in place for a number of years so there is little need to incur extra carrying costs by making discretionary purchases.

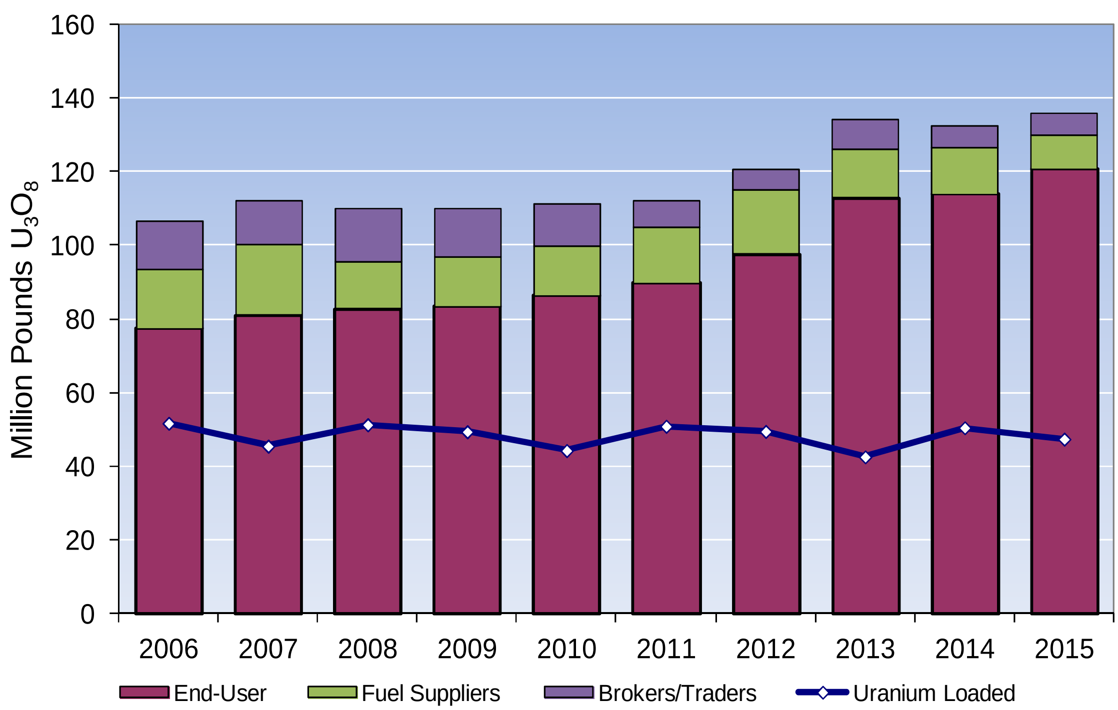

Figure 4.44 U.S. Commercial Uranium Inventories

EIA reports total inventory, including both pipeline and strategic, held by U.S. nuclear power plant operators as of 2015 is 121 million pounds U_3O_8 equivalent, while the ESA reports 135 million pounds in the EU-28 as of the end of 2015. Significant inventories are held in East Asia, primarily in China and Japan, and estimated at approximately 370 million pounds. China has rapidly increased its strategic inventory over the past five years and is expected to continue to do so for a number of years. ERI estimates that the total inventory presently being held by operating companies worldwide is 670 million pounds U_3O_8 equivalent. Close to 500 million pounds is considered by ERI to be beyond pipeline needs. While most of this is thought to be strategic, the beyond strategic excess is still significant.

Following the Fukushima Daiichi accident and the shutdown of a significant number of units in Germany and the extended outages of reactors in Japan, the potential for the release of inventories has overhung the uranium market. The early shutdown of five reactors in the U.S. with prospects for at least eight more in the next few years has also added to the excess inventory. The excess inventory in Germany and the U.S. resulting from reactor shutdowns is being made available and impacting the market. Thus far it appears that the excess inventories built up in Japan have not been marketed for the most part, but renegotiation of delivery schedules still left some suppliers with available inventory. The threat from the potential release of Japanese inventory will remain until enough Japanese reactors are given restart permission by safety authorities as well as local approval.

With regard to inventory held by suppliers and traders, EIA reports a total of 15 million pounds U_3O_8 equivalent for 2015. This is 51% less than was being held by U.S. suppliers in 2007. Of the 15 million pounds, EIA reports that 62% is being held by U.S. uranium producers, convertors, enrichers and fuel fabricators, with the balance being held by U.S. brokers and traders. Outside the U.S., at the end of 2015 ERI estimates that uranium producers, convertors, enrichers, fuel fabricators and traders held 95 million pounds. Another 20 million pounds U_3O_8 equivalent is held by various types of financial investors (e.g. Uranium Participation Corporation with 14 million pounds). This results in a total of approximately 130 million pounds U_3O_8 equivalent.

Some suppliers have explicitly increased inventory in order to take uranium off the market. Leading the way is Cameco which increased its inventories by 8.5 million pounds in 2015 and is expected to purchase additional inventory in 2016. Kazatomprom announced in April 2016 that it planned to build a uranium reserve with excess production over the next two years. It is not yet known if the January 2017 decision to reduce planned 2017 production by approximately 10% will affect Kazatomprom's uranium reserve plans. These inventories may have to be held off the market for far more than a few years if they are to help foster a sustainable recovery in uranium prices. Overall, significant excess inventories (beyond target strategic levels) are held worldwide by suppliers and end users. The excess will be gradually drawn down, as was indicated in Figure 2.4 for uranium. Market prices will remain under pressure until the excess inventory is reduced. While the above discussion has centered on uranium, significant inventories of LEU (containing enrichment and conversion services) are held worldwide as well. ERI estimates that excess inventory "overhang" will be reduced by approximately 80 million pounds U_3O_8, 20 million kgU as UF_6 and 20 million SWU over the next five to ten years,

As noted in Section 4.2.2 for the conversion market, there has been a marked change in contracting for nuclear fuel components over the past five years, with lower volumes of contracting under both long-term and spot market purchases[88,89] as shown in Figure 4.45 for uranium. During the period 2006 to 2012, term contract volumes averaged an estimated 185 million pounds U_3O_8 annually (more than 118% of annual requirements during that period) as shown in Figure 4.43. In contrast, during the period 2013 to 2016, term contracting for uranium has been an estimated 56 million pounds annually (35% of requirements during 2013 to 2016). Spot market purchases during the 2006 to 2012 time period were an estimated 40 million pounds per year. A similar level of spot market purchases occurred during 2013 to 2016, averaging 47 million pounds per year. New term sales of uranium concentrates have been well below annual deliveries during the past four years.

