

# Uranium: Growing Demand, Rapidly Depleting Stocks



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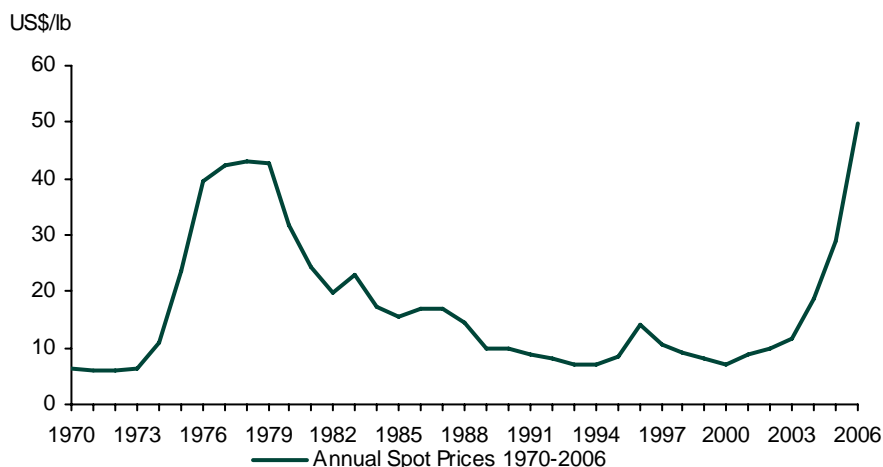
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*Uranium has suffered from twenty years of underinvestment and the erosion of secondary supplies, including inventories. Prices are likely to remain robust until new mining production comes on stream later this decade.*

Uranium has been a darling of investors for much of this decade, as the recent exponential run-up in prices attests (Figure 1). In 2001 uranium oxide (U<sub>3</sub>O<sub>8</sub>) was selling for \$6.75 per pound, rising to \$10.20 at the beginning of 2003, \$20.50 at the start of last year and to \$72 in early 2007. This past week it was trading 93% higher, at \$138. With short-term speculative investors now in the market, it is no wonder that, as with other energy sources (and indeed other commodities), two questions arise: How high will prices go? And, how much of this price is driven by market fundamentals and how much by investor flows? This is especially the case in that uranium oxide has not experienced a price “correction” since the current run-up in prices began.

**Figure 1. U<sub>3</sub>O<sub>8</sub> average annual spot prices, 1970-2006**



Source: TradeTech ([www.uranium.info](http://www.uranium.info)).

*Uranium has been a darling of investors for much of this decade*

Market fundamentals weigh heavily on the determination of raw uranium prices. But unlike some other commodities, such as aluminium and coal, prices for uranium are driven not by massive Chinese buying but by two decades of limited investment in the nuclear sector and, along with that, limited investment in uranium mining. We believe the exponential increases of the past four years will begin to taper off by next year. The average price of uranium year to date has been \$94. We project average prices for all of 2007 at \$120 and forecast a peak of \$165-\$170 by 2009, followed by a drop toward \$60 over the next half decade.

*Amid the surge in nuclear plant construction prices have soared—a consequence of decades of underinvestment in raw uranium*

Nuclear power was the technological solution of choice for two decades following the mid-1950s, but it confronted a series of political obstacles and safety concerns in the 1980s, amid declining fossil fuel prices and growing concerns about nuclear accidents and non-proliferation. Nuclear power growth stalled and focus shifted to fossil fuel plants, especially coal and natural gas, to meet growing global power requirements. At the start of this decade, nuclear power had largely receded from much of the commercial

landscape of the world. However, as global warming and increasing environmental obstacles to further fossil fuel growth have coincided with rising costs for carbon-based primary energy sources, nuclear power has re-emerged as an alternative of choice. Amid the surge in nuclear plant construction, prices have soared – a consequence of decades of underinvestment in raw uranium. However, unlike other energy sources, the cost of the nuclear fuel supply ( $U_3O_8$ ) is a relatively minor element, with utilities far more concerned about securing supply than about input prices, at least up until now.

