MODULE B

Conversion

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B-MD. SHORT DESCRIPTION OF METHODOLOGY USED FOR ESTABLISHMENT OF MOST RECENT COST BASIS AND UNDERLYING RATIONALE

- **Constant $ base year for 2017 Update:** FY 2017
- **Nature of this 2017 Module update from previous AFC-CBRs:** Escalation only
- **Estimating Methodology for latest (2012 AFC-CBR) technical update from which this 2017 update was escalated:**
  - Price and market analysis similar to that use for Uranium Mining & Milling (Module A1)

It should be noted that Module B (Conversion) prices should correlate with mining and milling (ore) unit costs and uranium enrichment costs. This fact should be recognized in any analysis.

B-RH. REVISION HISTORY

- **Version of AFC-CBR in which Module first appeared:** 2004 as Module B.
- **Latest version of module in which new technical data was used to establish unit cost ranges:** 2012
- **New technical/cost data which has recently become available and will benefit next revision:**

  The US conversion plant at Metropolis, Illinois has had to make several NRC-mandated safety upgrades to maintain its license. These may affect the price the owner must charge to cover costs.

  Due to recent poor market conditions (late 2017) the metropolis plant is being placed in standby mode.

  The availability of byproduct HF from depleted UF6 deconversion operations could help reduce feedstock costs to conversion plant owners.
- **A market analysis in 2016 served as a "spot check" on the situation in the market for conversion.** A summary of that spot check is included in section B-6.1.

B-1. BASIC INFORMATION

Module B discusses the step in the nuclear fuel cycle where the mined natural U_3O_8 concentrate is further purified and converted to a natural uranium hexafluoride (UF_6) solid in cylinders for feed to a uranium enrichment plant (Canaux 1997). It involves receipt of feed stock, chemical operations, and shipment of cylinders.

Conversion of the U_3O_8 yellow cake to UF_6 is driven basically by the need for chemically-purified uranium gaseous form to enrich for fuel fabrication. The U.S. annual demand for conversion (as of 2012) is approximately 22,000 MTU. Worldwide, the demand for conversion is approximately 64,500 MTU per year, excluding Pakistan, India, and China. The major suppliers of conversion capability are BNFL/Cameco (United Kingdom), Cameco (Canada), Areva (France), ConverDyn (U.S.), and Rosatom (Russia). The Russian capacity is utilized internally and not available for export at this time.

The U.S. capacity resides in only one facility, Honeywell Specialty Chemicals, located in Metropolis, Illinois. The nominal 14,000 MTU/yr capacity is marketed by ConverDyn, a joint venture of Honeywell International and General Atomics. Because the U.S. demand of approximately 22,000 MTU/yr exceeds supply, the U.S. uses both domestic and foreign sources of conversion services. This facility has been in service since 1959 and ConverDyn plans to expand its capacity to 18000 MTU/yr by around 2013 (Steyn, Danilov 2008). A second conversion facility, the Sequoyah Fuels Corporation plant, was operated by General Atomics and located in Gore, Oklahoma. However, following numerous safety and environmental challenges, it was shut down in 1992 and is now undergoing decommissioning.

The cost of conversion represents only approximately 4% of the overall cost of fuel manufacture and is representative of a competitive market relative to cost of operations. Conversion cost is typically reported in U.S. dollars/kgU in the UF_6 product and includes related transportation costs to the enrichment plant.

B-2. FUNCTIONAL AND OPERATIONAL DESCRIPTION

Following formation of the U_3O_8 "yellow cake" at the mill, the uranium must be further purified and enriched as necessary for use as a reactor fuel. The chemical and physical form of the conversion product depends on the subsequent use of the product. If enrichment is not required, such as for many CANDU-type pressurized-heavy-water reactors (PHWRs), the yellow cake can be processed directly to UO_2 for fuel fabrication. In the more common LWR fuel cycle case, enrichment of the ^{235}U is desired, and the yellow cake is converted to a purified UF_6 gas suitable for subsequent enrichment operations. The "conversion" to UF_6 is achieved using either a wet or dry chemical process.

The basic steps of a dry process are as follows. The yellow cake is ground into a fine powder and fed into a fluidized bed reactor at 1,000–1,200°F where it is reduced by hydrogen and emerges as uranium dioxide (UO_2). The crude UO_2 is passed through two successive hydrofluorination fluidized bed reactors, where interaction occurs with anhydrous hydrogen fluoride (HF) at a temperature of 900–1,000°F. Uranium tetrafluoride (UF_4), a green salt, is formed which is a nonvolatile solid with a very high melting point. The UF_4 is treated at high temperatures with fluorine gas (F2) to form UF_6 gas. Volatile impurities are removed at several steps in this process, leaving a uranium product that is at least 99.95% pure (see Figure B1– 1).