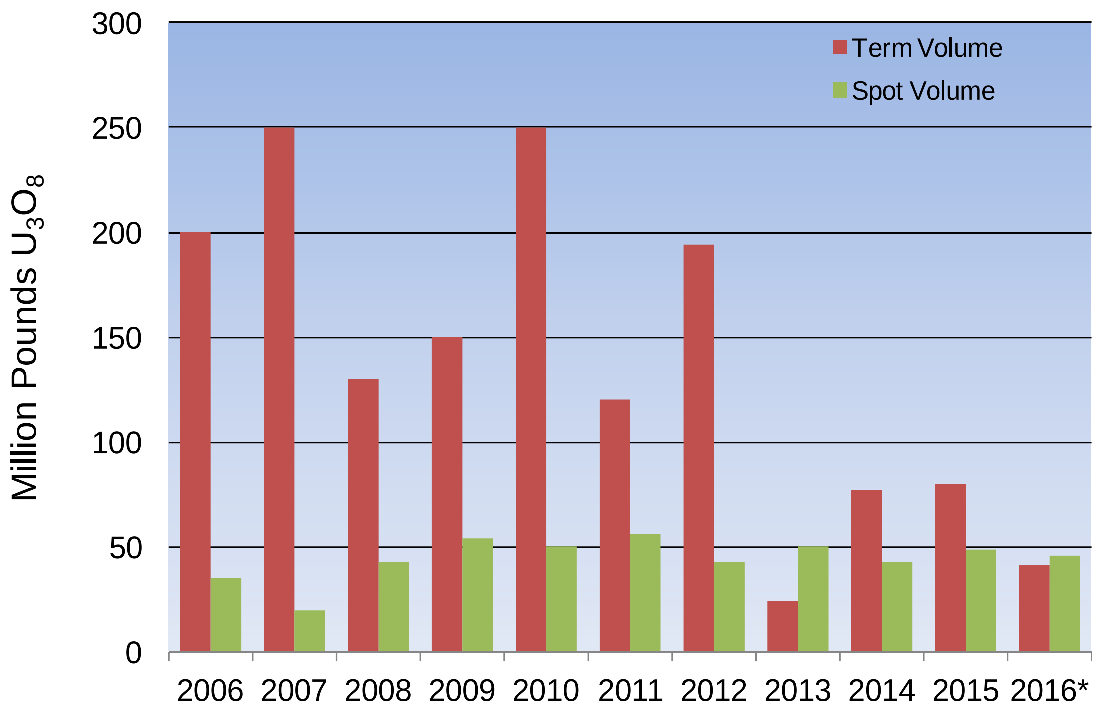

Figure 4.45 Uranium Term and Spot Contracting Volumes

[88] Cameco Corporation, "Management's discussion and analysis for the quarter ended September 30, 2016", November 2016.
[89] Cameco Corporation, "Management's discussion and analysis" for the year ended December 31, 2015, February 5, 2016 and similar filings for prior years.

It should also be noted that ERI estimates that only about 40% of the spot market volume has consisted of purchases by end users. The remaining 60% are purchases by traders and producers. Much of the end-user spot buying has been discretionary in recent years. More importantly, much of the term contracting in recent years has been in the form of mid-term contracts where deliveries take place in the near term - one to three years forward. Supply for these mid-term contracts is often the result of arbitrage known as "carry trades" where traders and banks purchase on the spot market and then resell in a mid-term contract, taking advantage of low costs of money. As long as excess inventory is available to support the mid-term activity, end user purchasing behavior is not expected to change.

4.3.5 Importance of Other Assumptions Made by ERI

Elasticity in the Uranium Markets

Price elasticity may dampen the price effects attributed to DOE transfer material. The price effects attributed to DOE material in this analysis are conservative in that they do not take credit for any DOE price effect dampening due to elasticity. In other words, the clearing price methodology assumed demand and supply are inelastic. ERI has not attempted to characterize the level of the potential effect of elasticity on the price effects attributed to the DOE transfer material, but believes it would not be significant[90].

Mix of DOE Material Deliveries to the Term and Spot Markets

For the Base Scenario, 44% of uranium concentrates and conversion services contained in the DOE inventory material is being delivered to end-users through spot market arrangements, while the remaining 56% is being delivered under term contract arrangements over the next ten years (2017-2026). The share of DOE inventory enrichment services delivered through the spot market is lower at 37% and is the same across all four scenarios. In the near term (2017-2019) the spot percentages for the Base Scenario are higher at 53% for uranium and conversion and 60% for enrichment services. Scenarios 2 and 3 are virtually identical to the Base Scenario as far as average share to the spot market is concerned. For Scenario 1, where EM transfers for services are halted, the share of DOE inventory uranium and conversion services delivered through the spot market declines slightly to 42% over the next ten years, but increases slightly to 60% in the near term.

[90] When current spot price is low enough (compared to current term price and expected future spot price) current spot market demand is increased and future demand is decreased via spot market purchases held for mid-term delivery by intermediaries. This shifting of demand represents a form of demand price elasticity. As stated, ERI does not attempt to characterize the change in the DOE price effect caused by such elasticity, but believes it is not significant.

