The Nuclear Energy Industry - Past, Present and Future?

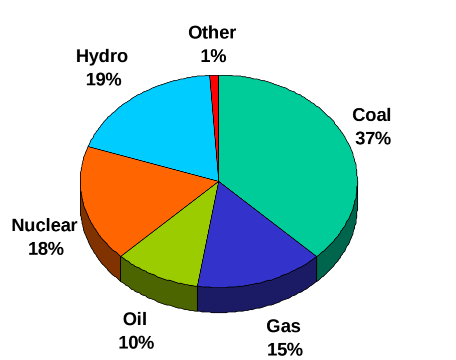
Presented by
Mr. James J. Graham
Cotter Corporation, Chairman
ConverDyn, President & CEO

Uravan, Ambrosia Lake, Gas Hills, South Texas …..historic names in U.S. uranium. Mining areas that supplied the uranium that brought the U.S. into the nuclear age and fueled the birth of nuclear energy for peaceful uses in the 1960s - a promise of nearly limitless, clean energy for the world's future.

That promise still exists today, but it is hard to hear over the constant whine of uneducated environmental extremists and the rhetoric of politicians thinking only of the next election. Nuclear power offers dependable electricity with very limited environmental impact at stable prices. Nuclear power releases no greenhouse gases or particulate matter into the atmosphere. High level nuclear waste (HLW), although long lived, is readily controlled and compact. In the U.S., generating 1 BkWh of electricity with coal produces 52,000 tons of solid waste (ash and sludge), compared to 4 tons of HLW produced by nuclear. Nuclear generated electricity is very cost competitive. The Utility Data Institute estimates that in 1999 electricity from nuclear power was the lowest marginal cost of the major baseload fuels, at about 1.85¢ per kWh, with natural gas the highest cost at 3.52¢ per kWh. Those estimates were made before the recent increases in gas. One may argue that nuclear is expensive to build, thus is not cost effective. A recent study in Finland, however, concluded that nuclear was the least-cost option for new generation capacity in that country because fuel cost is a major factor in the economics of other fuel generation types.

For most people in Colorado, it comes as a surprise that nuclear power is alive and well in many parts of this country and the world. Currently, there are 435 reactors operating worldwide generating nearly 18% of the world's electrical needs, with an additional 27 reactors under construction. In the U.S. we have 103 reactors producing 20% of the electricity consumed in the U.S. More electricity is generated from nuclear energy in the U.S. than any other country in the world.