## DEMAND TO EXPAND WITH NEW REACTOR CONSTRUCTION

*The military no longer competes for civilian uranium supply*

Historically, the two main sources of demand for uranium since the end of World War II have been the military and civilian sectors. But in the wake of the disarmament that followed the Cold War, civilian use of uranium as the fuel used in nuclear power plants has been the major source of demand. As of May 31, 2007, there were 437 commercial nuclear power reactors were operating in 30 countries, with about 370,040 MWe of total output<sup>1</sup>. Nuclear power supplies roughly 16% of the world's electricity needs and nuclear plants are becoming more efficient. Figure 2 shows nuclear electricity production and its share of total electricity production world-wide from 1970 to 2003. While nuclear power's share of base capacity for power generation grew dramatically until 1987, it has since been fairly flat at around 16%. Yet the total power produced by nuclear fuel increased about 20% as a result of enhanced reactor efficiency, increased enrichment value and advancement in reprocessing technology.

*Nuclear demand is surging in Asia, Russia*

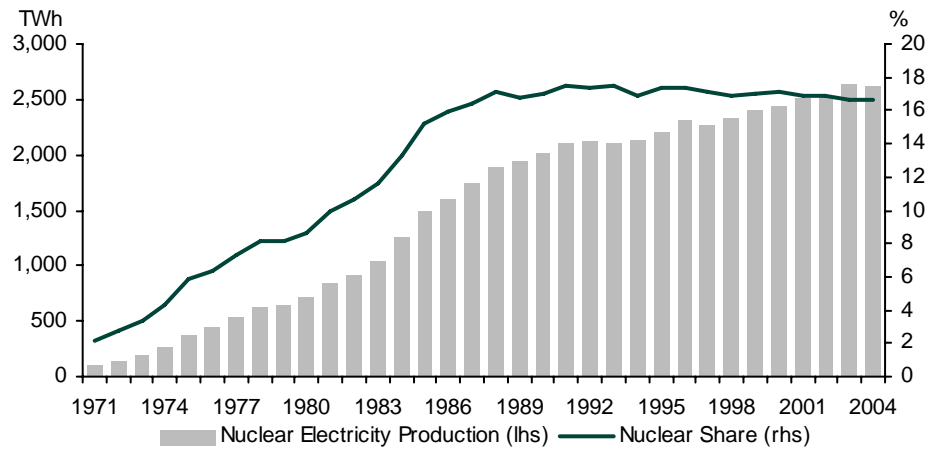
In addition to the 437 reactors in operation, 30 more are in construction, 74 have been planned or are on order and about 182 more have been proposed. Most of the facilities that are under construction or are planned lie in Asia, with China, Japan and India taking the top spots; Russia is the biggest investor in nuclear power in Europe.

*Core and reloading requirements lead demand increase*

The two biggest drivers of demand over the next 3-5 years will likely be the initial core requirements of new reactors and the reloading of cores for reactors already in operation. Initial core requirement refers to the amount of fuel that will be needed to sustain a reactor as it begins its first operating cycle. We assume that the initial core requirement is 1,185 lbs of  $U_3O_8$  or 0.45 tU (tonnes of uranium) per thermal megawatt (MW) of power generated. Reloading demand comes from the need to refuel the core at the end of an operation cycle, which could last anywhere from 12 to 24 months. We conservatively assume that reloading will take place every two years and one third of the initial core will need to be replaced. Depending on design and engineering requirements, some reactors might need half the core replaced. There is a difference in the average enrichment of the initial fuel and the reload fuel. Typically, the enrichment in the reload fuel is roughly 2% more enriched than the initial core since there is a reduction in the amount of fissile U-235 atoms available in the entire assembly compared with the initial core. Accounting for this, we assume that the reload requirement is two-thirds of the initial core demand, which translates to reloading demand of 790 lbs of  $U_3O_8$  or 0.3 tU for every MW of power generated.

<sup>1</sup> MWe refers to Megawatt net, or electrical, as distinct from thermal Megawatt.

**Figure 2. Nuclear electricity production and share of global production, 1970-2003**



Source: World Nuclear Association (WNA).