The calculation of market clearing price effect considers total market supply, including DOE inventory, and total market requirements. It does not differentiate as to whether the supply was contracted to end-users under spot or term arrangements. The uranium industry has consistently stated its preference for DOE inventory releases through term market sales rather than spot market sales. While contracting practices differ among companies, it is typical for about 50% of delivered uranium prices to be linked to the spot market price[91]. Contract pricing in the conversion and enrichment markets are not typically linked to spot market price indicators.

Section 4.1.2 looked at the effect of DOE inventory releases on uranium spot prices using an econometric correlation model. The correlation indicates that if a greater percentage of DOE inventory is sold through spot market arrangements then the effect on uranium spot market prices is higher. The analysis has assumed 50% of EM transfers for services and 100% of NNSA transfers for services, together with 50% of proposed future DUF_6 and off-spec releases, take place under spot arrangements. The average spot market price effect was projected to be \$4.1/lb U_3O_8 in 2017-2019 and \$3.2/lb U_3O_8 in 2020-2026, corresponding to 12% and 7%, respectively, of expected spot market prices without the Base Scenario sales. If instead all of the future Base Scenario EM and NNSA transfers for services and proposed future DUF_6 and off-spec releases are assumed to take place on the spot market, then the DOE effect on spot price increases to \$5.7/lb U_3O_8 in 2017-2019 and \$5.8/lb U_3O_8 in 2020-2026 corresponding to 16% and 12%, respectively, of expected spot market prices without the Base Scenario sales. If none of the future releases are assumed to take place on the spot market, then the DOE effect on spot price declines to \$1.7/lb U_3O_8 in 2017-2019 and \$1.0/lb U_3O_8 in 2020-2026 corresponding to 5% and 2%, respectively, of expected spot market prices without the Base Scenario sales.

Proportion of the DOE Material Going to the U.S. Market

The uranium, conversion and enrichment markets are global in nature and the commodities are fungible. In general, pricing for uranium, conversion and enrichment is the same for the U.S. market and non-U.S. markets. The one exception is conversion, where both spot and term prices for North American delivery have averaged 6% lower than prices for European delivery[92] in recent years (2014-2016). The effect of DOE inventory material on global prices is the same whether material goes to end-users inside or outside the U.S. market. The proportion of the material going to the U.S. market has been assumed to be 100% for the historical transfers (TVA BLEU and ENW DUF_6), 50% for EM and NNSA transfers and 50% for proposed releases (primarily DUF_6 to GLE). The resulting total share of DOE inventory going to the U.S. market over the next ten years for the Base Scenario is then 59% for uranium and conversion and 81% for enrichment services. The

[91] Floors and ceilings can limit the impact of large spot market price changes on the delivered price.

[92] The difference stems from a location imbalance between enrichment and conversion capacity. North America has more conversion capacity relative to enrichment capacity while Europe has less. The resulting need to incur additional shipping charges for required transport to European enrichment plants results in the price difference.

shares going to the U.S. market are the same as the Base Scenario for Scenarios 2 and 3 for all three front-end markets. For Scenario 1, the share of DOE inventory going to the U.S. markets rises slightly to 64% even though it is a smaller total quantity. The effect of the proportion of DOE material going to the U.S. market on domestic industry sales volumes is discussed in conjunction with domestic industry market share below.

Domestic Industry Market Share

It can be argued that there may be some regional differences in the effect of the DOE material, specifically in the U.S. The proportion of the DOE material sold to U.S. end-users is expected to be larger than the U.S. markets' share of total world demand. Similarly, the share of sales typically contracted with U.S. end-users by the domestic industries may be larger than the U.S. markets share of total world demand. These conditions could lead to a larger effect on domestic industry sales volumes from the DOE material. The larger effect is based on the assumption that domestic industry is unable to adjust market share with non-U.S. customers in response to a lower market share with U.S. customers resulting from the DOE material sales. ERI finds this assumption to be too rigid. The markets for uranium, conversion and enrichment are global in nature and the commodities are fungible. While the Russian market has been closed to U.S. industry, there are no trade restrictions on U.S. nuclear commodities (the same cannot be said for Russian exports). The Chinese market is responsible for much of the expected future growth in requirements and while enrichment and EUP sales have been made by foreign suppliers, there may not be much opportunity for new conversion and enrichment sales as China intends to meet those needs from internal supply. China does import large amounts of uranium concentrates and is expected to continue to do so for the long term. There are some reasons why domestic end-users and suppliers may prefer doing business with another, but market shares are not set in stone and respond to changes in market dynamics.

Regional Differences Affecting Supply and Demand Curves

There are regional differences in the markets for uranium, conversion services and enrichment services that may affect supply and demand. Western converters have not typically had access to the supply of UF_6 for power reactors in Russia and Russian-supplied reactors in Eastern Europe. For example, ConverDyn has noted in the past that it does not have access to the markets in either Russia or China. Historically, western enrichers also have not had access to the market for the supply of enrichment services or EUP to power reactors in Russia or Russian-supplied reactors in Eastern Europe. While the Russian enrichment market remains closed, the enrichment markets in Ukraine and the Czech Republic are now available to Western enrichers. The Ukraine and Czech markets may also be opening up to convertors as well. Western enrichers have sold enriched uranium to China; however, China is generally expected to increase its indigenous production of UF_6 and enriched uranium to keep pace with its growing reactor requirements. So, while long-term demand from China and Russia is expected to increase, this does not necessarily result in increased demand for services from Western converters and enrichers and sales into these markets are expected to be limited.

DOE Material Effect on Sales Volumes

The introduction of DOE material results in an increase in the level of secondary supply for each of the three domestic uranium industries relative to the secondary supply available absent the DOE material. It is typically assumed that secondary supply will first be exhausted and that primary supply will then be used to fulfill remaining market demand. Thus, any increase in secondary supply, including DOE material, will result in a decrease in sales volumes sourced from primary production for these industries. Sales volumes for both domestic and non-domestic suppliers will decline relative to the scenario where no DOE material is made available to the market. The uranium, conversion and enrichment markets are global in nature. End-users purchase from suppliers worldwide in each of these industries and suppliers worldwide are able to sell into markets in most regions, not just to the region in which the supplier is located. Thus, as a first order estimate, the effect of DOE material on individual supplier sales volumes will be proportional to the supplier's world market share as well as the quantity of DOE material relative to world demand.

