STATUS REPORT ON THE COST AND AVAILABILITY OF ENRICHED URANIUM FOR RESEARCH REACTORS

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ABSTRACT

Availability and price development of enriched uranium contained in fuel elements for research reactors plays an important role with regard to reliability and economic and planning reasons. The leading price factors of LEU (19.75% enriched uranium metal), are the contained natural uranium equivalent in the form of UF6 (feed component), the separative work of the enrichment (SWU), conversion of the enriched uranium into metal form and associated services, such as transportation. World market price of feed material for enrichment was more or less stable in the last decades. After very moderate feed price increases between 2001 and mid-2003, the price gained momentum and almost doubled in the short period between the 2nd half of 2003 and year-end 2004.

This paper tries to give an answer to the question how the increased feed and SWU price affects the price and availability of LEU for research reactors. This paper deals also with the historic development of supply sources and origins of LEU, present status of supplies, price formulae, available stocks, value and advantages of fuel origin and return possibilities of spent LEU.

1. Introduction

Mandatory for the operation of research reactors is the safe supply of fresh fuel and a viable option for the disposal of spent fuel. In the 1990s both the supply of fresh LEU and the take-back of spent fuel were adversely affected by the U.S. side due to a supply problem at the Y-12 plant and the lack of timely renewal of the U.S. Return Program for spent fuel. In the European Union (EU) the shortfall of supply from the US could be bridged by the use of no longer needed, considerable stocks of enriched uranium. This supply was organized by RWE NUKEM.

The question is now whether a supply gap will again occur and whether research reactor operators can rely on a stable pricing for the needed LEU.

2. Historical development

As in the past the major suppliers of LEU were Russia and the U.S. From the 1960s until the mid-1980s, the material supplied by the U.S. for production of fuel elements for research reactors inside and outside the USA was mainly highly enriched uranium (HEU). In the same period, the Soviet Union supplied HEU with enrichments from 36 to 90% U-235 in the form of fuel elements to Soviet-designed research reactors inside and outside the Soviet Union.

In 1977, U.S. President Carter expressed concern about the widespread use of weapons-grade uranium in research reactors worldwide. In the same year, the USA launched a program to reduce enrichment in research reactors in Western countries in order to eliminate proliferation risks and misuse of HEU. The International Fuel Cycle Evaluation (INFCE) under Working Group 8 [10] recommended that the ideal U-235 assay for research reactor fuel should be less than 20%, namely 19.75%, in order to address the non-proliferation concerns of the U.S. In 1978, the U.S. installed a program to reduce the enrichment of research and test reactors (RERTR Program) under the lead of the U.S. Department of Energy (USDOE) and Argonne National Laboratories with the goal to convert all reactors with HEU fuel to LEU fuel and to reduce the annual export of U.S. HEU as a first step from 450 kg/a to 150

kg/a. After the end of the Cold War, Russia joined the RERTR Program with the same objective to reduce enrichment in Russian-supplied research reactors.

Following the success and progress of the worldwide conversion program to replace highly enriched uranium (HEU) by low enriched uranium (LEU) the standard fuel for research reactors is uranium with an enrichment of 19.75% U-235 in the form of metal pieces.

3. Supply sources of LEU

Today, LEU is mainly provided by the U.S. by using excess military stocks of HEU. The U.S. has discontinued the production of fresh HEU, and has major programs underway to reduce their surplus stockpiles of HEU. In Russia, HEU may still be produced for civil purposes (fast reactor and research reactor fuel).

Through another international program Russia is selling uranium for power reactors below 5% U-235 derived from 500 tons of Russian surplus HEU to the USA, and the USA has a separate program to eliminate 174 tons of U.S. HEU that has been declared surplus. Together these programs are currently supplying up to 15% of the uranium demand for power reactors worldwide.

The United Kingdom, France, and South Africa have discontinued all HEU production.

4. Annual demand for LEU

The annual quantities of HEU needed to produce LEU for research reactors are relatively small. It is estimated that at present among the Western countries about 1 ton of LEU is being used to fuel already converted reactors. This quantity could increase to 2-3 tons if high flux reactors in the USA and the EU would be converted to LEU as well. The production of 3 tons of LEU would be equivalent to a dilution of approximately 600 kg of HEU (90% U-235).

5. LEU situation in the USA

The U.S. surplus disposition program for 174 tons of HEU has allocated up to 10 tons of HEU for the production of LEU for research reactors for the period of 2002 to 2016. The LEU is generated by blending down of the HEU to LEU by melting in induction furnaces. The quantity of 10 tons of HEU is sufficient to produce more than 45 tons of LEU.

