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Fueling the Future: A New Paradigm
Assuring Uranium Supplies in an Abnormal Market

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Introduction

We are at an exciting, but challenging phase for our industry. On the one hand, new nuclear reactors are being ordered, efforts are being made to pave the way for other orders, and there is a greater appreciation on the part of governments and individuals for the role that nuclear power can play in meeting both energy and environmental needs. On the other hand, nuclear fuel supply is in a very fragile state, and any greater demands associated with a growth in nuclear power threaten to further expose the deficiencies in the industry's supply base. If nuclear power is to be an important part of the energy solution for the future, and I believe it is, then the issue of fuel availability needs to be addressed.

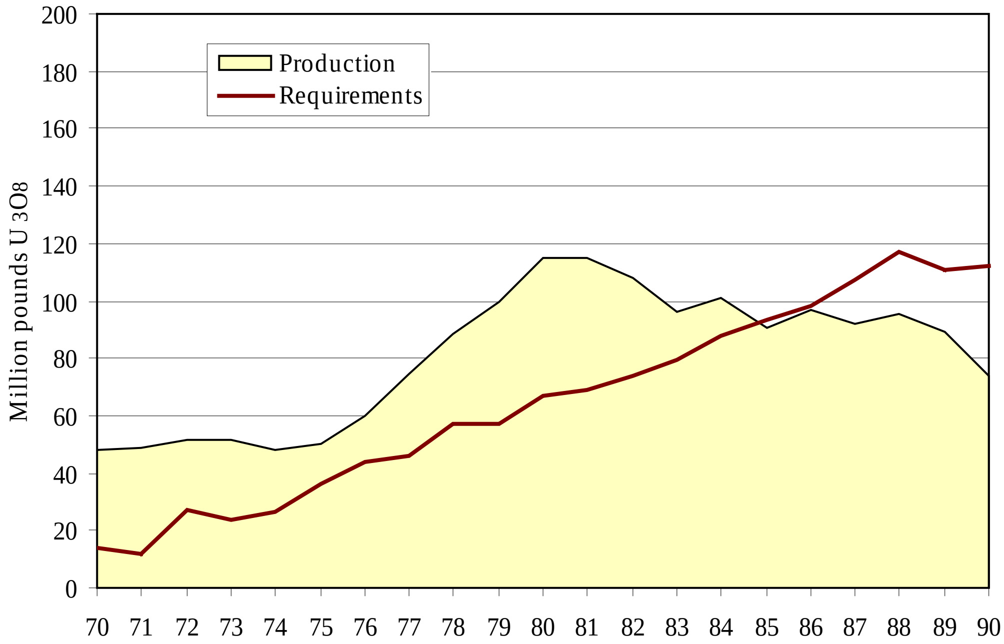
It appears that many market participants have been perplexed by the recent state of the market and are grappling with ways to explain it. As usual, there is sense of disbelief about the price jump, following by a feeling (or at least a hope) that things will return to "normal." Some have attributed the price rise to the confluence of freak events while apparently others believe that collusion among producers might be the reason that price increased (1). However, these "explanations" ignore the fundamental changes that have been occurring in the market over a number of years, as well as warnings on several fronts that the market was changing, and serve only to direct attention away from the real problems that face the industry (2).

This Paper proposes to provide some perspective on the current market and the challenges that lie ahead by examining the development of the uranium market. In many ways, this development has been quite abnormal in the sense that production and consumption have almost constantly been out of balance, due in large part to a large degree of government involvement and the fact that price has often failed to reflect the relative scarcity of uranium supplies. There also have been some important changes in supply and demand which are necessary to take into account in assessing the market going forward. The Paper will conclude by making some observations about improving the market infrastructure in the future.

An Abnormal Market

To understand the market as it exists today, you must first understand its unusual evolution. To do this, it is instructive to view supply and demand over three different time periods and different perspectives. *Figure 1* shows uranium production and requirements from a Western perspective over the 1970-1990 period. It is clear that supply was out of sync with demand, a development that resulted in a build-up of inventories which depressed price and production after 1980.

Figure 1. Western Production versus Requirements, 1970-1990



With the dissolution of the Soviet Union and the opening up of the world market, another perspective became warranted. *Figure 2* extends the timeframe of Figure 1 to 1995, and adds Eastern production and requirements to their Western counterparts. This figure shows an even greater disparity between production and requirements, which resulted in an even longer period of price depression and thus further downward pressure on production, in both the West and the East.

The market still had one more evolution to go through — the introduction of military material. *Figure 3* extends *Figure 2* forward to the current period and also backward to the beginning of uranium production in the late 1940s. With the introduction of military material, this earlier production, imbedded in weapons material, started to become a factor in the market. Now that even more uranium inventory — resulting from production in earlier periods — was coming into play, price and production remained depressed.