As noted above in the discussion on domestic industry market share, the DOE material could have a larger effect on domestic industry sales volumes than indicated by the industries' global market share. The larger effect is based on the assumption that domestic industry is unable to adjust market share with non-U.S. customers in response to a lower market share with U.S. customers resulting from the DOE material sales. The markets for uranium, conversion and enrichment are global in nature and the commodities are fungible. Although there are reasons why domestic end-users and suppliers may prefer doing business with another, market shares typically respond to changes in market dynamics.

5. Summary of Market Effect

This section summarizes the market effects associated with the entry of DOE inventories into the domestic uranium, conversion and enrichment markets. This includes an evaluation of the price effect associated with the entry of DOE material in the commercial markets and the subsequent displacement of commercial supply. Other metrics were also evaluated for the domestic industries including: employment, production, volumes of inventory relative to market volumes, market capitalization, realized prices and production costs for the uranium production industry; and U.S. converter sales volumes, production costs, margins and workforce reductions; and effect on volumes of enrichment services. The DOE inventories were compared to other market factors to help gauge the relative impact of the DOE material on the markets. The price effects of the different DOE inventory categories of material were also detailed. Additional nuclear fuel market considerations examined included price volatility, price elasticity and other assumptions regarding the markets.

5.1 DOE Inventory Affecting the Market, 2017 to 2026

The quantities of equivalent DOE uranium, conversion and enrichment services expected to affect the commercial markets during the time period addressed by this analysis (2017 - 2026) were split into three categories. The categories of material include (i) historical DOE transfers still affecting the commercial markets, (ii) current and near-term inventory transfers in exchange for services (transfers for services), and (iii) future transfers of DOE inventory, primarily additional DUF_6 under agreement with GLE, but also proposed transfers of off-spec LEU and off-spec non-UF_6 that are currently under consideration. Four release rate scenarios were provided to ERI by DOE.

During the period 2017 to 2026, the total DOE inventory affecting the market is 15,700 MTU as UF_6 under the Base Scenario, which is equivalent to 41 million pounds of U_3O_8. Under Scenario 1 the total DOE inventory affecting the market is 10,400 MTU as UF_6, which is equivalent to 27 million pounds of U_3O_8. Scenarios 2 and 3 release the same total quantities as the Base Scenario over the next ten years, but the release rates in the near term vary. A total of 4.2 million SWU will enter the market during the period 2017 to 2026 for all four scenarios. The DOE inventory releases expected to displace global commercial supply in the markets over the next ten years (2017 through 2026) under the Base Scenario and Scenarios 2 and 3 average 1,570 MTU as UF_6, equivalent to 4.1 million pounds U_3O_8 per year, and 0.4 million SWU per year. This is equivalent to approximately 9% of annual U.S. uranium and conversion requirements and 3% of annual U.S. enrichment requirements. Under Scenario 1, the DOE inventory releases are equivalent to 6% of U.S. uranium and conversion requirements.

The DOE inventory releases expected to displace global commercial supply in the markets in the near term (2017-2019) is higher, averaging 2,398 MTU as UF_6, equivalent to 6.3 million pounds U_3O_8 per year, and 0.9 million SWU per year under the Base Scenario. This is equivalent to approximately 13% of annual U.S. uranium and conversion requirements and 6% of annual U.S. enrichment requirements. Under Scenario 1, the DOE inventory releases are equivalent to 4.5% of U.S. uranium and conversion requirements.

5.2 Current Market Conditions

It remains clear that all of the markets - uranium concentrates, conversion services and enrichment services - are in states of considerable oversupply, with mainly discretionary near-term demand for nuclear fuel and a decline of long-term contracting. The current oversupply in these markets is due to a number of factors such as demand losses in Japan resulting from the March 2011 accident at Fukushima Daiichi; demand losses resulting from changes in Germany energy policy; recent and expected early closures of nuclear power plants in the U.S. and Western Europe for economic and other reasons; increased uranium production in Kazakhstan; increased secondary supply from underfeeding by enrichers and upgrades of DUF_6 in Russia; and DOE inventory transfers.

The long-term prospects for nuclear power and nuclear fuel supply are generally viewed as positive, with a steady average annual nuclear capacity growth rate of approximately 2% through 2035. Related growth in nuclear fuel requirements will be even higher at about 2.5% per year as current requirements have been lowered by the ongoing reactor outages in Japan. Growth in the U.S. remains relatively flat through 2035, with the strongest growth expected to take place in China, India, and South Korea as well as growth due to planned and expected new entrants to the nuclear power sector in countries such as Belarus, Poland, Saudi Arabia, Turkey, the U.A.E. and Vietnam.

It is clear that excess supply will need to be reduced and excess inventories worked down before any significant recovery in market price can take place. In the meantime, the domestic industries have felt the effects of the oversupplied markets and have taken actions, such as production and staffing cutbacks, in order to try to weather the downturn. The effects of current market conditions are acute in all three markets – for uranium, conversion and enrichment.

5.3 Nuclear Fuel Market Effects

Market conditions have continued to deteriorate since ERI's analysis was last conducted in February 2015. The current spot market price for uranium concentrates is 46% lower than the January 2015 price referenced in the February 2015 ERI market analysis and the long-term price is 40% lower. The conversion services spot market price is 29% lower and the long-term price is 19% lower, while the enrichment services spot price is 47% lower and long-term price is 41% lower. The price for uranium as natural UF_6 based on spot market prices is 44% lower and the long-term price is 38% lower.