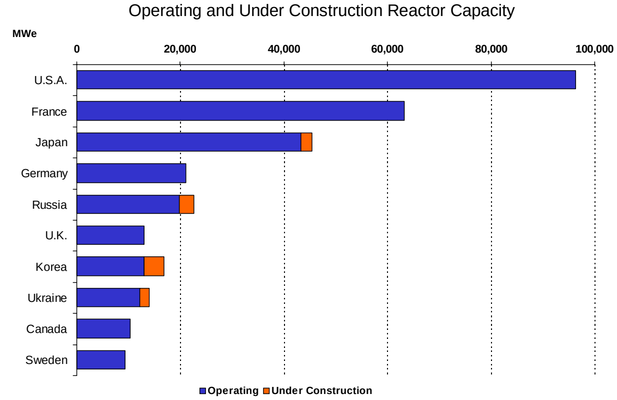
Sources of World Electrical Power



Source: UI, EIA, 1999

Top 10 Nuclear Powered Countries - 2000

Operating and Under Construction Reactor Capacity

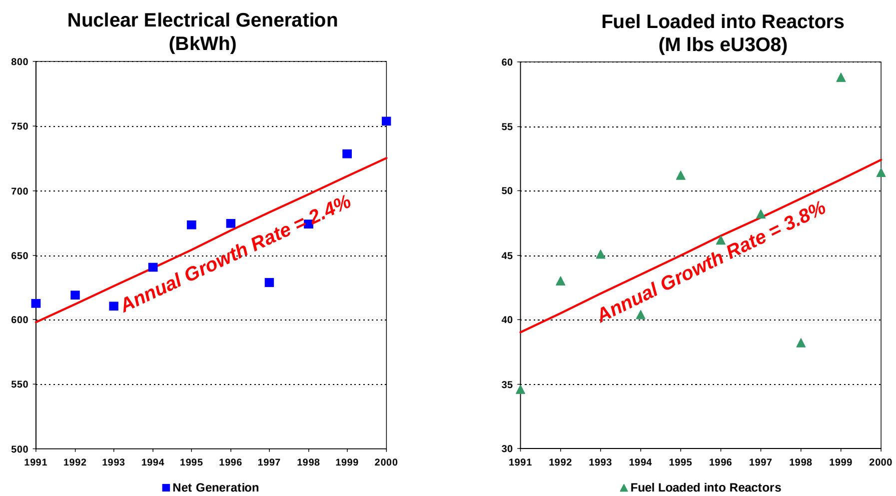


Predictions of the demise of nuclear power have proven to be far from reality. After the tragedy at Chernobyl, a great hue and cry went up to shut down existing, operating, safe, efficient reactors. Rather than recognize that Chernobyl happened as a result of a faulty cultural system, some saw it as a flaw of nuclear power. In some countries where alternative sources of power existed, such as Germany and Sweden, the anti-nuclear activists were able to garner enough support to implement phase-out laws. But in other countries, particularly in the Far East, nuclear has continued to be developed and has continued to provide clean, dependable, economic electricity. Firm plans for new reactors are on the books in Japan, Taiwan, Korea and China. Finland is moving ahead with plans for a new reactor. In light of global warming concerns, Sweden is reconsidering its premature phase-out of reactors. India continues to build new reactors, and in the UK great consideration is being given to building new advanced reactors to replace old inefficient, reactors that are being decommissioned. Even Germany's nuclear phase-out, as currently designed, will not be completed until the 2020s, time enough for public opinion to change drastically.

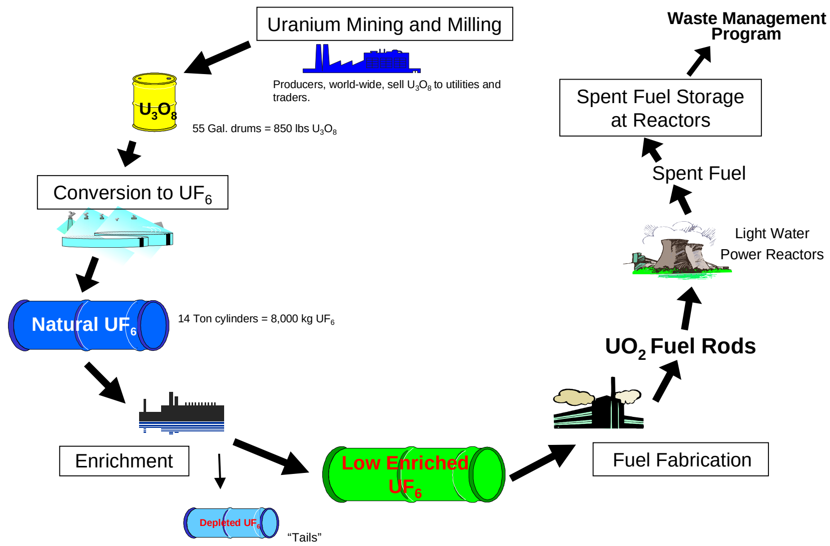
In the United States, two new reactors have come into operation while 10 reactors have been shutdown (9 permanently) for economic reasons since 1991. In that same period, however, the amount of electricity generated from nuclear in the U.S. has risen from 610 BkWh to 750 BkWh. This is equivalent to 20 new 1,000 MW generating stations. Increased output has been achieved as a result of: 1) extending re-fueling cycles and increasing fuel burn-ups which reduce down time; 2) improving fuel fabrication design; and 3) improving fuel loading management within the reactor core. U.S. reactor capacity factors have risen from an average of 70% in 1991 to 88% in 2000.

Increased performance has benefited the nuclear fuel industry. As can be seen in this slide, over the last 10 years, nuclear electricity generation has increased about 24%, with a corresponding 38% increase in fuel loaded into reactors. Thus, fuel consumption has risen 60% faster than electricity generation.