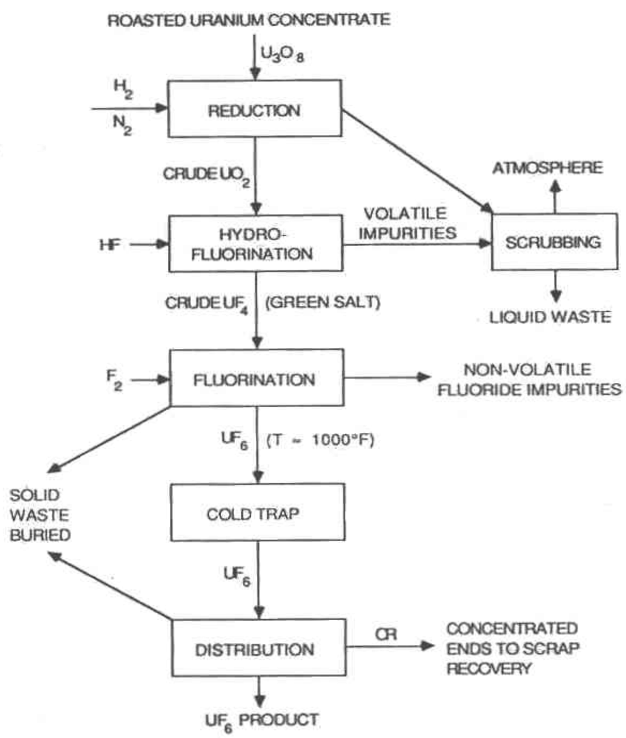

Figure B1– 1 Simplified flow chart of the dry hydrofluorination process to convert U3O8 to UF6.

The basic steps of a wet process are similar to the dry process, but the yellow cake is initially dissolved in nitric acid and goes through a solvent extraction process to remove impurities. The extraction is followed by the hydrogen-reducing furnace as well as the hydrofluorination and the fluorination steps to again produce a very pure UF_6 gas (see Figure B1– 2).

With both processes, the UF_6 gas is distilled to remove the light fraction gases, pressurized, and cooled into a liquid. In the liquid state, it is drained into 14-ton mild steel cylinders where it solidifies after cooling for approximately 5 days. The UF_6 is a solid at room temperatures, which makes it easy to handle and ship. At a slightly elevated temperature above the triple point (~147°F), it becomes a gas, which makes it ideal for current enrichment technologies. As future enrichment technologies develop, the needed chemical and physical form of the conversion product could change (Varley 1997). Physical losses are small (<0.5%).

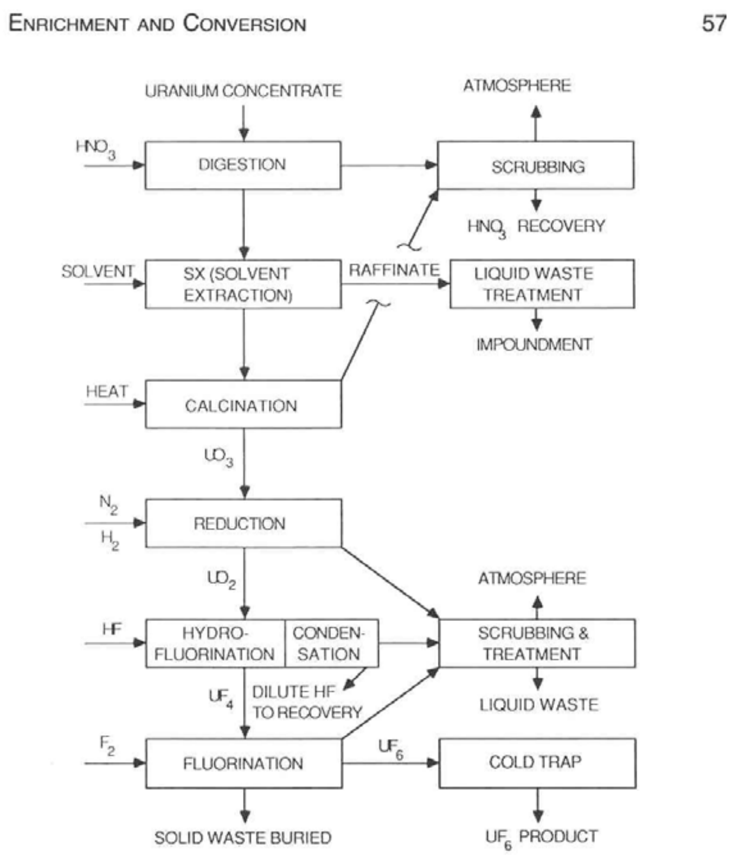

Figure B1– 2 Flow chart of the wet solvent extraction-fluorination process to convert U3O8 to UF6.