Market prices have declined considerably since the Fukushima event in March 2011, with prices declining steadily over the past year in the uranium and enrichment markets. Uranium, conversion and enrichment spot price indicators have all demonstrated steep declines, with prices as of December 31, 2016 ranging between 54% and 71% lower than prices on February 28, 2011 just prior to the Fukushima event. For the term markets, enrichment prices are down 66%, a similar decline to the spot price behavior. Uranium term prices are down 57%, which is a lower decline than observed for the uranium spot price. Conversion term prices are 16% lower than on February 28, 2011, a more modest decline than seen in the uranium and enrichment term indicators.

The overall status and changes in the nuclear fuel markets have been characterized in this market analysis as have the effects of the DOE inventory releases, even though it is difficult to attribute the relative contribution of each of the many factors which influence the market price indicators. ERI continues to believe that attributing a difference in market price to DOE inventory releases provides an important measure of the DOE material's effect on the domestic industry. However, there is no absolute measure of the isolated effect any one particular market factor or event, such as the DOE inventory material, has on market prices. There are many market factors which combine to determine the relationship between supply and demand, and ultimately market prices as found in published price indicators.

5.3.1 Price Effect

ERI's February 2015 analysis used an annual market clearing price approach to calculate price effects. The annual methodology assumed that the supply curve in a given year is independent of the DOE inventory releases in prior years. However, the uranium, conversion and enrichment markets are characterized by large quantities of excess inventories which have built up over the last five years. The effect of excess primary production on an annual basis is exacerbated by the excess inventories, or overhang. ERI has therefore developed a cumulative market clearing price methodology that takes into account the large quantities of excess inventories which have built up over the last five years. A cumulative clearing price methodology accounts for the fact that when some inventory is removed in one year (DOE releases for example) then the size of the inventory overhang in the following year is reduced. Over time, the cumulative effect of reduced inventory overhang can have a more pronounced effect than is captured by the annual methodology.

The cumulative methodology estimates the change in average clearing price attributed to the DOE inventories during the last three years (2014-2016) to be $5.1/lb for the uranium market, $0.8/kgU for the conversion market and $6.5/SWU for the enrichment market. Using the cumulative methodology on a forward-looking basis, during the next ten years (2017-2026), the change in average clearing price attributed to the DOE inventories using the cumulative methodology is estimated to be $3.0/lb for the uranium market, $0.9/kgU for the conversion market and $8.2/SWU for the enrichment market under the Base Scenario. Scenarios 2 and 3 provide similar price effects to the Base Scenario. For Scenario 1, where all EM transfers for services are halted in 2017, the future price effects are lower at $1.6/lb for uranium and $0.7/kgU for conversion services.

ERI has also developed a multivariable correlation between the monthly spot market prices for uranium concentrates published by TradeTech and the active spot market supply and active spot market demand, which are also published monthly by TradeTech. This correlation was then used to simulate the 2009 through 2026 spot market price for uranium concentrates with and without the DOE inventory released to the spot market. Application of the correlation results in an estimated spot market price effect of $5.3 per pound U_3O_8 over the last three years (2014-2016). This indicates an estimated effect that spot market prices were 15% lower over the past three years due to DOE inventory releases compared to no release of DOE inventory. Looking forward and assuming the Base Scenario DOE inventory release rates, the correlation results in projected spot market price effects of $3.5 per pound U_3O_8 over the next ten years (2017-2026). This represents an estimated effect of 8% lower spot market prices if Base Scenario DOE inventory releases take place over the next ten compared to no release of DOE inventory. The DOE effect is higher in the near term (2017-2020) at $4.4 per pound and 12% lower prices. The price effect is on future spot market prices, which are projected to eventually rise with or without the DOE inventory releases. The price effects attributed to past and current DOE inventory releases are already built into current spot market prices. If the past releases had not occurred, then current spot market prices would be higher.

5.3.2 Other Market Factors

In addition to quantifying the effect of DOE inventory on the price of uranium, conversion and enrichment, this market analysis addresses additional metrics such as employment, production, volumes of inventory relative to market volumes, market capitalization, realized prices and productions costs in the uranium market. Effects, in addition to market price changes associated with DOE inventory, include changes in U.S. converter sales volume and production costs, and the reduction in workforce associated with reduced sales volumes. The DOE inventories were compared to other market factors to help gauge the relative impact of the DOE material on the markets. The price effects of the different DOE inventory categories of material were also detailed. Additional nuclear fuel market considerations examined included price volatility, price elasticity and other assumptions regarding the markets.

5.4 Market Effects for Uranium, Conversion and Enrichment Services

Summary of Uranium Market Effects

- **Employment**: A price-employment correlation has been used to estimate the effect of the DOE inventory releases on U.S. uranium industry employment. The correlations indicate the cumulative DOE price effect lowered employment by an average of 73 person-years during 2012-2015. In other words using the cumulative methodology, employment was 7.2% lower in the last four years than it would have been if no DOE inventory releases had occurred. Looking forward, the correlations indicate the cumulative DOE price effect lowers employment by an average of 40 person-years, or 6.0%, during 2017-2026 for the Base. It is important to note that the cumulative effect of past DOE releases is already in place. If DOE were to halt future releases consistent with Scenario 1 then employment would still be lowered by an average of 31 person-years, or 4.7%, during 2017-2026. This represents an improvement of 9 person-years (40 - 31) or 1.3% (6.0% - 4.7%) over the Base Scenario

- **Production**: U.S. uranium production has generally risen since the low of 2 million pounds in 2003. The decline in prices has affected the actual and planned production of most U.S. operations. Two of the new operations (Willow Creek and Palangana) stopped developing new well fields and were effectively place on care and maintenance. In mid-2014 both Ur-Energy and Uranerz announced they would limit production expansion at new ISL facilities at Lost Creek and Nichols. Mestena halted well field development at its Alta Mesa ISL facility in Texas in 2013. In April 2016 Cameco announced its decision to discontinue well field development at all U.S. sites. Cut backs have also taken place at Energy Fuels conventional mines and the White Mesa mill is placed on standby periodically. These cut-backs were finally recognized in 2015 U.S. production, which declined 32% from 2014 levels to 3.3 million pounds. U.S. Production in 2016 is expected to decline an additional 10% to 3.0 million pounds. The 2015 and 2016 production is the lowest in the ten years dating back to 2005. The expected 2016 production is 39% below the recent 2014 peak. A further 10% - 15% reduction in production is estimated for 2017. U.S. uranium producers characterize themselves as in "survival mode".