Figure 2. World Production versus Requirements, 1970-1995

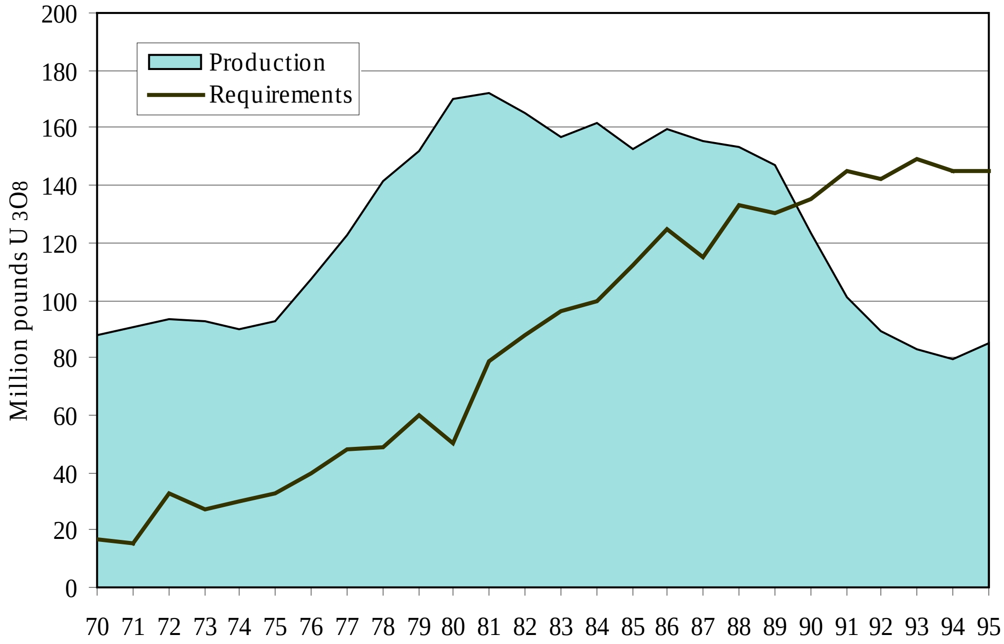
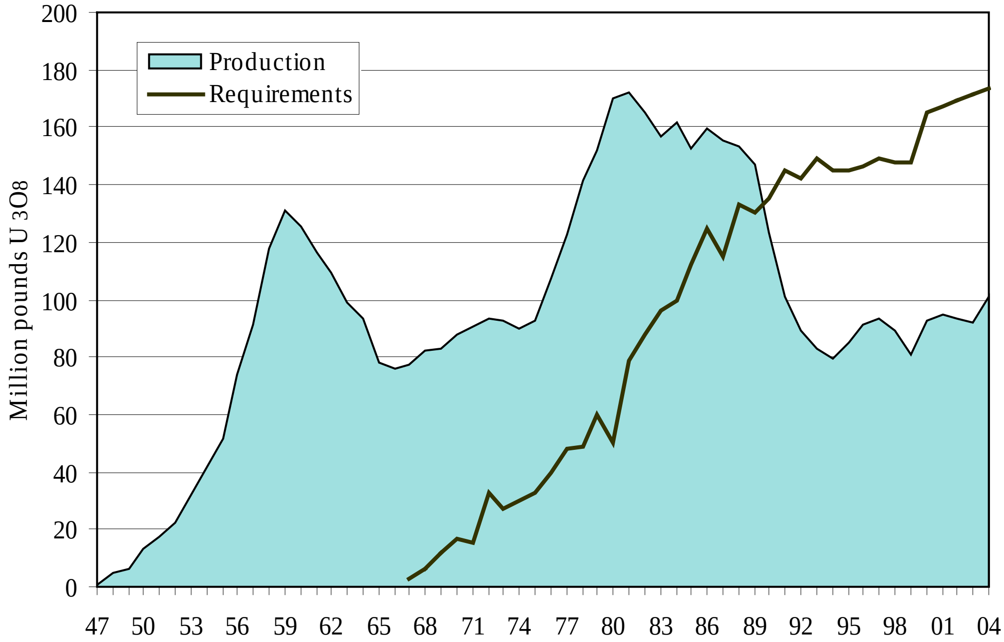


Figure 3. World Production versus Requirements, 1947-2003



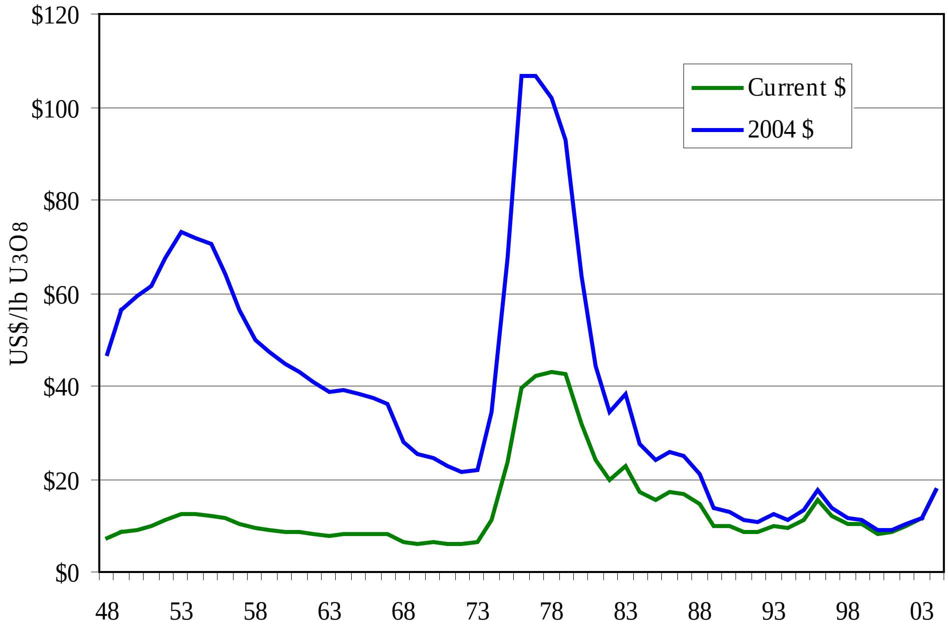
The uranium market is abnormal in the sense that in most markets you don't decide to mine far in excess of needs in one period and then use the excess inventories in the next, which is pretty much what has happened in uranium. Rather, production and consumption are more closely aligned, although there are short periods of overproduction and underproduction and associated price volatility. Of course, the reason that uranium is unique relates to the dominant role of governments, which in turn stems from the military applications of uranium.