B-3. PICTURES AND DIAGRAMS

Cameco is an integrated uranium fuel supplier with fuel services facilities (conversion and fuel fabrication) at Port Hope, located in Ontario, Canada. (The company's Port Hope conversion services plants chemically change the form of the [UO_3] to either uranium hexafluoride [UF_6] or uranium dioxide [UO_2]). During 2006, Cameco became a nuclear fuel manufacturer by acquiring Zircatec Precision Industries, Inc. (Zircatec) in Port Hope. Zircatec manufactures natural UO2 fuel bundles for use in Canada deuterium uranium (CANDU) reactors. Pictures of the conversion facility are shown in Figure B1– 3 and Figure B1– 4. A loaded UF_6 cylinder is shown in Figure B1– 5.

Figure B1– 3 Port Hope Conversion and Fuel Fabrication Plant (Cameco) in Ontario, Canada.

Figure B1– 4 Port Hope conversion facility.

Figure B1– 5 Loaded UF6 cylinder at Port Hope.

B-4. MODULE INTERFACES

The need for conversion services is highly dependent on Modules A, C1, C2, D1, F2/D2, and K, which essentially define the supply and demand relationship. Raw uranium pricing impacts the source uranium cost of conversion. The availability of mixed oxide, reprocessed uranium, and/or blend down of highly enriched uranium (HEU) impacts demand for enrichment services from UF_6. Timing of fuel fabrication also impacts the need for conversion services. In addition to real-time feed and product needs, decisions relative to inventory levels along the front-end of the fuel cycle will have impact on this conversion module.

The key dependencies on supply and demand as impact costs are discussed in the following subsections.

B-4.1 Supply

Mid-2012 world nameplate annual conversion capacity stands at around 75,000 tonnes U in UF_6 (Table B-1). This is considerably in excess of requirements, even if secondary supplies of conversion services[a] are discounted. Important secondary supplies include the ca. 9,000 tU in UF_6 of conversion requirement avoided by HEU down blend [Schwartz et al 2012a] (see Module C2) and inventories of natural U as UF_6 held by utilities and governments around the world.

In France, AREVA anticipates the COMURHEX II facilities at Malvesi and Pierrelatte to enter production in 2012, reaching a capacity of 15,000 tU in UF_6/year shortly thereafter (WNA 2007a). COMURHEX II involves substantial renovations and construction at Malvesi and an entirely new plant at Pierrelatte. These operations will improve the efficiency of the chemical process equipment and the waste treatment systems. While the project will add only 1,000 tU/year of capacity as compared to the current COMURHEX level, the AREVA website[b] indicates that capacity may rise to 21,000 tU in UF_6/year.

As reported in the *2009 Advanced Fuel Cycle Cost Basis Report*, the industry has been beset with temporary plant closures and production shortfalls, notably at Port Hope, Ontario in Canada. Also, the nominal capacities reported in Table B-1 cannot be achieved at each plant. Port Hope, with a nameplate capacity of 12,500 tU in UF_6/year, has been reported to sustain an annual operating capacity of 8,000 – 10,000 t/year. The Rosatom (Russia) facilities together represent 24,000 tU in UF_6/year of nameplate capacity, but a significant portion of that is not maintained and currently not operational. Operating capacity has been estimated at just 11,000 [Schwartz et al 2012b] to 18,000 [WNA 2012] tU in UF_6/year and actual production during 2008-10 averaged 8,500 tU in UF_6/year [Schwartz et al 2012b].

Part of the Metropolis Works (MTW) in Southern Illinois is offline indefinitely, so that plant has a de facto capacity of 12,000 tU in UF_6/year [Schwartz et al 2012b], 20% below its nameplate level; during 2007-10, production at MTW averaged 9,110 tU in UF_6/year [ENERCON 2012]. In part, this reflects a slowdown associated with a labor disagreement that was resolved in 2010. In July 2012, the US Nuclear Regulatory Commission issued a finding that the UF_6 released from “a credible seismic event could result in a higher risk to the public than currently assumed.” As a result, MTW will likely be offline for 12-15 months, through late 2013, while it conducts remedial actions [Steiner-Dicks 2012].

Springfields (United Kingdom) is managed by Westinghouse for the UK Nuclear Decommissioning Authority, but Cameco has contracted for 5,000 tU in UF_6/year conversion services to process UO_3 feed from its Blind River Refinery. Once Cameco’s contract expires in 2016 it is likely that Springfields will be decommissioned.