- **DOE Inventory Relative to Total Market Supply:** The DOE inventory's share of total uranium market supply grew from about 1% in 2008 and 2009 to a peak of 4.4% in 2013, but has declined to 3.0% in 2016 as a result of the 2015 Secretarial Determination's decision to reduce the transfer quantities. The DOE inventory share is expected to average 3.4% over the next three years (2017-2019) for the Base Scenario, but then drop to 0.4% in 2021 before returning to an average of 3.0% in 2022-2023 before returning to an average of 2.7% in 2024-2026 based on the assumed onset of DUF_6 processing. The Base Scenario average over the next ten years is 2.2%. For Scenario 1, the DOE inventory share declines to 1.4% over the next ten years (2017-2026), Scenarios 2 and 3 are similar to the Base Scenario. Comparison of DOE inventories relative to total secondary supply for uranium shows that DOE inventory has grown from 4% of secondary supply in 2008 to a peak of 22% in 2015. The total secondary supply and DOE's share under the Base Scenario remain relatively constant over the next three years at 20%, but then declines to 3% during 2021-2021 and then recovers to 17% during 2024-2026. The decline is due to gap between the elimination of EM natural UF_6 inventories in 2020 and the assumed start of DUF_6 processing in 2024. It is apparent that the DOE material sold on the spot market constitutes just a fraction of total spot market volume. The DOE share of spot volume averaged 5% in 2004-2007 and declined to 1% in 2008 and 2009 but then increased to an average of 9% in 2013-2015 and 7% in 2016. The DOE material sold on the spot market for the Base Scenario and as a share of 2016 total spot market volume is expected to remain at 7% during 2017-

2019, but then decline to less than 1% in 2020-2023 before climbing back to 5% in 2024-2026.

- **Market capitalization**: Market capitalization is an important metric for the smaller, publicly traded mining companies in the U.S. because it is representative of the ability of these companies to raise funds needed to move projects through the licensing process, which can take many years, as well as initial project development in some cases. A review of market capitalization for U.S. uranium producers shows that capitalization is sensitive to changes in the spot market price, particularly for smaller mining companies. For example, during 2010, spot price increased from $40 per pound up to $70 per pound, an increase of 75%. The market capitalization of the smaller U.S. miners increased 150% to 600% in response. Following the Fukushima accident in March 2011, market capitalization declined rapidly. Market capitalizations decreased further starting in mid-2014. The market capitalization decrease started in advance of the rapid spot market price decline, which began in early 2016 as the spot price dropped below $30/lb in March 2016, below $25/lb in September 2016 and below $20/lb in October 2016. While the effect of large changes in the spot market price is obvious, the effect on market capitalization from the smaller price changes attributed to DOE inventory is not as clear.

- **Realized Prices**: The EIA publishes average delivered price in the U.S., which have increased steadily over the past ten years, before leveling off in 2012 and declining to \$44/lb-U_3O_8 in 2015, or 21% below the 2011 peak. Additional decline is expected by ERI for 2016, although floor prices in many market-related contracts are preventing end users from reaping the full benefit of the 2016 spot market decline. The U.S. producer average realized price published by EIA has also been in general decline since 2011 and was \$43/lb-U_3O_8 in 2015 or 18% below the 2011 peak. Realized prices for the U.S. uranium supply industry varies from one company to another. Comparing realized prices to the spot market price during the period 2011 to first three quarters of 2016 shows that some mining companies' realized prices are spot-market based while others have hedged their exposure to the spot market by locking in prices using a base price escalated approach for a portion of their portfolio. The share of U.S. production coming from companies that are effectively unhedged (no long-term contracts with higher fixed prices) has declined from about 25% in 2012 and 2013 to just 3% in 2015 and 2016.

- **Production Costs**: The EIA reports total industry expenditures for U.S. uranium production, including facility expense, in its annual Domestic Uranium Production Report. Three-year average production costs rose steadily between 2004 and 2009, and were then fairly level between 2009 and 2012 at about $40/lb. The EIA average production costs have steadily declined since 2012, however. While some new lower cost supply was added, U.S. producers have cut costs in response to lower market prices including curtailed operations at higher cost mines, resulting in a three-year average production cost of $31/lb in 2015. Since maintaining production at ISL projects requires continual development drilling, it is appropriate to look at average production plus development drilling costs. Ongoing costs have declined from $49/lb in 2012 to $37/lb in 2015 and could decline further to $35/lb in 2016. The pattern of mine cutbacks over the past few years as well as domestic industry production costs seem to indicate that adding back the $5 per pound cumulative price effect attributed to all DOE inventory material for the Base Scenario in 2014 to 2016 would not have prevented the cutbacks by U.S. producers, although it might have delayed the cutbacks at some facilities. The difference in future DOE price effects between the Base Scenario and Scenario 1 is only $1.4/lb. This is not enough to cause producers to ramp well field development and production activities back up.

- **Margins**: The large spot price margins[93] available in 2006 and 2007 show why there was a rush to bring new properties into production. Despite the cost cutting efforts by the U.S. industry, the spot margins have been negative since 2013, and this is why "unhedged" producers selling at the spot price ramped down their operations at that time. The average realized price margins for the U.S. uranium industry have been mixed at best over the last ten years and have been minimally positive since 2011. Producers with hedged sales portfolios which include contracts with fixed base prices have maintained a positive realized price margin, but as those contracts roll off they can only be replaced by new contracts at lower prices. As a result the realized price margin may be eliminated or go negative in 2017.