6. LEU situation in Russia

No exact figures are available, but we have an information that the annual production of HEU fuel in Russia for research reactors inside and outside Russia was in the year 2002 approximately 850 kg with U-235 assays ranging from 20 to 90%.

7. Price factors for LEU

The main price factors for enriched uranium for power reactors are the contained natural uranium equivalent in the form of UF6 (feed component), the separative work of the enrichment (SWU), conversion of the enriched uranium into metal form and associated services, such as transportation. Two factors, namely the natural uranium price and the SWU price, are market related prices and subject to changes. These changes are mainly due to the supply and demand situation, but partly also due to psychological factors, such as the mere perception of supply surplus or scarcity. The recent price shifts in the uranium market show that low prices for LEU - if really determined upon the market prices of the individual cost components - can be no longer taken for granted.

8. World market price developments for natural uranium

Starting in the late-1970s until the mid-1990s, natural uranium prices experienced an almost continuous decline. However, there was a temporary peak in uranium prices around mid-1996, with prices exceeding the level of US$ 16/lb U3O8. But thereafter prices decreased again almost irresistibly and bottomed out late in 2000 and early in 2001, at levels of even slightly below US$ 7.00/lb U3O8. But - as stated earlier - from that time on natural uranium prices increased again almost continuously.

And these were the reasons for this price development:

The fall of the iron curtain around 1990 heralded the gradual evolvement of a global nuclear fuel market. Massive new nuclear fuel quantities became available, first from the Soviet Union and then from the Commonwealth of Independent States (CIS). In the mid-1990s, the release of uranium derived from Russian nuclear weapons was launched. Shortly thereafter, the U.S. government decided to liquidate most of its civil nuclear inventories, through the privatization of the United States Enrichment Corporation (USEC).

This massive influx of uranium from the new supply sources into the Western market depressed prices to extreme low levels - as just stated - causing a cut-back in uranium production and exploration efforts. In effect, inventory holders sold most of their excess material at the cost of the cheapest uranium mines, not noticing that they were driving higher-cost uranium mines out of the business, thus preventing investment in existing and new uranium production centres.

However, more recently a number of events triggered and stimulated the perception of an approaching uranium supply shortage, thereby accelerating uranium price increases throughout 2003 and 2004:

- Secondary nuclear fuel supply sources feeding the uranium spot market, such as utility excess inventories, have largely dried out.
- A fire in the solvent extraction area of the Australian Olympic Dam mill late in 2001 led to a sharp cut of the project's output scheduled for 2002.
- In the first half of 2003, the rapid increase of water flowing into the world's largest individual mine, McArthur River in Canada, led to the suspension of production for about three months.
- The accidental UF6 release from Converdyn's Metropolis operations late in December 2003 caused a temporary interruption of part of the light water reactor fuel supply chain in North America as well in Europe. Most importantly, the temporary shutdown of the Metropolis facility was about to adversely effect the provision of HEU feed under the US-Russian HEU-LEU Agreement.
- And - last but not least - according to the amendment of the contractual stipulations of the HEU-LEU Agreement in spring 2004, the Russians were conceded to take back almost 30% of the HEU feed, thereby reducing the Western market's availability of UF6 originating from this deal over its remaining term by about 25,000 tons U.

Despite little new generating capacity being brought on line on a worldwide basis, uranium demand is steadily increasing. Part of this increase is due to NPP capacity factor improvements, upgrading of NPPs, and reactor lifetime extensions. This is happening primarily, but not exclusively, in the USA. As a result, world uranium requirements are continuing their upward trend.

In 2004, natural uranium production worldwide was about 38,500 tons U, compared to the actual demand of around 66,700 tons U. Thus, just below 60% of the total demand was covered by fresh production; the balance of slightly more than 40% came from secondary sources. The prospects concerning the future uranium supply situation are currently not so good:

- There are just a few new uranium production projects in the pipeline.
- There is only limited ability to squeeze additional uranium out of existing projects.

- Lead times of new mining and milling projects are lengthening, partly due to time-consuming Environmental Impact Assessments.
- Producers' willingness to invest in the extension of existing or the start-up of new mines is adversely affected by uncertainties over the timing of potential governmental sales of additional nuclear fuel, such as military uranium and plutonium.
- Exploration activities were extremely low in previous years. However, they buoyed up under the impression of recent uranium price increases.