*Demand is likely to surge with new builds in 2012-2013*

Projecting demand also requires an analysis of timing, both with respect to demand from current reactors and of the surge in demand stemming from new-build or new grassroots nuclear power plants (see Appendix for details). Timely delivery of enriched uranium product (EUP), which is processed from uranium oxide concentrate, requires a lead time of at least three years. With incremental demand coming from new-builds, the time frame is likely to be four years for plants entering operations after 2013.

*More substantial growth of nuclear power depends on a solution to spent storage at Yucca Mountain*

The current annual demand for uranium as reported by the World Nuclear Association (WNA) is 66,529 tU for the 370,040 MW installed capacity. We assume that all of the 30 plants (22,398 MW) currently under construction will be built. Of the 74 plants (81,601 MW) that have been approved with funding in place or for which construction is well advanced, we assume that 75% will be built. In addition, a whopping 182 plants (151,345 MW) have been proposed globally but are still without funding and/or approvals. We assume that 20% of the proposed capacity will be built, bringing the total new demand to 113,867 MW by 2030. If political obstacles to storing spent fuel at Yucca Mountain in Nevada are removed, that percentage could grow substantially. Our analysis focuses only on the period to 2020, in which we expect roughly 80,000 MW to be added globally in that time-frame (Figure 3). Fuel demand for initial core requirements should be high, and there will also be significant demand for reloads, especially with plant life extensions of about 30 years in Japan, 20 years in the United States, 15 years in Russia and 10 years in the UK.

**Figure 3. Anticipated base capacity additions to nuclear power generation globally**

Year	New Nuclear Power Addition (MW)
2007	4,609
2008	3,254
2009	3,885
2010	5,386
2011	6,035
2012	7,295
2013	16,100
2014	9,213
2015	2,700
2016	3,000
2017	3,620
2018	6,000
2019	5,000
2020	4,000

Source: WNA, Lehman Brothers estimates.

**NEW MINING PROJECTS SHOULD INCREASE SUPPLIES**

*The uranium investment cycle points to boom and bust*

Relatively few uranium deposits are sufficiently concentrated to make mining worthwhile. Uranium ore-bodies are defined in tonnes, which can be recovered within certain cost constraints. Like other commodities – hydrocarbons as well as metals – the uranium market experiences cycles of investment leading to heightened exploratory activity, additions to the base of proven reserves and, most important, greater production levels.

*But uranium’s 72-year reserve base should provide ample supply once harnessed*

As a metal, uranium is found in most rocks in concentrations of 2-4 parts per million, is similar in abundance in the earth’s crust to tin, tungsten or molybdenum and is also found in sea-water, albeit in much smaller concentrations. Although growing demand from the nuclear power sector has raised concerns about availability, the combination of enhanced capital spending and new technological applications in mining as well as in processing and enrichment should provide ample supply. The WNA reports the current known reserve base globally as 4,743,000 tU, representing some 72 years of supply at the current annual consumption rate of about 66,000 tU – a figure higher than most widely used metals, oil and natural gas.

*Secondary supplies from ex-military use and government are rapidly depleting*

There are two major sources of uranium globally: mining, which satisfied about 60% of demand in 2006, and dismantled military weapons, government and utility stockpiles, and mixed oxides, mostly from US and Former Soviet Union (FSU) sources, which account for about 35%. The remainder comes from reprocessing and re-enrichment by European utilities. The uranium ore-body discovered so far seems to be concentrated in mines in Canada, Australia and Kazakhstan, which produce more than half of the world’s uranium. Figure 4 lists the ten largest mines in the world, which produced 68% of the 39,655 tU that was mined in 2006.

**Figure 4. Ten largest uranium-producing mines in 2006**

Mine	Country	Main owner	Type	Production (tU)	% of world
McArthur River	Canada	Cameco	underground	7,200	18.2
Ranger	Australia	ERA (Rio Tinto 68%)	open pit	4,026	10.2
Rossing	Namibia	Rio Tinto (69%)	open pit	3,077	7.8
Krazbokamensk	Russia	TVEL	underground	3,000	7.6
Olympic Dam	Australia	BHP Billiton	by-product /underground	2,868	7.2
Rabbit Lake	Canada	Cameco	underground	1,972	5.0
Akouta	Niger	Areva/Onarem	underground	1,869	4.7
Arlit	Niger	Areva/Onarem	open pit	1,565	3.9
Beverley	Australia	Heathgate	ISL	699	1.7
McClellan Lake	Canada	Cogema	open pit	690	1.7
Top ten total				26,971	68.0

Source: WNA.