- **DOE Inventory Relative to Other Market Factors**: There have been a number of important market factors influencing the markets since DOE inventory affecting the commercial markets began to increase with the first transfers in December 2009. These factors have affected both supply and demand as the markets have gone from balanced in 2008 to highly over-supplied with considerable excess supply capacity and large excess inventories at present. Important factors in addition to the DOE inventory releases include demand losses in Japan resulting from the March 2011 accident at Fukushima Daiichi; demand losses resulting from changes in Germany energy policy; increased uranium production in Kazakhstan (compared to 2008); increased secondary supply (other than DOE inventory) from underfeeding by enrichers and upgrades of DUF_6 in Russia; ramp up in supply from the Russian Suspension Agreement; ramp up and subsequent end of U.S. - Russian HEU Agreement in 2013. The DOE inventory was equivalent to about 6% of all the uranium market factors (including DOE) in 2012, rising to 9% in 2013-2014 before declining back to 7% in 2016. The total of all the non-DOE uranium market factors is expected to remain fairly constant over the next decade as the slow increase in Japanese reactor restarts is offset by additional retirements in Germany. The Base Scenario DOE share averages 8% in 2017-2019, but then drops to 1% in 2021-2023 before returning to 7% in 2024-2026. If Scenario 1 DOE inventory is assumed, the DOE share declines to 3% in 2017-2020 but is similar to the Base Scenario thereafter. Scenarios 2 and 3 are similar to the Base Scenario.

[93] Spot price less production and development costs per pound produced.

- **Price Effects**: The uranium market price effect attributed to DOE inventory averaged $5.1 per pound over the last three years (2014-2016) using the cumulative method for calculating market clearing price. This is equivalent to 14% of the average spot price and 10% of the average term price in those years. If no DOE inventory releases had taken place, then current (2016) market prices would be $4.9 per pound higher as the price effect attributed to DOE inventory is already built into current market prices. The uranium market price effect attributed to DOE inventory averages $3.0 per pound over the next ten years under the Base Scenario using the cumulative method for calculating market clearing price. This is equivalent to 7% of the clearing price calculated if no DOE releases had taken place since 2009. The uranium market price effect attributed to DOE inventory declines to $1.6 per pound over the next ten years for Scenario 1. This means that halting all EM transfers for services in 2017 would increase prices by $1.4 per pound ($3.0 - $1.6) relative to the Base Scenario, as the effects of past DOE releases cannot be undone.

Summary of Conversion Market Effects

- **Impact on Conversion Services Sales Volume**: Sales volume effects to ConverDyn due to the introduction of DOE inventory result in a sales volume reduction of 6% under the Base Scenario, 2% under Scenario 1, 5% under Scenario 2 and 6% under Scenario 3.

- **DOE Inventory Relative to Other Market Factors**: Conversion market factors do not include increased uranium production in Kazakhstan, but do include the ramp up of supply under the Russian Suspension Agreement. The DOE inventory was equivalent to about 10% of all the conversion market factors (including DOE) in 2012, rising to 15% in 2013-2015 before declining back to 12% in 2016. The total of all the non-DOE conversion market factors is expected to decline slightly over the next decade. The Base Scenario DOE share averages 15% in 2017-2019, but then drops to 2% in 2021-2023 before returning to 15% in 2024-2026. If Scenario 1 DOE inventory is assumed, the DOE share declines to 6% in 2017-2020 but is similar to the Base Scenario thereafter. Scenarios 2 and 3 are similar to the Base Scenario.

- **Impact on Conversion Services Production Cost**: The loss of sales volume is estimated to increase ConverDyn's production costs by 5% under the Base Scenario, up to 1% under Scenario 1, by 4% under Scenario 2, and by 5% under Scenario 3.

- **Workforce Reduction Associated with Volume Reduction**: When Metropolis Works restarted in 2013, the workforce was 80% of the pre-shutdown workforce in early 2012. The decrease in work force was due to lower market demand. In January 2017, Honeywell announced a planned staffing reduction through layoffs of 22 full-time equivalent (FTE) employees as well as reduction of contractor staffing. The loss of staff attributed to DOE sales in 2018 is estimated at 14 FTE for the Base Scenario, 5 FTE for Scenario 1, 12 FTE for Scenario 2 and 17 FTE for Scenario 3.

- **DOE Inventory Share of U.S. and World Conversion Services Demand**: The release of approximately 2.1 and 2.4 million kgU as UF_6 of DOE inventory into the market annually in 2017 and 2018, respectively, represents 4% of worldwide conversion services, 5% of accessible world conversion services demand and 13% of U.S. conversion demand under the Base Scenario. Under Scenario 1, release of 0.5 kgU and 0.8 million kgU of DOE inventory into the market in 2017 and 2018, respectively, represents 1% of worldwide conversion services demand, 2% of accessible world conversion services demand and 4% of U.S. conversion demand Under Scenario 2, the release of approximately 1.7 and 2.0 million kgU as UF_6 of DOE inventory into the market annually in 2017 and 2018, respectively, represents 3% of worldwide demand, 4% of accessible world conversion services demand, and 11% of U.S. demand. Under Scenario 3, the release of 2.5 and 2.8 million kgU as UF_6 of DOE inventory annually in 2017 and 2018 represents less than 5% of worldwide demand, 6% of accessible world conversion services demand, and 15% of U.S. demand.

  Price Effects: The conversion market price effect attributed to DOE inventory averaged $0.8 per kgU as UF_6 over the last three years (2014-2016) using the cumulative method for calculating market clearing price. This is equivalent to 12% of the average spot price and 6% of the average term price in those years. If no DOE inventory releases had taken place, then current (2016) market prices would be $1.0/kgU per pound higher as the price effect attributed to DOE inventory is already built into current market prices. The conversion market price effect attributed to DOE inventory under the Base Scenario using a cumulative clearing price methodology averages $0.9 per kgU as UF_6 over the next ten years. This is equivalent to 7% of the clearing price calculated if no DOE releases had taken place since 2009. The price effect for Scenario 1 declines to an average of $0.7 per kgU as UF_6 over the next ten years. This means that halting EM transfers for services in 2017 would increase prices by $0.2 per kgU ($0.9 - $0.7), as the effects of past DOE releases cannot be undone. The average price effect for Scenarios 2 and 3 is similar to the Base Scenario.