Initially, uranium was mined for use in nuclear weapons, but fortunately little of this was consumed. Following this, the U.S. government became a monopoly supplier of enrichment services to the West. By means of both of these positions, the U.S. government largely dictated the production of uranium in the West until about 1980. Production far exceeded requirements, initially because of the success of the government's buying program for military needs and later because the government inflated uranium demand levels via its enrichment contracting policy.

This abnormal nature of the market is reflected by and, to a large extent, is a product of the nature of prices. As shown in *Figure 4*, price has varied greatly over the history of uranium production, more so when expressed in constant dollars.

Some observations about *Figure 4* are in order. Initially, there was no commercial market, and the U.S. government was the sole purchaser, buying uranium for its military program. Price was set at a level necessary to stimulate supply (the first price spike), and the buying program proved to be overly successful, prompting the government to cut it back significantly given the supply response. This price-production response behaviour was repeated during the first part of the commercial market in the 1970s (the second price and production spike). In this case, one of the main factors for the price rise was the U.S. government's enrichment contracting policy, which led to artificially high demands for uranium. Price and production increased dramatically, forcing the government to eventually relax its contracting policies so demand could better match actual needs.

Figure 4. Historical Prices Expressed in Current and 2004 Dollars



The message in both of these cases was clear: production will respond to a price stimulus, but it can be over-stimulated. Still, the prices in these periods were much higher than recent prices when expressed on a constant dollar basis. In fact, over most of the history of uranium production, recent price levels below the US$20 level (on a 2004 constant dollar basis) have been the exception and not the rule.

If price can be over-stimulated, which obviously has been the case, then the corollary is also likely true: production can be under-stimulated. This issue is at the heart of the current debate in the market, and brings us to a consideration of the role of price information and the interpretation of prices by industry participants.

The Role of Price Information

Ever since commercial uranium prices were first published, there has been some controversy about them, and this controversy has continued until today. Just several years ago, questions were raised in some circles whether the spot price was "accurate" or not. At the time, price had been flat at US$9.90 for some time. This question caused us to write a series of editorials examining price more closely. In these editorials, we warned about referencing spot prices in long-term contracts (although we publish the most widely referenced spot price) and expressed our concern that the spot price did not reflect the future scarcity of uranium (3). We cautioned that if it did not, then a future price reaction to this situation could be "rather violent."

To us, the real price issue was not one of "accuracy," but whether the price was a good indicator of the scarcity of uranium and thus an effective indicator of what price would be in the future. In other words, there was no question whether spot deals were occurring at the published price levels, but there was a serious question of whether those price levels bore any relationship to what price might bring forth adequate supplies. This was an important consideration because it clearly appeared that market participants were interpreting spot prices as the true indicator of supply scarcity—that is, they were basing procurement coverage and production (and even exploration) decisions on those prices.

In June 2003, alarmed by what we considered to be an excessive level of unfilled requirements on the part of U.S. utilities just three years in the future, we wrote an editorial that asked the question of whether the uranium market was failing (4). This failure would be complete if there were not enough uncommitted supply to meet these unfilled requirements, as this situation would cause price to soar dramatically out of control. We do not know the answer to this question yet for 2006. And, even if it turns out that the market clears at a reasonable price level in 2006, there is still 2007, 2008, and so on, with which to contend.

It should not be surprising that the uranium market may be exhibiting some degree of failure. One of the classic characteristics of a failed market is heavy government involvement. Of course, involvement of the government in nuclear fuel has been extensive and to a large extent unavoidable. During the 1990s and into this decade, governments sold off large amounts of inventory, much of this former weapons material, and this had the effect of pushing price to very low levels and suppressing production and exploration efforts. This observation is not to place blame on governments—in fact, getting rid of HEU was a positive development, but it did have important impacts on the market stemming from how it was sold.

Market Failure and the Gap

There has been considerable discussion recently about a production or supply gap in uranium. Discussing the existence of such a gap really doesn't make any sense without introducing the concept of market failure. This is because the gap problem can be seen as directly related to the disconnect between the current price and a future price that would result in the requisite amount of supply. Market failure is also the reason why it is so difficult for market participants to believe that there may be a supply gap problem. The reasoning goes that if prices are low, then uranium supplies must be plentiful, and if they're plentiful, there shouldn't be any problem meeting demand in the future at prices not too different from today's.

Compounding the problem is the fact that we have all heard for a number of years about the supply or production gap and the high prices that it would bring. When the higher prices suggested by the gap projection didn't materialize, people became complacent. In hindsight, there were considerable inventories to be worked off. As prices fell and stayed low, utilities opted to hold fewer inventories, so even more inventories were worked off, further depressing price and production.

Of course, if prices didn't adequately reflect the scarcity of supplies (i.e. the market was in failure), then utilities and producers were making incorrect decisions. What is becoming clearer than ever is that spot price is giving us a different message than the one we get from a simple examination of production versus requirements. It is in this vein that for several years the Euratom Supply Agency has been urging utilities to hold more inventories despite the existence of a low price which suggested supplies were plentiful.[5]

The seriousness of market failure should not be underestimated. It's like the market's gas gauge is broken. The gauge (price) suggests the tank is full or nearly so (supplies are plentiful), when in reality it's much closer to being empty (supplies are scarce). Having the correct price signals is crucial to providing adequate supplies in the future.