Our analysis assumes that mine output will grow steadily at an annual rate of 3%. We also project the addition of some major mining facilities such as the Cigar Lake facility in Canada (7000 tU/year starting in 2012), the tripling of output from the Olympic Dam facility in Australia (12,700 tU/year by 2009) and Kazakhstan's expected production of 15,000 tU/year by 2010, as reported by the WNA. Based on WNA's base-case estimates, secondary supply will likely decline from more than 25,000 tU in 2006 to 19,000 tU in 2010 and 11,000 tU in 2015. We forecast a continued decline to 5,000 tU by 2020 because of the limited amount of previously mined uranium that can be recovered from former weapons materials and inventory depletions. We also factor in a 0.3% per year increase in supply from reprocessed fuel.

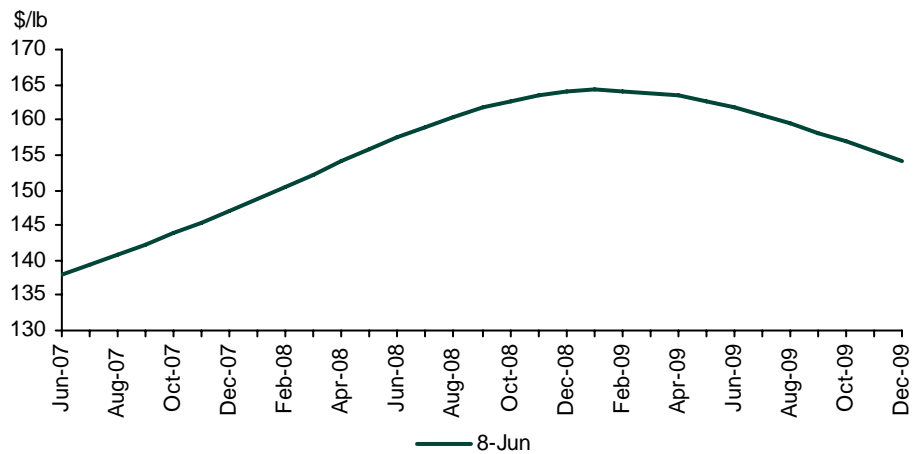
### PRICES TO PEAK IN 2009, FALL THROUGH 2020

*Illiquid market and limited transactions pressure the forward curve*

Current spot prices for U<sub>3</sub>O<sub>8</sub> are at record high levels, reaching \$138/lb for sales this past week. Recent data show that spot prices are fairly sensitive to relatively minor transactions, sometimes as small as 100,000 lbs of U<sub>3</sub>O<sub>8</sub>, that take place through auctions organized by producers, reflecting a less than fully liquid market.

On May 6, 2007 the NYMEX launched a financially settled U<sub>3</sub>O<sub>8</sub> futures contract which was intended to make it easier for utilities and investors to trade the product financially. One objective was to create greater price transparency given recent speculative interest. But trading volume has been light; this illiquidity combined with wide bid-offer spreads, makes the uranium forward curve a questionable benchmark in the current scenario (Figure 5).

Figure 5. U<sub>3</sub>O<sub>8</sub> forward curve (19 months)



Source: Lehman Brothers.

*Tight 1970s markets provide clues to today's price dynamics*

The previous peak in uranium prices was in the late 1970s when rising demand from commercial nuclear reactors faced a supply bottleneck (Figure 1). High prices spurred increased capital expenditures, but the Three Mile Island incident in 1979 curtailed expansion just as new supply came to market, causing prices to collapse. Supply from secondary sources increased as military programs were dismantled, and the 1994 US-Russia “Megatons to Megawatts” program diluted highly enriched uranium (HEU) to make it available for commercial use. These factors kept prices in check through the 1980s and 1990s. Figure 5 shows the behavior of spot prices from 1970 to 2006.