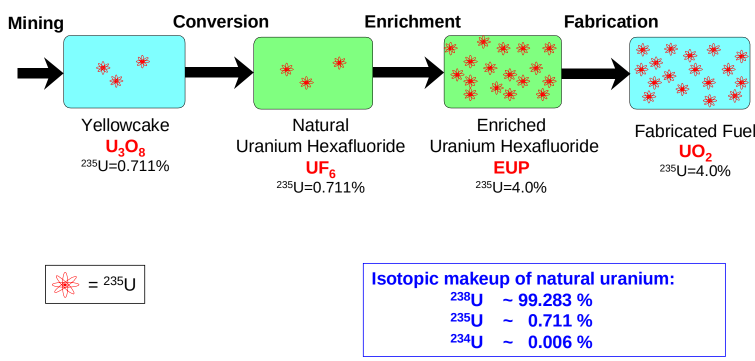
U.S. Nuclear Electrical Generation
vs. Fuel Requirements



The Nuclear Fuel Cycle



Typical Nuclear Fuel Cycle



How does fuel consumption relate to uranium? All nuclear fuel begins with the mining and processing of naturally-occurring uranium. This uranium is then enriched from a natural concentration of 0.711% U-235 up to 5.0% U-235, leaving a depleted tail of about 0.3% U-235.

Based upon this "typical" enrichment process, producing 1 pound of EUP for fuel fabrication requires about 10 pounds of natural U_3O_8. An average reload for a 1,000 MW light water reactor would use nearly 800,000 pounds U_3O_8.

U.S. producers are currently well represented in all stages of nuclear fuel production except one – uranium mining. With increased fuel demand and new reactors coming on-line, one might think that the U.S. uranium industry would be in a strong position at present. However, the U.S. uranium industry has been hurt by factors that all mining operations must contend with: increasingly more stringent environmental and labor laws, and new higher grade, lower cost deposits being developed outside the U.S. More significantly, uranium mining has always been subject to political whims, and the story is the same today.

Looking at the price of uranium through time helps tell the story. In 1974, there were 55 operable reactors in the U.S. and an additional 175 reactors ordered. Orders for uranium to feed these new reactors were piling up, and prices rose accordingly. As stricter construction

Major Nuclear Fuel Cycle Companies

Uranium Production

Cameco (CA)
Cogema (FR)
ERA (AU)
RTZ (NA)
WMC (AU)

Conversion

BNFL (UK)
Cameco (CA)
Cogema (FR)
ConverDyn (USA)
Minatom (RU)

Enrichment

Cogema (FR)
MINATOM (RU)
Urenco (UK)
USEC (USA)

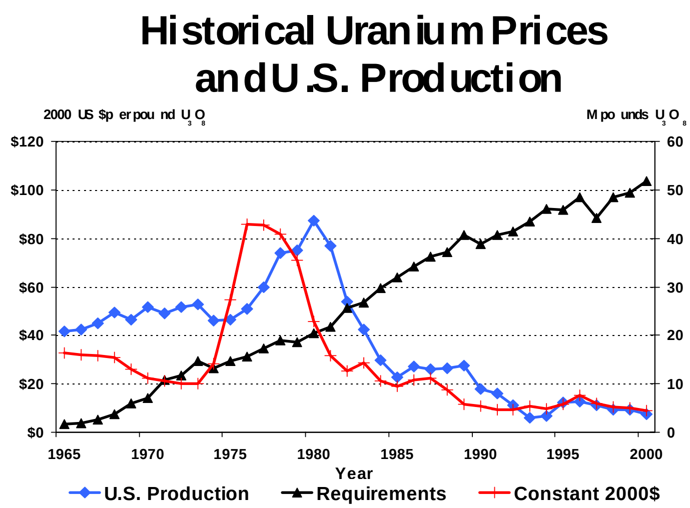
Fabrication

BNFL (UK)
Framatome (FR)
GE (USA)
MINATOM (RU)

and environmental regulations were passed, nuclear plants were required to be redesigned and retrofitted to meet these new regulations. Costs of new plants began to escalate, leading to many plant cancellations. When the event at Three Mile Island occurred in 1979, 40 reactors had already been cancelled. Public reaction and high costs resulted in additional cancellations. When Chernobyl occurred in 1986, nearly 100 of those plants that had been on order in 1974 were already cancelled. The story was the same around the world. Uranium demand weakened, and utilities and governments worldwide built up large uranium inventories.

With the collapse of the Iron Curtain in the late 1980s, large quantities of Soviet uranium began flowing into the world market. Coincidentally, many government inventories were being liquidated, putting additional pressure on an already oversupplied market.