The Changing Nature of Supply

With the dissolution of the Soviet Union, uranium supply has changed in important ways. New supply sources have emerged, both in terms of the location of the suppliers and the nature of supply. Before that time, market supply came primarily from Western production and commercial inventories of uranium. Around the late 1980s, supplies started to come from the Soviet Union. Subsequent to the Soviet Union's fall, supplies came from the newly independent republics, but also from military inventories of highly enriched uranium and from the enrichment of tails. The magnitude of such supplies certainly is a factor in the market today, and will be going forward.

Fifteen years ago, Tom Neff and I co-authored an article in the *NYNCO Newsletter* that examined issues associated with integrating Soviet uranium supplies into the Western market (6). That article essentially identified two new sources of supplies that would become important in meeting reactor needs. It mainly dealt with the enrichment of tails material by the Soviets. But it also mentioned, perhaps for the first time in print, the possibility that former nuclear weapons material could be used as fuel.

The rest, as they say, is history. Approximately two years later, Dr. Neff published an op-ed piece in *The New York Times* recommending what was to become the HEU deal (7). But it became evident early on that these supplies could have an adverse impact on the market. In 1998, when the U.S. government decided to liquidate a large share of its inventories through the privatization of USEC, we projected that the combined impact of the HEU feed supplies and the U.S. government inventory sales would push price down to extremely low levels (8).

Importantly, the article highlighted the intrinsic substitutability of uranium for enrichment. We suggested that DOE tails be exported to the Soviet Union, enriched to normal and re-exported to the U.S. to be overfed in the DOE enrichment process, an approach that was tantamount to DOE importing electricity from the Soviet Union. While this specific path was not followed, it did demonstrate the feasibility of tails enrichment.

While the thought of producing uranium supplies in this manner might have appeared misplaced in the wake of record low prices that were to ensue, history has shown this in a different light. The Russians started enriching tails in the 1990s when as early as 1992 they were enriching $0.36^{w}/_{o}$ tailings (9). Although we did not know it in 1989, it also turned out that the enrichment of tails was a crucial step in making HEU supplies available to the market. Because of the high concentration of U_{234} in HEU, it became necessary to blend this material with other material that was depleted in U_{234}. This was achieved by blending HEU with tails material enriched to $1.5^{w}/_{o}$, since the tails were depleted in U_{234}.

By 2000, Russia was using about 40% of its enrichment capacity to enrich tails and operating its enrichment plants at a $0.10^{w}/_{o}$ tails assay (10). Taken together, the amount of uranium in the HEU feed and the amount of normal uranium created by enriching tails approaches 40 million pounds. While all of this material is not immediately available to the market due to limits on the sale of HEU feed, it is still a sizeable source of supply, twice the level of McArthur River production. There is also some U.S. HEU that has been made available for conversion to reactor fuel, but this amount is considerably less than what Russia has made available.

Thus, in the space of fifteen years, the supply portfolio of uranium has changed notably. It is important to recognize that to a large extent this was possible only because Russia had a considerable amount of economic enrichment capacity. Without this capacity, uranium supply would be much lower than it is today. Key questions for the future are whether and to what extent such supplies—military-based and tails-derived—will be available.

As a way of answering this question, Oleg Bukharin notes in his paper on the Russian centrifuge complex that much of the expansion of Russia's enrichment capacity may be driven by the need to produce uranium (i.e., enrich tails) (11). This is a logical conclusion if Russia depends on this source of uranium supply and is planning to expand its consumption of uranium and/or is forced to process lower assay tails. It appears that both of these developments are occurring. It also may be the case that Russia needs to consume more or all of the HEU supplies to meet its internal needs and those of countries to which it has traditionally supplied uranium or is adding to its reactor export market. Clearly, more demands are being placed on Russian supply and, absent any notable expansion of uranium production, Russia will continue to rely on these "non-traditional" sources of supply.

The Changing Nature of Demand

There have also been several important changes in demand over the past fifteen years. For one, reactor requirements were able to grow considerably due to an increase in capacity factors, something that we have referred to as "stealth demand." (12). This is perhaps seen most vividly in the case of the United States, where capacity factors increased by almost 50% over the 1989 to 2001 period, resulting in the equivalent of 25 new 1000 MWe reactors coming on line, even though the number of operating reactors declined slightly.

Another, more recent, change has been the growth of nuclear power in developing economies, including China, India and Russia. While the story of the 1990s was the emergence of supplies from the East with the dissolution of the Soviet Union, the story of this decade has been the growth of nuclear power in countries that had not participated in the market to a great extent, and, in the case of India, is still not participating, although this is expected to change in coming years. And, while Russia has been a large net supplier to the market, it finds that its requirements are growing steadily due to the increases in capacity factors in operating reactors and the fact that it is bringing new reactors on line.

A third change affecting uranium demand results from the interface of uranium and enrichment. Over this period, enrichment contracting became more competitive, and with this development enrichers granted greater tails assay flexibilities to customers. For most of the period, utilities opted to select higher tails assays, resulting in higher uranium demand. This, however, did not necessarily result in more uranium being consumed, as enrichers typically operated their plants at lower tails assays than nominated by their customers, meaning that they were underfeeding their plants and ending up with uranium.

The emergence of Russia as a factor in the market signaled an even more important change in demand. With its large economic enrichment capacity, Russia has been able to enrich at low tails assays (e.g., 0.10$^{w}/_{o}$). This not only allowed Russia to strip tails, which has directly affected the supply of uranium, but to economize on the amount of uranium it needed to supply its internal needs and those of its traditional (and emerging) customers.