Table B-1. Nominal June 2012 conversion capacities.[1]

Operator / Plant(s)	June 2012 Capacity (tU in UF_6/year)	Technology, Notes
CNNC/Lanzhou, China	3,000	
AREVA-Comurhex/Malvesi and Pierrelatte, France	14,000	Wet process: UF_4 conversion at Malvesi, fluorination to UF_6 at Pierrelatte. Comurhex II coming online 2012.
Cameco/Port Hope, Canada	12,500	Blind River refines yellowcake to high purity UO_3. Port Hope (wet process) converts purified UO_3 to UF_6.
Westinghouse – Cameco / Springfields, UK	6,000	Wet process: Main Line Plant converts to UF_4, Hex Plant to UF_6. May cease operations in 2016.
ConverDyn / Metropolis, IL,USA	15,000	Dry process.
Rosatom / Angarsk, Sverdlovsk-44, Russia	24,000	Wet process: UF_4 conversion at Chepetsk Mechanical Plant, fluorination to UF_6 at Angarsk and Sverdlovsk-44
TOTAL	**74,500**	

1. Only plants having greater than 250 tU/yr capacity reported. Data Source: Ref. B-1. Note that at some facilities operable capacity may be significantly lower than nominal capacity: see text.

[a]. Secondary supplies of conversion represent avoidance of the need to convert natural uranium. This may come about if the uranium was previously converted and is stored as UF_6, or if reactor fuel can be directly produced without the need for conversion and enrichment (e.g. HEU down blend, or conversion to UO3 for PHWR fuel—see footnote 17).

[b]. http://www.areva.com/EN/operations-806/the-comurhex-ii-project-modernization-of-the-industrial-conversion-facility.html

Taken together, the outages, pending retirements and unavailable capacity indicate a considerably tighter supply situation than a comparison of Table B-1 with requirements would indicate. In the near term, the temporary closure of MTW in particular is likely to spur higher prices. On the other hand, much capacity could be brought online relatively quickly by refurbishing unused equipment. Therefore, when looking to medium to long term costs, a future pattern of frequent closures and low facility availability will be considered to inform the high cost estimate. The nominal and low estimates will assume that recent events are not indicative of industry performance in the future.

B-4.2 Demand

Requirements for conversion services closely track uranium requirements, with small differences arising from reactors that use natural uranium as fuel and need no enrichment[c]. The Energy Resources International, Inc., reference forecast predicts that conversion requirements will rise from their 2012 level of 58,000 tU in UF_6/year to 73,000 tU in UF_6/year in 2020 and of 92,200 tU in UF_6/year in 2030 [Schwartz et al 2012b]. The contemporary requirement is somewhat lower than the value in the *December 2009 Advanced Fuel Cycle Cost Basis Report* because elevated uranium prices have pushed utilities to conserve uranium by lowering enrichment tails U-235 assays. The reduction in uranium requirements also lowers the need for conversion services.

Thus, existing capacity, if refurbished, fully utilized and reliably operated, along the mooted AREVA and expansion and secondary conversion supplies would be adequate to meet demand through this decade.

B-5. SCALING CONSIDERATIONS

Scale-up is not an issue for application of mature technology. Additional capacity can be added via expansion of existing facilities or new capacity. Location relative to enrichers within a continent is of importance because shipping UF_6 overseas adds cost, requires additional time, and thus more in-pipeline inventory.

B-6. COST BASES, ASSUMPTIONS, AND DATA SOURCES

The historical spot market price of conversion services is shown in Figure B1– 6. Most conversion service requirements are met via long term contracts and these have not shown the volatility of the spot prices. They are reported to have remained at around $11-12/kg U as UF6 from 2005-10, closely tracking the spot price. Since that time, though, they have risen steadily, reaching $16.75/ kg U as UF6 as of the end of the first quarter of 2012 [Schwartz et al 2012b]. This reference also notes that the work slowdown at MTW as well as an announcement by ConverDyn regarding future pricing (discussed below) coincided with the increase in long-term contract prices. Contract prices lag spot prices, so the contract price may decline in the near future. Or the low spot price could be a function of lowered expectations for demand post-Fukushima as well as a short-term supply glut. [2017 Note: As of June 26, 2017 the North American and European spot price per UxC stands at $5/kgU as UF6 in an extremely depressed market.]

[c]. These fuels still require conversion services of a sort – from U_3O_8 to UO_3 with an intervening aqueous purification step and subsequently to UO_2. In Canada, the UO_3 operations are carried out at the Blind River refinery, and Port Hope contains facilities for converting the UO_3 to both UO_2 for domestic use and UF_6 for export.