9. What is the influence of increased natural uranium prices for LEU for research reactors?

Although LEU is mainly produced by blending of HEU, the following pricing parameters could apply if one would adopt the pricing system for low enriched uranium for power reactors:

1 kg of 19.75% enriched uranium contains 47.324 kg of natural uranium equivalence and 37,783 separative work units (SWU), if proceeding on a tails assay of 0.3% U-235.

LEU Price = 47.324 x Unat price (US$/kg) + 37.783 x SWU price (US$) + conversion of UF6 to U metal (US$)

Prices of natural uranium (Unat) and separative work (SWU) are subject to market developments:

Average Unat price for the period 1997-2001:	approx. 22 US$/kg UF6
Current Unat price:	approx. 65 US$/kg UF6
Average SWU price 1997-2001:	approx. 70 US$
Current SWU price:	approx. 100 US$

Calculation of LEU price based on current market:

47,324 kg U (in UF6) x 65 $/kg U (UF6)	= US$ 3,076
37,783 SWU x 100/SWU	= US$ 3,778

The resulting price is US$ 6.854 per kg LEU in the form of UF6.

Additional cost for conversion from UF6 to U-metal applies when LEU is produced from UF6. However, while the conversion of enriched UF6 to UO2 as part of the power reactor fuel fabrication - with product assays below 5% U-235 - is done in industrial-scale facilities, the conversion of UF6 with assays up to 19.75% U-235 to U-metal is performed in very small conversion facilities with safe geometry and is subsequently very expensive. Thus, the price for this latter type of conversion is not at all comparable with the one for the conversion of UF6 to UO2 for power reactors.

Prices for such LEU conversion are not published and are subject to local conditions. According to RWE NUKEM's experience, such conversion prices are in the range of US$ 2,000/kg U. This cost factor is not very much market related and could be assumed as constant cost (GDP related only).

As a result, the theoretical price of 1 kg LEU metal (19.75% U-235) would be US$ 8.854.

Since this price consists of 1/3 part of the cost for natural uranium, the LEU price will be depend on uranium market price movements. Quite some analysts predict that the current natural uranium price has still the potential of further growth, but that it should at least remain at its current high level.

10. How are the major LEU producers facing the new uranium prices?

As a matter of fact, Russia and the U.S. being the major LEU producers have different ways of production: While the Russians use mostly fresh uranium for enrichment, the U.S. uses existing military HEU stocks for down blending. Accordingly, we have two different price calculation scenarios:

Russia has to take into account the elevated cost of natural uranium and separative work since they have to source the feed material and to provide enrichment services. Even conversion cost increases more in Russia than elsewhere since their GDP is higher than in Western states. As a result, the price of Russian LEU is relatively close connected to market prices.

The US producer uses material from shelf which has been paid already in the past under military programs. Additional cost for down blending with the help of induction furnaces is non-market related internal cost. Since money earned from LEU sales has to be returned to the treasury (treasury owns the 10 tons HEU source for research reactor use), the sales price does not necessarily be at market price. Since USDOE has mostly agreed upon long-term requirements contracts with research reactor operators there is only little clearance for price increases (escalation clause). However, new contracts will certainly at least partially reflect the increased market prices for feed and SWU.

11. Conclusion

Recent market price increases have influenced the market of power reactor uranium as well as for LEU for research reactors. The calculated market price for LEU with an assay of 19.75% U-235 as needed for research reactors rose within the last few years from about US$ 6,000 to US$ 8,800 now.

This price is an indicator only. Reactor operators may see cheaper LEU prices, depending on quantity and availability of the requested material. Most important may be the date of commitment to a (long term) contract. All contracts concluded in the years before 2003 are earmarked with low prices and low escalation. New contracts may follow – at least partially – the uranium market price.

Russian material follows close to the market price development of feed and SWU component contained in the LEU, since production is mainly made from fresh material.

US-origin LEU has a higher value than Russian-origin LEU (the difference is in the range of at least US$ 500 /kg U), since its return possibility is still a most interesting option. In spite of this known fact US material does not follow the market price factors (plus surcharge) since the LEU is produced from existing, paid HEU stocks. It might be part of the USDOE policy to offer LEU for attractive prices to keep control on the RERTR program and to attract the use of LEU rather then HEU.

In principle Russian and US prices of LEU should be close together – with a premium of approximately 500 USD/kg for US material as long as return of spent fuel to the US is possible.

About one thing the experts from uranium trading are quite sure: There are currently no indications for a price relaxation. A moderate scenario would be that prices remain at the current high level. As a consequence the LEU price for research reactors should follow this development unless policy demands for discounted prices.

Well set are those reactor operators who have made long-term commitments in contracts which are not subject to the spot price development.