This ability to substitute enrichment for uranium is becoming more important now that uranium prices have increased relative to SWU prices. Recently, we have seen some utilities reduce their tails assays from $0.35^{w}/_{o}$ to $0.30^{w}/_{o}$, and in some cases to below $0.30^{w}/_{o}$. This downward trend in tails assays can be expected to continue as long as uranium is expensive relative to enrichment. This tails selection has the effect of reducing demand, but it also reduces supply to the extent that enrichers were underfeeding their plants or enriching tails to produce feed or blendstock.

The use of enrichment technology as a way to economize on uranium has been known for a while but has only become a factor recently. In 1989 I wrote a paper that argued that in choosing an enrichment technology, one should consider the fact that enrichment and uranium were substitutes, and a low-cost technology would gain market share at the expense of uranium (13). Again, this observation initially seemed out of place in a market that experienced record low uranium prices in the 1990s and into 2000 when there was apparently no need to economize on uranium. However, Russian enrichment plants were operated at low tails assays in the 1990s either out of design or necessity, and this operating practice has continued until today, when the need for this technology for resource tradeoff has become more obvious.

Where Are We Today?

We have seen that the uranium market has exhibited great imbalances between production and consumption over its history, and currently production is far below consumption, as excess inventories from earlier periods are being consumed. Price also has been under considerable upward pressure, reflecting the fact that production must increase to keep the market in balance. To a large extent, the current imbalance is due to the failure of the uranium price in past periods to stimulate the correct level of production, although the leading source of the market failure as well as the imbalance itself has been the considerable involvement of government in the market due to the dual-use nature of uranium. Simply put, the low prices that have persisted until recently suggested a surfeit of uranium that turned out not to have existed, and now the market must struggle to attain a better balance.

Before moving into the future, it is useful to re-examine one characterization of the market in the light of what we have discussed here. The recent state of the uranium market has been described as a “perfect storm,” a confluence of events that produced supply disruptions and higher prices. While this is certainly true in one sense, such a description suggests that the current problem is a once-in-a-lifetime event, belying the longer-term perspective presented here. If what happened over the past year or so was a perfect storm, how would one describe what happened in the latter part of 1970s, when price rose to over US$100 in today’s dollars?

Perhaps a better analogy for the situation in uranium would be that of climate change. It is the cumulative effect of doing or not doing certain things that is creating an environment that can have serious consequences. To carry this analogy further, one of the byproducts of global warming is the creation of conditions for violent storms. The difference between this and the perfect storm analogy is that even after the storm has passed, the conditions remain for other, potentially more violent, storms to follow. Of course, the direst consequence for nuclear power would be if a lack of economic uranium supply somehow prevented reactor growth from reaching its potential.

The important point here is that these trends have been years in the making, and were not the result of unexpected disruptions, although these disruptions served to expose the supply/demand imbalance. There have also been ample warnings that changes were taking place, and that something might be amiss. In another such warning, and one in keeping with the climate change analogy, we noted back in 2001 that the market in the current decade was expected to be much different than the one in the 1990s, with particular reference to a "sea change" that was taking place due to the growth of nuclear power in Russia and China (14).

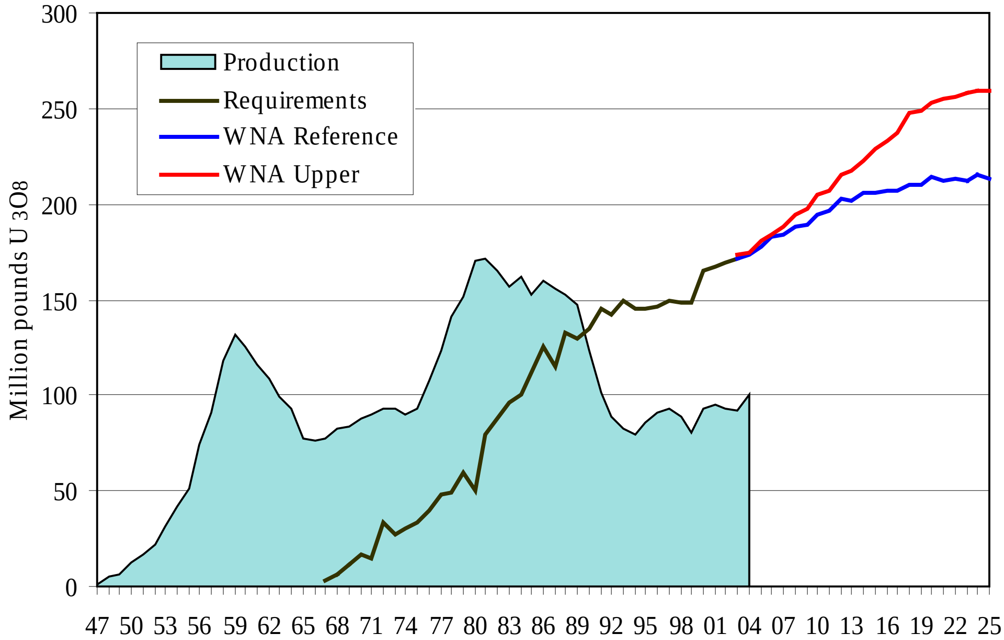
Addressing the Supply Problem

As we look to the future, the problem facing the industry is to provide for a sufficient level of economic uranium supply to fuel whatever level of nuclear power growth is dictated by imperatives other than the cost of nuclear fuel. That is, we do not want nuclear fuel economics to be a limiting factor when it comes to the growth of nuclear power. Ideally, we would like for fuel to be supplied in the least-cost manner, making this an optimization problem.