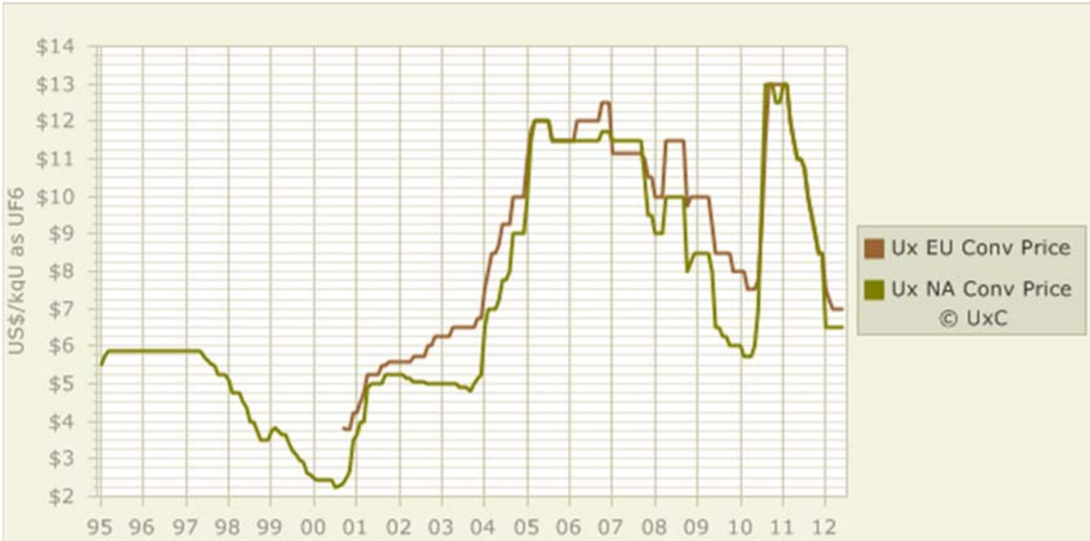

Figure B1– 6 UxC Conversion Spot Prices, 1995-2012, for European (EU) and North American (NA) deliveries. Figure source: The Ux Consulting Company, LLC, http://www.uxc.com/.

An essay at the website of UxC, a brokerage firm whose spot price data is shown in Figure B1– 6, suggests that raw material expenses have played a role in elevating conversion prices [Ux Consulting]. The costliest raw material input to the conversion process is hydrofluoric acid (HF). HF is in turn produced by reacting the mineral fluorspar (CaF_2) with an acid. China, Mexico, South Africa and Canada are major producers of fluorspar, with the United States receiving most (78% in 2011) of its supply from Mexico [USGS 2012]. The spot market price of fluorspar experienced a boom in 2007-08, increasing by 140% from early 2007 to its peak in the fourth quarter of 2008. This boom was in part caused by an increase in an export tax in China, a major producer, as well as sharply increasing demand inside of China and worldwide [Henkel Adhesive Technologes 2009]. Fluorspar prices, which had stood at $290/tonne at the end of 2010, rose again in 2011, reaching $450/tonne[d] by the end of that year, $600/tonne when insurance and freight are included.

Fluorine derivatives are widely used across the industrial sector, for instance in the production of refrigerants. Conversion related consumption of fluorspar represents a tiny fraction of world consumption. For example, US consumption of fluorspar in 2011 was 454,000 tonnes [USGS 2012]. Even if the domestic converter, Metropolis Works, operated at its full capacity of 15,000 tonnes U in UF_6 per year, it would require the equivalent of 14,700 tonnes of fluorspar, just 3.2% of domestic consumption[e]. And even at the end-2011 delivered fluorspar spot price of $600/tonne, purchase of fluorspar would only contribute $0.59/kg U in UF_6 to the cost of UF_6 conversion[f].

The large and diverse demand pool is considered to make it more likely that new fluorspar resources will be prospected and exploited. Additionally, substitutes may be developed within other industries where the commodity is used, restraining prices from increasing dramatically over the long term. While speculative effects and stockpiling arising from a sudden, unexpected increase in the price of fluorspar could affect short-run conversion prices, as arguably occurred in the late 2000s, the contribution of the fluorine input to the cost of UF_6 conversion remained relatively small. While modest further increases in

[d]. Prices are numerical averages of Chinese- and Mexican-delivered free on board (f.o.b.) fluorspar filtercake.

[e]. There are 0.487 kg of fluorine per kg of fluorspar and 0.479 kg of fluorine per kg of U in UF_6. Fluorination of 15,000 tonnes U per year thus requires (15,000)*0.479/0.487 = 14,700 tonnes of fluorspar.

[f]. ($0.60/kg CaF_2)*(2.052 kg CaF_2/kg F)*(0.479 kg kg U in UF_6/kg F in UF_6) =$0.590.

the price of fluorspar are possible, in the long term it is considered unlikely that these will materially affect the cost of conversion.

The cost of energy inputs is more substantial. Metropolis works, which uses a "dry" conversion process, reported average electricity and natural gas consumption over 2007-10 of 6.8 MWh/tonne U as UF_6 and 4.59 thousand cubic meters/tonne U as UF_6, respectively [Enercon 2012]. Other facilities around the world use the wet process, but data furnished by AREVA indicated roughly equivalent final energy consumption on a per unit product basis [Simon et al 2011][g]. Assuming for illustration electricity prices of $100/MWh (10 cents/kWh) and natural gas prices of $111 per thousand cubic meters[h], the direct energy costs for Metropolis would be roughly $1.2/kg U as UF_6.