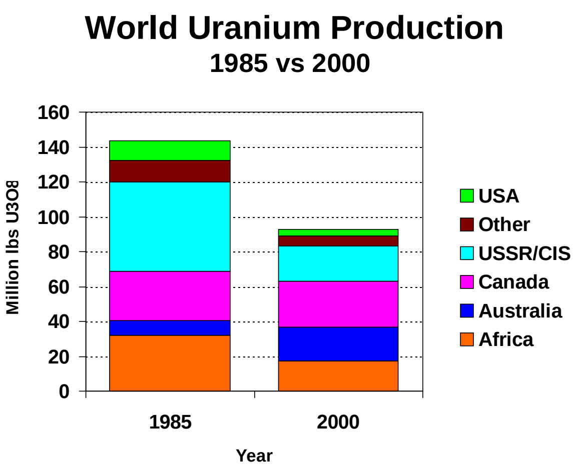
Although Government Suspension Agreements with several of the former Soviet republics stemmed the flow of Soviet-era uranium into the market, the impact of these agreements was negated by yet another government action. In January 1994, to help stabilize the former Soviet nuclear arsenal, the United States and Russia signed a contract implementing the purchase by the U.S. of Low Enriched Uranium (LEU) produced from the downblending of HEU from Soviet nuclear weapons. The LEU would be suitable for use as nuclear fuel in Western commercial reactors. The agreement was for the downblending of 500 mt HEU (containing the equivalent of 400 M pounds U_3O_8) derived from some 4,500 nuclear warheads over a 20 year period, equal to over 4 years of world production at current rates. This was a landmark agreement for the world, but the commercial nuclear fuel industry was to bear the <u>entire</u> impact of this material entering the market.

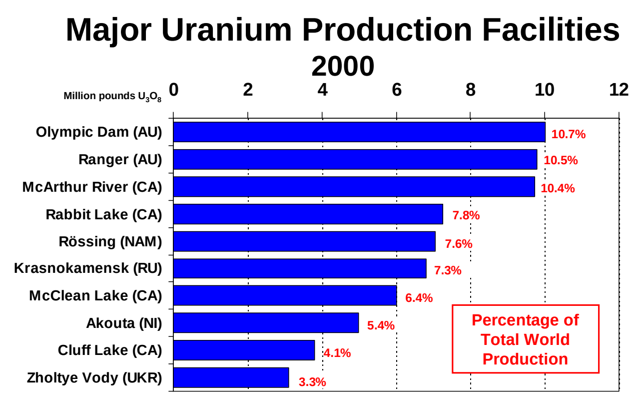


When it rains, it pours! Deregulation, which has been forced upon many utilities around the world over the last decade, has had an unforeseen impact on the uranium industry. To survive in an increasingly competitive environment, cost-cutting became a top priority for utilities. One cost-cutting measure undertaken worldwide has been the drastic reduction of strategic inventories of fuel. In the U.S., for example, regulated nuclear utilities were often required to maintain a strategic fuel inventory of 18 to 24 months. Under deregulation, many utilities now carry less than a 6-month inventory. A large portion of these excess inventories flowed directly into the market, reducing further the demand for new production.

The straw that seems to have broken the back of the U.S. uranium mining industry, pushing prices to record lows, was the privatization of the United States Enrichment Corporation (USEC). In response to pressure to create "smaller government", the decision was made to privatize the federal uranium enrichment operations, a decision which in and of itself should have been neutral on the nuclear fuel industry. However, in the final stages of the privatization process, USEC received huge inventories of surplus U_3O_8 and natural UF_6 from the U.S. government. This material was sold very quickly into the market (primarily the U.S. market) to offset USEC's high cost enrichment operations.

All these factors have combined to bring us to the current situation. At present, the ten largest production centers account for over 70% of world production, which is concentrated in the hands of just 6 companies.