At the outset of examining this issue, we should point out that uranium is an abundant mineral, which, if exploited in a timely fashion, should be able to support virtually any nuclear power expansion path. However, with production currently at very low levels relative to requirements, it alone cannot fuel the immediate future of nuclear power. Thus, in the near term there are some constraints that we must work around. Fortunately, there are substitutes for current production—commercial and military inventories (which are the result of production in earlier periods) and enrichment services. A more specific objective then is to use these substitutes to help provide sufficient economic uranium supplies in the short-to-intermediate term without destroying the incentive to expand production, both in the short term and the longer term. In other words, you don't want to solve a short-term crisis in uranium supply at the expense of assuring future supplies.

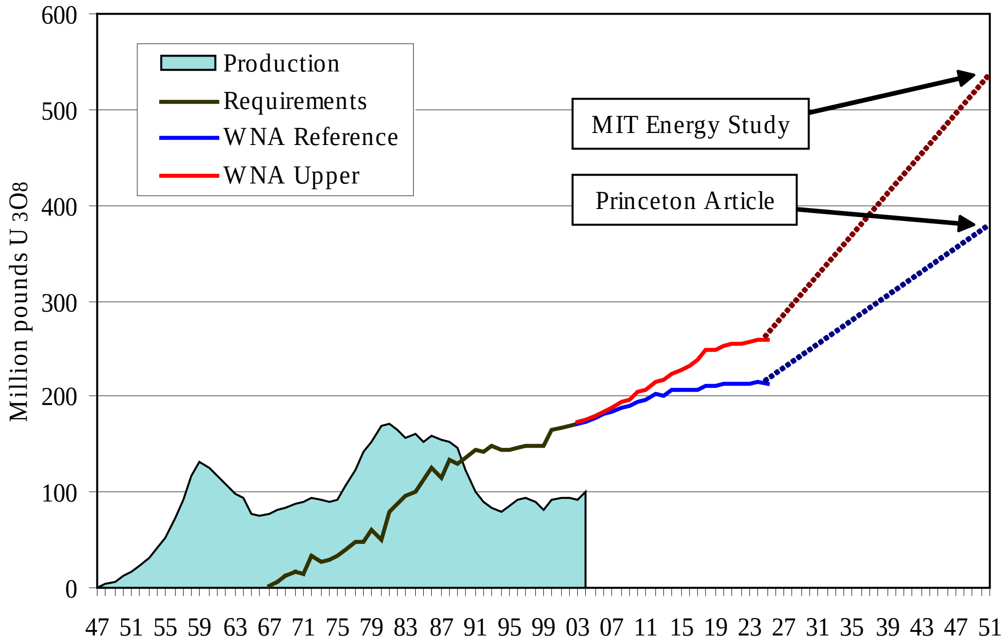
Ultimately, the vast majority of future uranium supply must come from new production, which means investment in exploration and development of new mines and mills. To place this into perspective, we present two views of the picture. The first, depicted by *Figure 5*, shows future requirements through 2025 based on the World Nuclear Association's reference and upper scenarios from its 2003 Market Report.

Figure 5. World Production versus Requirements, 1947-2025



The second perspective *(Figure 6)* looks out to the year 2051 and shows a range of requirements, the upper one based on the MIT energy study, and the lower one a product of a recent article by Princeton scientists (15). Rather than being projections of what is likely to happen, these are two measures of the amount of nuclear power that may be needed in the future to mitigate the emission of carbon gases. They roughly equate to a doubling (Princeton) or a trebling (MIT) of current capacity to around the mid-century mark. (The MIT study focuses on needed capacity by the year 2051 while the Princeton article looks out fifty years to 2054.)

Figure 6. World Production versus Requirements, 1947-2051



Comparing these two figures, it is evident that inventories of military or commercial inventory can play a much more significant role over the course of the first time period than in the second, as historical production embodied in inventories pales in comparison to what may be needed by the middle of the century. In this context, many of the suggestions below are intended to enhance the environment where production can expand to meet future needs. The value of this exercise is not so much in the specific recommendations, but the recognition that in making these recommendations it is necessary to consider both the short-term and longer-term effects of creating a more stable platform for supply.

The Role of Price and Market Information

In assessing the future market, market participants need to understand the limitations of price information, especially the spot price. While the spot price certainly has a role to play and should become more indicative of production costs as excess inventories are depleted, it still will not completely capture the future scarcity of uranium. If contracting is delayed because utilities think price (as represented by the spot price) is too high, or alternatively if producers believe that price is too low and do not add capacity in a timely manner, then the current supply problem will get even worse.

There is good reason why utilities and producers may be reacting differently to the current price. The market is presently going through two adjustments that are having a dramatic impact on price. One is that it is transitioning from an inventory-driven price to a production-driven one. The other is that we are transitioning from a strong dollar to a weak dollar. The net effect of this is not only do prices have to increase to encourage new production, but they have to go higher yet in terms of U.S. dollars because almost all production is located outside of the United States. U.S. utilities see a sharply rising published price, while for producers (and non-U.S. utilities) the price rise is not as pronounced.

Basically, we believe that utilities should not worry as much about future spot market prices as they do about future supply. If supply is not expanding, it is almost axiomatic that there will be higher prices in the future. To this end, we have recommended to our clients for some time now that they forgo the spot market and enter into new long-term contracts using a base-escalated pricing mechanism. In this respect, uranium may become more like enrichment, where there is little focus on spot prices but renewed focus on signing long-term contracts, with terms of ten years or more.