To this must also be added the energy consumed in creating feed chemicals, particularly hydrofluoric acid. In the 1970s, Rotty estimated the energy embodied in process materials (as cited in [Simon et al 2011]) at 4.25 MWh/tonne U as UF_6 and 3.09 thousand cubic meters of gas/tonne U as UF_6. Using the prices given above, the energy used to create process materials would cost an additional $0.77/kg U as UF_6, bringing the total contribution of operational energy use, both direct and via energy embodied in materials, to roughly $2.0/kg U as UF_6. This constitutes a substantial share of the nominal conversion cost estimate presented in Section B-3 below – one that would increase if natural gas prices rise from their current (2012) depressed levels.

True production costs at the various conversion facilities around the world are proprietary, and market effects are such that prices are not generally tied to production costs at any one facility. But some information can be gleaned. In late 2010, ConverDyn disclosed that its conversion operations were incurring financial losses and as a result it would not offer conversion services at prices lower than $15/kg U as UF_6 [Schwartz et al 2012b]. MTW's production costs can thus be inferred to be at or near this level. It may be the case that MTW is the marginal (i.e. costliest to operate) producer and its move spurred the increase in long term contract prices mentioned earlier. Having been in operation for over 50 years, MTW is the oldest supplier, and as such it is reasonable to assume its operating costs are higher than those of the modern plants.

It should be noted that hydrofluoric acid (HF) is now (2017) being produced as a byproduct of the deconversion of depleted UF6 "tails" from uranium enrichment plants. (See Module K1). Use of this very slightly contaminated HF in another nuclear facility such as a conversion plant is an ideal symbiotic use.

Recent studies by Harvard University, Massachusetts Institute of Technology, and Atomic Energy Commission-Nuclear Energy Agency (CEA-NEA) suggest a range of $4–8/kgU is reasonable for evaluation of conversion services (Nuclear Energy Agency 1994; Bunn et al. 2007; Deutch et al. 2003). This is based on the adequacy of secondary supplies for uranium and an expected leveling of inventory management. At present, secondary supplies ensure that primary uranium requirements (tU as U_3O_8/yr) are not equal to UF_6 conversion requirements (tU as UF_6/yr). HEU downblend by the U.S. and Russia is one such source. This and the release of DOE-held UF_6 will play a role in UF_6 price evolution. Agreements between the countries control and limit the amount to be placed in to the supply chain. DOE has stated that it will not release UF_6 in amounts greater than 10% of annual domestic demand, so the dramatic drop in price experienced in the late 1990s should be avoided.

Should the demand for natural uranium begin to grow quickly, in the short term the price for conversion could increase. However, as uranium and UF_6 prices go up, the use of more separative work units to drive to a lower enrichment tail becomes a check and balance on longer-term price growth.

[g]. The Areva figures, from the project Epicure reprocessed uranium conversion facility study, are 28.1 MWh/tonne U as UF_6 and 1.94 thousand cubic meters/tonne U as UF_6. The Areva design evidently favors electricity over natural gas combusted on site, but the total energy use (in GJ/tonne U as UF_6) is very similar to that of MTW. The MTW data is used as it is taken from an operating facility.

[h]. A spot price for July 2012 reported at http://www.indexmundi.com/commodities/?commodity=natural-gas.

B-6.1 2016 Spot Market Check on Market for Conversion

The long-term U3O8 to UF6 conversion price trend has generally followed that of U_3O_8, but within a tighter range and without the speculative spike in 2007. Spot prices have descended from $13/kgU in 2011 to $6/kgU as of the end of August, 2016 [UxC 2016]. Unlike U_3O_8, prices for conversion had a plateau for a year in 2013 around $11/KgU due to the main facility in North America (Honeywell's Metropolis, Illinois facility) being down for seismic retrofits[i]. These retrofits were ordered by the NRC in response to Fukushima.

As of 2016, the conversion spot prices are on the lower end of the range in the 2015 CBR (low $6, mode $13, high $19, mean $13/KgU) and the historic prices have only reached the middle of this range. However, prices for conversion were running between $11-13/kgU between 2011 and 2014, indicating the spot market has been depressed, possibly by DOE inventory sales of UF6 [UxC 2015] – See Figure B1– 7.