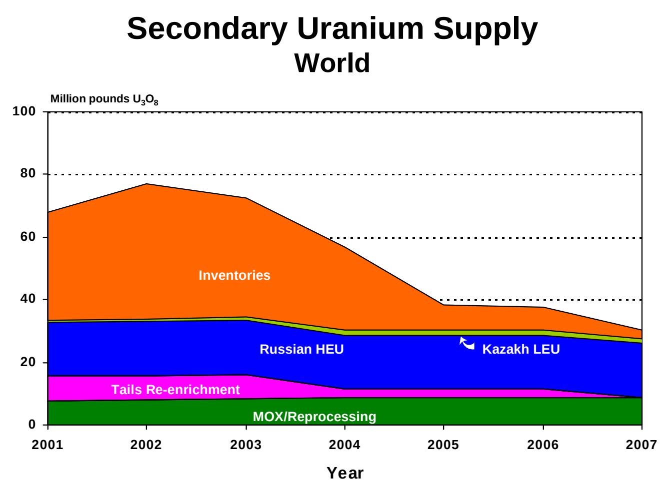




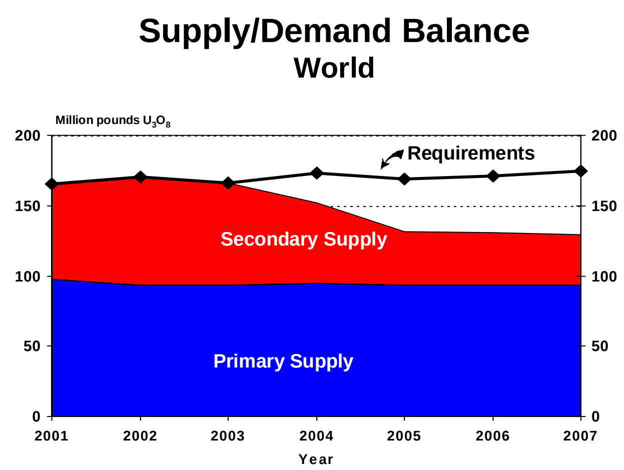
Uranium Industry Statistics 1985 vs. 2000		
	1985	**2000**
Uranium Requirements (M lbs U_3O_8)	92.5*	162.0
Uranium Production (M lbs U_3O_8)	92.1*	92.7
Supply Deficit (M lbs U_3O_8)	**-0.4***	**-69.3**
Commercial Uranium Production Companies	32	18
Commercial Uranium Mines	68	34

** excluding former Soviet Union*

The current uranium supply deficit is being filled by the secondary sources previously mentioned: inventories held by both utilities and others such as USEC; inventories accumulated in Russia during the Soviet era; and reactor grade LEU obtained from the downblending of Russian nuclear warheads. All of these sources are limited and will eventually be depleted. In addition, fuel produced from the re-processing of spent nuclear fuel as well as material created by the re-enriching of depleted tails displaces some uranium requirements. These latter sources are expensive, however, and are not expected to have significant impacts on uranium supply in the next ten years.



The near-term uranium supply/demand balance is shown below. As can be seen, uranium demand and primary supply are expected to remain relatively stable in the mid-term.



Primary supply on this graph represents expected scheduled production; production capacity is, of course, greater. Certainly, prices will have to rise above the current $9 per pound level before excess capacities are utilized.

As discussed earlier, the cornerstone of the nuclear fuel cycle is uranium. Without U_3O_8, converters cannot produce UF_6. Without UF_6, enrichers cannot produce EUP. Without EUP, fabricators cannot produce enriched fabricated fuel for reactors. Any change in the uranium stage will ultimately be reflected in the later fuel cycle stages. Exacerbating the effect of the downturn in the uranium mining industry since 1985 on those later stages has been the end of the nuclear arms race, which resulted in conversion and enrichment capacities previously utilized for the production of nuclear weapons becoming available to the commercial nuclear fuel industry.

In the conversion industry, of the six facilities operating in 1985, one has closed (Sequoyah) and one is no longer actively marketing, anticipating closure in 2006 (BNFL). In enrichment, the pattern is much the same. Two facilities in the U.S. have closed, the remaining U.S. facility is operating at 50% capacity. Only Urenco, a British-Dutch-German consortium that has developed new, lower cost centrifuge technology, is expanding.