The Role of the Government

In some cases, market failure is given as the rationale for government involvement in a market, based on the thinking that the government can do a better job allocating goods and services than the market. In the case of nuclear fuel, it is obvious that many of the conditions that led to market failure were created by government participation in the first place, so additional government involvement to correct these problems is not the solution.

By and large, it appears that governments are aware of the potential impact of their actions and are not likely to rush to take actions to "correct" the market. In this regard, the U.S. government has shown considerable restraint by not interfering in the market as a supplier, recognizing that if prices are suppressed to any degree, inadequate production may be forthcoming in the future. It may have learned this lesson the hard way, having had to take the step of buying some of the Russian HEU feed after price was depressed following DOE's transfer of inventory to USEC.

The forgoing does not mean that the government should take no interest in the market or supply security. As mentioned earlier, for a number of years the Euratom Supply Agency has been expressing (in our opinion, appropriately) its concern about low inventory holding by its member utilities in a market that was becoming increasingly dependent on secondary supplies. In its most recent annual report, it expresses heightened concern about supply security issues, and notes that it has set up a task force to examine security of supply issues, with plans to finalize a report this year containing "recommendations for appropriate actions by different actors in order to prevent problems in the nuclear fuel cycle" (16). However, the Supply Agency is also sensitive to the potential market impacts of its recommendation that utilities bolster their inventories when it states "a sudden rush by all utilities to increase their inventories would just put more pressure on prices" (17).

There are several steps that governments can take to enhance the operation of the market. These relate to providing more information about the market, and reducing constraints on production and exploration. Along these lines, governments can do the following:

- publish data on commercial requirements, contracting, prices, and inventories
- publish data on their own inventories and disposition plans
- open up land for exploration, including to foreign investors.

There is one area in which the government - especially the U.S. government - has indicated its intent to stay involved in the nuclear fuel arena, and that is through the supply assurances it appears ready to provide countries that agree to forgo enrichment and reprocessing. Some suggestions on how to do this are given below.

The Use of Military Material

Of course, an important subset of government decisions that can affect the nuclear fuel market is the disposition of military material. One of the ironies of the initial decision to make military material available to the market is that because production and exploration efforts have been depressed due to the ensuing low prices, it will be necessary to continue to use former weapons material to help balance supply and demand. Of course, this is not necessarily a bad thing, if it is done in predictable ways by both the U.S. and Russian governments.

Another irony is that, if governments are serious about using assurance of supply as a way of convincing countries to forgo enrichment and reprocessing, then they will likely have to resort to the use of military material, given the likelihood that other conventional supplies will likely be stretched thin. Further, if military material was the source of the uranium offered to these countries, it is likely that the candidate countries would be more receptive to this initiative because the countries providing the supply assurance would also be reducing their own stocks of fissile material.

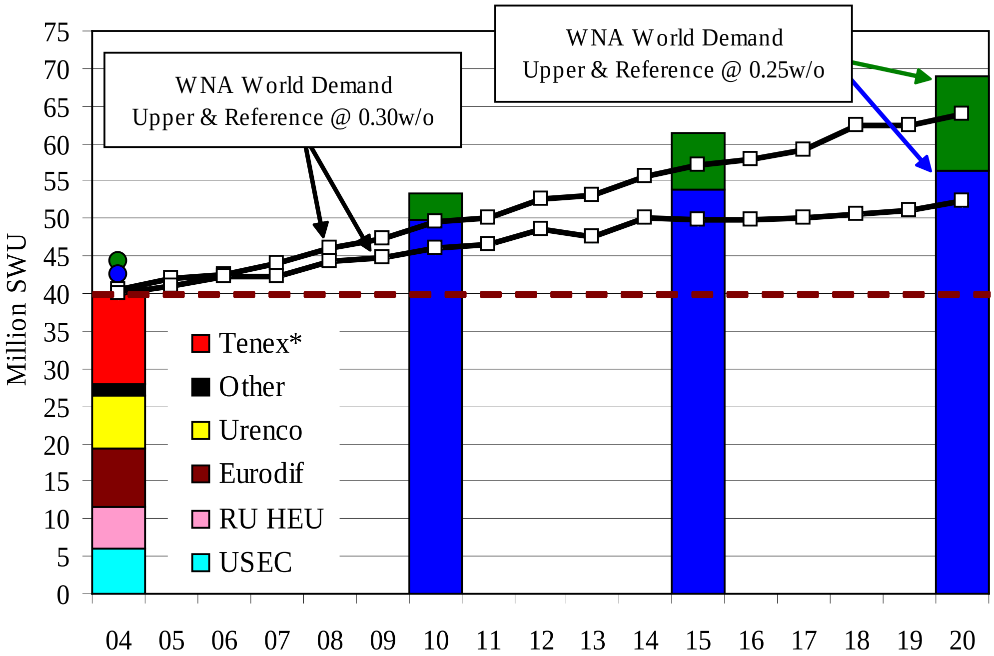
The impact on the market of such a government program would be mitigated to the extent that such former military supplies were made available to meet new, emerging demand, since in this case they would not displace existing supplies (which was largely the case under the HEU deal). Further, this action would be market neutral to the extent that such supplies were used as an enticement to build new reactors, or if reactors were built for the purpose of burning military material, such as the Isaiah project proposed by USEC.