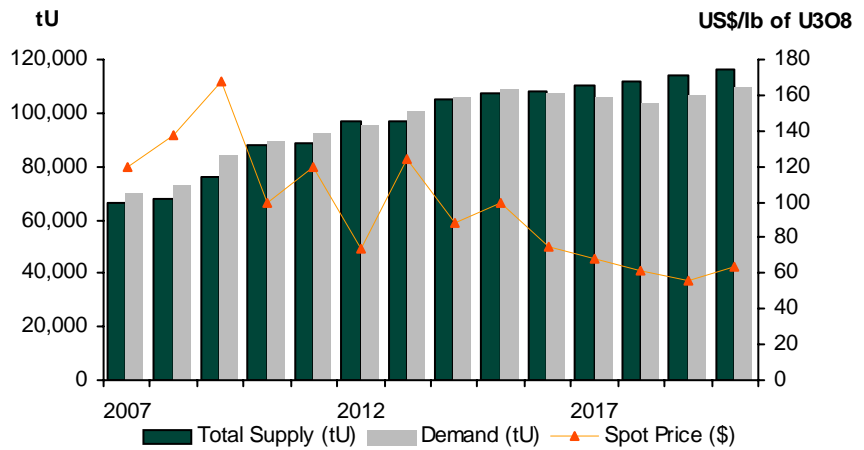
*We assume prices increase by \$0.01 for every tU imbalance between demand and supply*

Based on price action during the spike of the 1970s and the related supply-demand imbalance, we forecast a \$0.01 increase in spot prices for uranium for every tU imbalance between demand and supply. We expect the spot price to peak at \$165-\$170 per pound in 2009 and then oscillate downward toward \$60/lb (Figure 6).<sup>2</sup> If the Three Mile Island and Chernobyl incidents had not influenced demand for two decades, we would have expected prices to exhibit the same behavior in the 1970s, owing to the initial core effect. Prices are expected to fall after 2015 because of an increase in supply, but this may change, since we are factoring in a four-year lead time between reactor start-up and demand from new reactors entering the market. Figure 6 shows our expectations for supply, demand, and related prices.<sup>3</sup>

<sup>2</sup> Our model shows a peak in U<sub>3</sub>O<sub>8</sub> prices of \$167.49/lb.

<sup>3</sup> The appendix provides greater detail on how we developed our supply and demand curves as related to the total MWe of base capacity each year as well as the source table for Figure 6.

**Figure 6. Supply, demand and price forecasts for U<sub>3</sub>O<sub>8</sub>**



Source: WNA, Lehman Brothers estimates.

**MARKET TO TIGHTEN UNTIL 2009,  
AND WEAKEN OVER THE FOLLOWING DECADE**

*We expect prices to continue to rise to \$164-\$170 by 2009*

Primary and secondary sources have been sufficient to meet global demand for uranium thus far. However, demand spikes caused by initial core requirements and greater need for reloading fuel due to extensions in the operating life of nuclear plants worldwide will likely lead to further increases in spot prices, which are already around \$140. For the first five months of 2007, spot prices have averaged \$94/lb. We expect an average price of \$120 for 2007, but we believe the exponential increases of the past four years will begin to taper off by next year, with a peak average price of \$165-\$170 in 2009.

*After 2015 prices should ratchet down toward \$60*

Rising prices for uranium, as for other commodities, reflect increasing demand and reduced inventories. Higher prices will almost certainly trigger fresh supply, which should be created by new mines and improved reprocessing and enrichment techniques. We expect prices to drop sharply because of major supply additions in 2010 and then oscillate downward until around 2015 because of demand from initial core requirements, sporadically and lumpy supply. After 2015, we expect prices to stabilize at \$60-\$70.■