Summary of Enrichment Market Effects

- The current over-supply in the enrichment market is due primarily to Fukushima-related demand loss, the premature shutdown of nuclear power plants in the U.S. and Europe, and the subsequent increase in inventories of EUP, with enrichment capacity well in excess of enrichment requirements. Since it is not practical to reduce production from existing centrifuge enrichment capacity, excess capacity is redirected to uranium production in the form of UF_6 by underfeeding and re-enriching tails. However, retiring centrifuge cascades are not being replaced and in 2016 Urenco mothballed a small amount of capacity in the U.K.

- The release of 0.4 million SWU per year associated with the entry of DOE inventory into the market during the period 2017 to 2026 under all four scenarios represents 1% of worldwide enrichment services demand, 1% of accessible world enrichment services demand, and 3% of U.S. enrichment services demand over this period.

- Enrichment market prices have declined by 70% in the spot market and by 66% in the term market since the Fukushima nearly six years ago.

- **DOE Inventory Relative to Other Market Factors**: Similar to conversion, enrichment market factors do not include increased uranium production in Kazakhstan. The DOE inventory was equivalent to about 8% of all the enrichment market factors (including DOE) in 2012, rising to 13% in 2013 before declining back to 10% by 2016. The total of all the non-DOE enrichment market factors is expected to decline modestly over the next decade. The Base Scenario DOE share remains about 10% in 2017-2019 but then declines to an average of 5% in 2020-2023 and is 0% by 2025. The release of DOE enrichment services is the same for all four scenarios.

- **Price Effects**: The enrichment market price effect attributed to DOE inventory averaged $6.5 per SWU over the last three years (2014-2016) using the cumulative method for calculating market clearing price. This is equivalent to 9% of the average spot price and 8% of the average term price in those years. If no DOE inventory releases had taken place, then current (2016) market prices would be $7.7/SWU per pound higher as the price effect attributed to DOE inventory is already built into current market prices. The enrichment market price effect attributed to DOE inventory under the Base Scenario using a cumulative clearing price methodology averages $8.2 per SWU over the next ten years. This is equivalent to 9% of the clearing price calculated if no DOE releases had taken place since 2009. The enrichment price effect is the same across all four scenarios.

GLOSSARY

centrifuge – A device that can spin at extremely high speeds and separate materials of different densities. For uranium, centrifuges are able to separate the uranium-235 isotopes from the uranium-238 isotopes based on their difference in atomic weight.

conversion – In the context of nuclear fuel, the process whereby natural uranium in the form of an oxide is converted to uranium hexafluoride.

depleted uranium (DU or DUF_6) – Uranium whose content of the fissile isotope uranium-235 is less than the 0.711 percent (by weight) found in natural uranium, so that it contains more uranium-238 than found in natural uranium.

down blending – The term used to describe the process whereby highly enriched uranium is mixed with depleted, natural, or low enriched uranium to create low enriched uranium.

enriched uranium – Uranium whose content of the fissile isotope uranium-235 is greater than the 0.711 percent (by weight) found in natural uranium. (See uranium, natural uranium, and highly enriched uranium.)

enrichment – In the context of nuclear fuel, the separation of the uranium-235 isotope from the more common uranium-238 isotope to create enriched uranium.

equivalent – In the context of uranium concentrates equivalent, conversion services equivalent, enrichment services equivalent, this refers to the equivalent amount of each of these materials and services that is included in the LEU that is derived from the blended down HEU. While the LEU is not physically subdivided into these components, from a commercial perspective the components can be transferred individually.

fissile material – Any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

gaseous diffusion – A uranium enrichment process where uranium hexafluoride in gaseous form is forced through a series of semi-porous membranes to increase the concentration of uranium-235 isotopes.

highly enriched uranium or HEU – Uranium whose content of the isotope uranium-235 has been increased through enrichment to 20 percent or more (by weight). (See natural uranium, enriched uranium, and depleted uranium.)

in situ leaching (ISL) or in situ recovery (ISR) –The extraction of uranium by injecting a solution underground which then leaches the uranium from a permeable ore-body. The uranium containing (pregnant) solution is pumped back to the surface and processed to produce uranium concentrates. The process involves little surface disturbance and no tailings or waste rock generation.

kgU – Kilograms of uranium.

long-term or term price – In the context of this report, refers to the price paid for nuclear fuel materials and services that will be delivered more than one year after the contract is signed.

low-enriched uranium or LEU – Uranium whose content of the fissile isotope uranium-235 has been increased through enrichment to more than 0.7 percent but less than 20 percent by weight. Most nuclear power reactor fuel contains low-enriched uranium containing 3 to 5 percent uranium-235.

MT and MTU – Metric tons and metric tons of uranium.

natural uranium or NU– The material provided to a uranium enricher for producing enriched uranium and uranium tails.

reactor core – The fuel assemblies, fuel and target rods, control rods, blanket assemblies, and coolant/moderator of a nuclear power plant. Energy is produced in this part of the nuclear power plant.

separative work units or SWU – The unit of measurement for the effort needed to enrich uranium.

spot market price or spot price – In the context of this report, refers to the price paid for nuclear fuel materials and services that will be delivered soon (e.g., usually within 12 months) after the contract is signed.

tails – Refers to depleted uranium produced during the uranium enrichment process.

term or term market price – See **long-term price**.

uranium concentrates or U_3O_8 – The form of uranium that is the end product of the uranium milling process, which follows mining of the uranium ore. This compound can be converted through a uranium conversion process into uranium hexafluoride.

uranium hexafluoride or UF_6 – The form of uranium that is the end product of the uranium conversion process. This compound can be easily transformed into a gaseous state at relatively low temperatures to allow the uranium to feed through a uranium enrichment process, either gaseous diffusion or gas centrifuge.