The Need for Enrichment Capacity

It is quite evident that the demand for enrichment will continue to increase, both because of nuclear capacity (and capacity utilization) growth and because of the movement to lower tails assays. Due to the relatively close balance between current enrichment supply (measured on a net economic basis) and demand, such increased demand means that enrichment capacity will have to increase in the future. How much it has to increase will depend on the pressure placed on uranium supplies and price, as well as the underlying trend in reactor growth.

The degree to which enrichment can be substituted for uranium is limited by the amount of economic enrichment capacity that is available. Thus, utilities cannot forever lower their tails, even if such action is dictated by relative uranium and enrichment prices, if enrichment capacity is not available. In some ways it is just as appropriate to talk about the looming gap in enrichment supplies as it is for uranium supplies. This is illustrated in *Figure 7*, which compares current enrichment capacity with WNA reference case and upper reference case SWU requirements at a $0.25^{w}/_{o}$ and a $0.30^{w}/_{o}$ tails assay (18). While this may be an extreme case, it shows that considerable expansion in enrichment capacity is needed if tails assays drop to 0.25$^{w}/_{o}$ and especially if the WNA upper reference case demand is to be realized.

Figure 7. A Potential SWU Supply Gap?



Because of constraints on how quickly new capacity can be added, enrichment is expected to have more of an effect on the uranium supply situation the further one goes into the future. But here it can play a fundamental role by reducing the pressure on uranium resources, especially in the high-demand cases where these resources would be under more stress. For example, annual uranium requirements evaluated at a 0.30$^{w}/_{o}$ tails assay under the WNA upper reference case in 2025 would be 266 million pounds. Reducing the tails to an average of 0.25$^{w}/_{o}$ would reduce these requirements to 244 million pounds.

The annual and cumulative resource savings would be that much greater if some of these higher nuclear power targets were reached at mid-century. For instance, the 533 million pound annual requirement at 0.30$^{w}/_{o}$ tails associated with the MIT study would be reduced to 480 million pounds at a 0.25$^{w}/_{o}$ tails assay and 438 million pounds at a 0.20$^{w}/_{o}$ tails assay. To a large measure, nuclear power can qualify as a renewable resource with the application of technology that can extend and reuse conventional resources.

References:

1. This latter issue was raised in a recent issue of *NuclearFuel*, Vol. 29, Num. 16, August 2, 2004, p. 2.
2. For a warning about supply shortages before the McArthur River flood and other supply disruptions that occurred last year see Thomas L. Neff, "Long-Term Supply: No Field of Dreams," Nuclear Energy Institute Fuel Cycle 2003, April 6-9, 2003. Also, there were other warnings that the market was changing before this. See, for instance, "A New Decade, A New Market," *The Ux Weekly*, December 3, 2001, p. 1-2.
3. We wrote several editorials on this subject when price was below $10. See, for example, "Putting Market Prices into Context," *The Ux Weekly*, April 8, 2002, p. 1-2; "What Price Information?," *The Ux Weekly*, September 30, 2002, p. 1; and, "More on Prices," *The Ux Weekly*, November 18, 2002, p. 1.
4. "A Case of Market Failure?," *The Ux Weekly*, June 9, 2003, p. 1-2.
5. For a discussion of this see "Euratom: Utilities De-stocking," *The Ux Weekly*, May 8, 2000, p. 1-2; "Euratom: Still Security of Supply Concerns," *The Ux Weekly*, May 21, 2001, p. 1-2; "Euratom: Making the Case for Holding Inventories," *The Ux Weekly*, May 20, 2002, p.1-2; and, "Euratom: Focus Intensifies on Security of Supply," *The Ux Weekly*, July 5, 2004, p. 1-2.
6. Jeff Combs and Dr. Thomas L. Neff, "The Soviets, SWU, and U – A Win-Win Solution?," *NYNCO Newsletter*, November 20, 1989, p. 1,2, and 5.
7. Thomas Neff, "A Grand Uranium Bargain," *The New York Times, OP-ED*, October 24, 1991.
8. "Market Impact of USEC Inventory Sales," *The Uranium Market Outlook*, July 1998, p. 2-13.
9. Oleg Bukharin, "Russia's Gaseous Centrifuge Technology and Uranium Enrichment Complex," Program on Science and Global Security, Woodrow Wilson School of Public and International Affairs, Princeton University, January 2004, p. 29.
10. Bukharin, p. 24. This is based on V. Shidlovsky, "On the Prospects and Plans for Modernizing Enrichment Facilities," *Atompressa*, 36, September 2000.
11. Bukharin, p. 30.
12. For a more complete discussion of this, see "Who Needs New Reactors for Demand Growth?," The *Ux Weekly*, August 20, 2001, p.1 (http://www.uxc.com/cover-stories/uxw_15-34-cover.html).
13. George F. Combs, Jr., "The Economics of Strategic Choice: U.S. Uranium Enrichment in the World Market: A Comment," *The Energy Journal*, Volume 10, Number 1, January 1989, p. 175-178.
14. This was discussed in "A New Decade, A New Market," *The Ux Weekly*, December 3, 2001, p. 1-2.
15. *The Future of Nuclear Power, an Interdisciplinary MIT Study* (http://web.mit.edu/nuclearpower/), and Steven Pacala and Robert Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science Magazine*, Vol. 305, No. 5688, 27 August 2004.
16. Euratom Supply Agency, *Annual Report 2003*, p. 21.
17. Euratom Supply Agency, *Annual Report 2003*, p. 23.
18. Russian enrichment capacity is net of that devoted to the enrichment of tails, which produces needed uranium supplies.