## APPENDIX

### Calculating demand

In addition to figuring out the volume of uranium that will be required for initial cores and re-loading, the timing of demand forces in the market is crucial to analyzing market fundamentals. The initial step in the manufacturing of enriched uranium product (EUP), which forms the core of the reactor, is the mining of uranium oxide concentrate ( $U_3O_8$ ). Most nuclear power technologies require the conversion of the uranium oxide into uranium hexafluoride ( $UF_6$ ), a gas, which facilitates the enrichment process. The fissile U-235 isotope is only 0.7% by volume in the original ore and its concentration is increased to anywhere between 2.5% for initial cores to about 5% for reload fuel. Once enriched, the  $UF_6$  gas is converted to uranium dioxide ( $UO_2$ ), which is then fabricated into the fuel assembly that forms the core of the reactor. To allow for timely delivery of EUP demand from nuclear power plants, initial core and reload, we assume that the initial demand for  $U_3O_8$  reaches the market three years in advance of the operation of the reactor. Because of the excessive demand that will hit the market from the new-builds around the world, we increase the time window to four years for plants beginning operation after 2013. The above assumptions about volumes/MW and deliverability schedules are central to our forecasts.

The tables below detail our supply forecast, broken down by major components (Figure 7), our demand forecast and total operational nuclear capacity in the period between now and 2020 (Figure 8), the details of our fundamental balances including our projected spot price over the same period (Figure 9) and a price comparison of uranium with other fuels used for power generation on a \$/mmbtu basis (Figure 10).

**Figure 7. Supply forecast broken down into major components, 2007-2020**

	Primary-Mining (tU)	Secondary-Weapons (tU)	Reprocessing (tU)	Total Supply (tU)
2006	39,655	25,000	1,874	66,529
2007	40,845	23,500	1,930	66,275
2008	43,870	22,000	1,988	67,858
2009	53,586	20,500	2,048	76,134
2010	67,194	19,000	2,109	88,303
2011	69,209	17,500	2,172	88,882
2012	78,286	16,000	2,238	96,523
2013	80,634	14,000	2,305	96,939
2014	91,053	12,000	2,374	105,427
2015	93,785	11,000	2,445	107,230
2016	96,599	9,000	2,518	108,117
2017	99,496	8,000	2,594	110,091
2018	102,481	7,000	2,672	112,153
2019	105,556	6,000	2,752	114,308
2020	108,722	5,000	2,835	116,557

Source: WNA, Lehman Brothers estimates.

**Figure 8. Demand forecast and the total operational nuclear capacity, 2007-2020**

	Uranium Demand (tU)	Total Nuclear Base Capacity (MW)
2006	66,529	370,040
2007	69,781	374,649
2008	73,103	377,903
2009	84,382	381,788
2010	89,719	387,174
2011	92,332	393,209
2012	95,395	400,504
2013	100,859	416,604
2014	105,789	425,817
2015	108,710	428,517
2016	107,080	431,517
2017	105,473	435,137
2018	103,891	441,137
2019	106,869	446,137
2020	109,627	450,137

Source: WNA, Lehman Brothers estimates.

**Figure 9. Supply, demand and price forecast, 2007-2020**

Year	Supply (tU)	Demand (tU)	Spot Price (\$)
2007	66,275	69,781	120.06
2008	67,858	73,103	137.45
2009	76,134	84,382	167.49
2010	88,303	89,719	99.16
2011	88,882	92,332	119.50
2012	96,523	95,395	73.72
2013	96,939	100,859	124.20
2014	105,427	105,789	88.62
2015	107,230	108,710	99.80
2016	108,117	107,080	74.63
2017	110,091	105,473	68.00
2018	112,153	103,891	62.33
2019	114,308	106,869	63.50
2020	116,557	109,627	69.00

Source: WNA, Lehman Brothers estimates

**Figure 10. Price comparison of energy sources for power generation**

Commodity	Spot Price 6-Jun-07 (\$/mmbtu)	Spot Price Year Ago (\$/mmbtu)
Uranium	1.39	0.69
Natural Gas (Henry Hub)	7.83	6.16
Fuel Oil (FO6 .03% - NY)	9.58	8.92
Coal (CSX)	3.10	3.19

**Note: Uranium price includes U<sub>3</sub>O<sub>8</sub> commodity, conversion to UF<sub>6</sub>, enrichment and fuel fabrication. It does not include future costs of waste storage/disposal.**

Source: Lehman Brothers estimates.

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