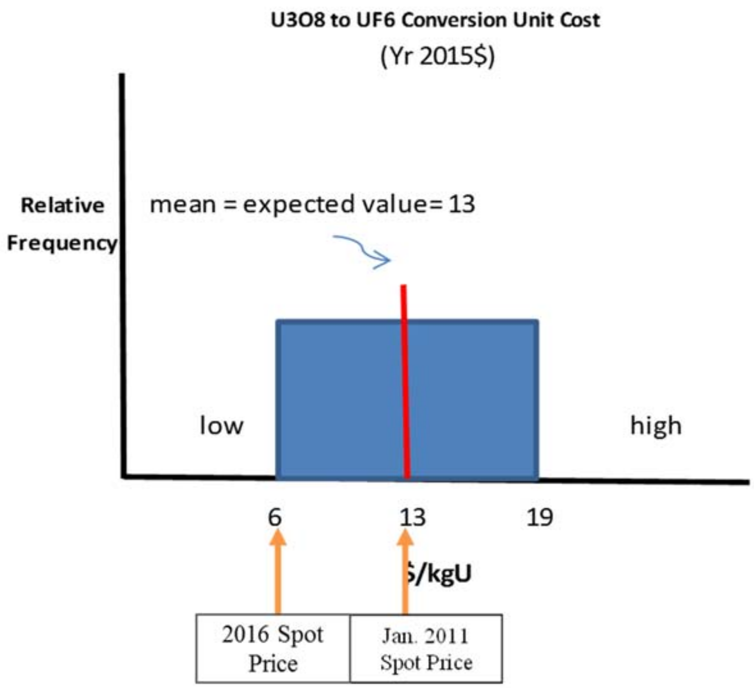

Figure B1– 7 Uranium Conversion Cost Range in 2015 CBR showing 2016 and pre-Fukushima spot prices.

No significant new conversion facilities have been built in 30 years, while demand in Asia had been increasing prior to Fukushima. The current construction in France (Comurhex II) will replace existing capacity. If significant reactor restarts occur in Japan and other construction in Asia and the Middle East continue, or if DOE inventory sales of UF6 cease, then upward pressure on spot prices will occur. For these reasons, we do not recommend any changes in the CBR recommended prices.

B-7. LIMITATIONS OF COST DATA

Most countries are beginning to take a proprietary view of long-term contract costs with reporting becoming less prevalent. Modelers and forecasters must view the total uranium supply picture and use the spot market trends as the feedback tool. Real time costs are relatively low initially, which represents

[i] The other facility in North America is Cameco's Port Hope plant in Ontario, Canada.

typically less than 4% of the fuel cost. Short-term fluctuations should have little to no impact on the overall fuel cycle costs.

B-8. COST SUMMARIES

This section presents low, high and nominal conversion **price forecasts**. Module B, along with other front-end modules, addresses an industry with a well-developed market. Therefore, although the forecasts presented here are labeled 'costs' for consistency with the format used across this report, they should be interpreted as estimates of the long-term average SWU contract price. See the earlier section in this addendum on the use of price data for further discussion.

The **nominal** estimate, \$12/kg U in UF_6, splits the difference between the recent spot and contract prices. It assumes that major supply disruptions, a fixture of the industry from the mid-2000s to the present, are a temporary phenomenon. The projection considers a future where first-generation plants are fully retired in favor of facilities utilizing modern equipment and offering favorable operating costs. This transition is being completed in the enrichment industry: see Section C-1 for discussion. On the other hand, the capital costs of many currently-operating plants are fully amortized, so the depressed spot market prices in 2012 may reflect recovery of operating costs alone and underestimate true production costs. Indeed, in April 2012 an Areva executive stated that the Comurhex II "business plan [is] challenged by current spot prices," [Hatron 2012], implying that production costs at Comurhex II will be above \$6/kg U in UF_6. Finally, the nominal projection assumes that the costs of commodity and energy inputs, which are presently mixed compared to their historical levels, will remain near long-term average values.

The **low cost** estimate, \$6/kg U in UF_6, approximates the 2012 spot price. It considers a future where a competitive transition to a new generation of plants does in fact lead to sharply lower production costs. While this will likely be the case for the enrichment industry where the new generation rests upon a substantially superior technology, the conversion process has taken a more evolutionary development path. This estimate allows for a scenario where the effects of technological advancement are substantial. Lower commodity and energy costs would also militate toward the low cost outcome.

The **high cost** estimate, \$18/kg U in UF_6, is close to the early 2012 long term contract price. If the industry continues to suffer from low availability, especially under conditions of strong demand growth and exhaustion of secondary sources of conversion supply, available suppliers will be operating at or near capacity and high prices can be expected to continue. By increasing production costs at all facilities, elevated input commodity and especially energy prices could also push future prices toward the high cost estimate. Per the 2009 CBR, a uniform distribution is recommended for Conversion costs.

Table B-2 summarizes the recommended unit cost range from previous versions of the AFC-CBR.

Table B-2. "What-it-takes" (WIT) Table , 2012\$.

Low Cost	High Cost	Nominal Cost
\$6/ kg U in UF_6	**\$18/ kg U in UF_6**	**\$12/ kg U in UF_6**
2009 CBR Values (in 2009\$):		
\$5/ kg U in UF_6	*\$15/ kg U in UF_6*	*\$10/ kg U in UF_6*

Table B-3 shows the 2012 AFC-CBD values escalated to year 2017 dollars and appropriately rounded. Note that with rounding this range is nearly the same as in the 2015 version, where a factor of 1.05 was used to escalate from 2012\$ to 2015\$. Using the escalation table from the front of this report, a value of 1.088 was used to escalate from 2012\$ to 2017\$. Keep in mind that these are long term price projections based on a price which are assumed to cover production costs. Today's (July 2017) price of \$5/kgU would not be sustainable over the long term of many decades.

Table B-3. “What-it-takes” (WIT) Table escalated to 2017 $.

Low Cost	Mode Cost	Mean Cost	High Cost
$6.5/ kg U in UF_6	**$13/ kg U in UF_6**	**$13/ kg U in UF_6**	**$20/ kg U in UF_6**

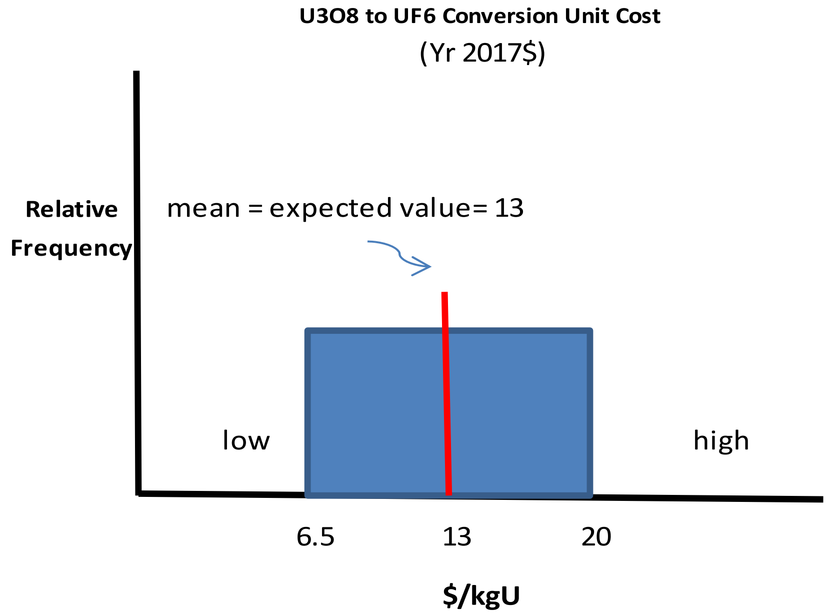

Figure B1– 8 Uniform distribution and parameters for Conversion Cost

This distribution is uniform, with every price between the lower and upper limits being forecast as equally likely to occur. See Section B-9 for discussion.

B-9. SENSITIVITY AND UNCERTAINTY ANALYSIS

Prior studies have highlighted the relative insensitivity of conversion cost to the overall fuel cycle as the conversion cost represents generally less than 4% of the fuel cost. The impact of doubling the price impacts the cost by only a few percent.

Figure B1– 9 is a histogram of monthly conversion prices on the spot market as reported by Ux Consulting, LLC. This data has been adjusted for inflation using the CPI and extends back to January 1981. It shows that prices have varied considerably, from a low of around $2.50/kgU in 1983 and again in 2000 to a high of nearly $13/kgU in 2005. This trend of variability, with prices varying by a factor of three or more over the time period for which data is available, is not atypical of market-driven prices for front-end services. Given the historically wide variation in conversion prices, then, a rectangular rather than triangular distribution is chosen for the cost distribution proposed in this module.

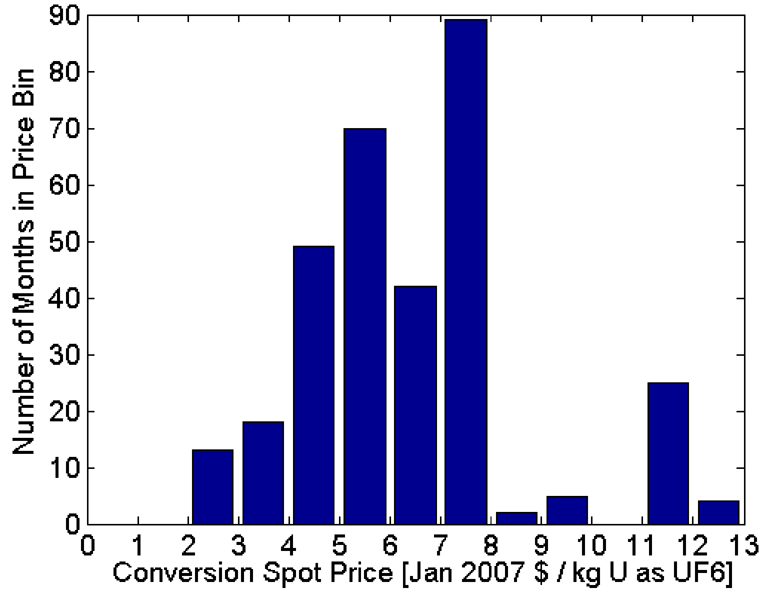

Figure B1– 9 Histogram of monthly conversion spot price.

B-10. REFERENCES

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