Active Participants in the World Conversion Industry
1985 vs Today

1985	Today
BNFL	Cameco
Cameco	Cogema
Cogema	ConverDyn
ConverDyn	Minatom
Minatom	
Sequoyah	

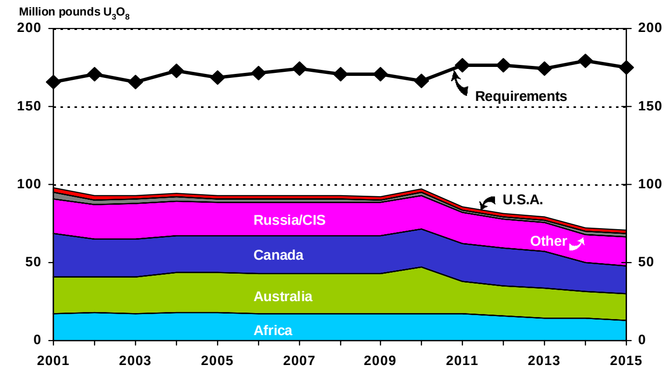
Active Participants in the World Enrichment Industry
1985 vs Today

1985	Today
Cogema	Cogema
DOE Oak Ridge	Minatom
DOE Paducah	Urenco
DOE Portsmouth	USEC - Paducah
Minatom	
Urenco	

Because different reactors types (Magnox, CANDU, BWR, PWR, VVER) require different fuel designs, the fuel fabrication industry has adjusted differently. Fabricators have consolidated to be able to offer a wider variety of fuel designs, but then have closed duplicated, surplus capacity. Atom of Sweden acquired Brown Boveri to form ABB, then acquired Combustion Engineering. BNFL then purchased both ABB and Westinghouse. GE, Hitachi and Toshiba have joined forces to form Global Nuclear Fuel, which operates GNF-Americas and Japan Nuclear Fuel (JNF). Framatome of France purchased Babcock & Wilcox to form FCF and Siemens purchased Exxon's fuel business to form SPC. Framatome and Siemens have since formed a joint venture merging both groups' nuclear operation into Framatome ANP.

We have seen many changes in the makeup of the uranium industry over the last 15 years. If we look 15 years into the future, assuming market conditions remain similar to today's, the situation we see is one that obviously cannot be sustained.

Uranium Supply/Demand
World



Uranium Industry Statistics 1985 – 2000 - 2015			
	1985	**2000**	**2015**
Uranium Requirements (M lbs U_3O_8)	92.5*	162.0	175.0
Uranium Production (M lbs U_3O_8)	92.1*	92.7	70.0
Supply Deficit (M lbs U_3O_8)	**-0.4***	**-69.3**	**-105.0**
Commercial Uranium Production Companies	32	18	11
Commercial Uranium Mines	68	34	18

** excluding former Soviet Union*

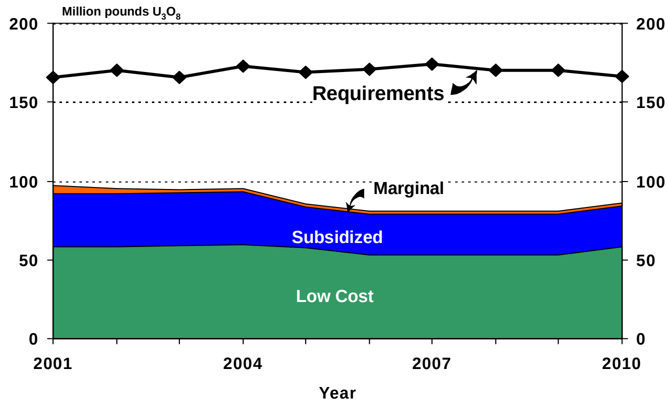
Barring any unforeseen catastrophes, the future for nuclear power remains strong. Will there be significant growth in generating capacity? Absolutely in the Far East. Europe may have new capacity come on line, but older, inefficient facilities will be shutdown. Russia has announced major growth in nuclear capacity, but the source of funding is not clear. In the U.S., the NRC has already granted some license extensions and licensed capacity increases, and is gearing up for an expected flood of additional requests, suggesting that the industry has no plans to go quietly into the sunset. There is talk of completing some partially constructed plants or possibly adding reactors at existing sites. Advanced designs in nuclear reactors, such as Eskom's (South Africa) Pebble Bed Modular Reactor and General Atomics' Gas Turbine Modular Helium Reactor, hold the promise of "off-the-shelf" designs that are pre-approved by the NRC, reducing construction time and costs, as well as providing inherently higher levels of safety than are found in older reactors. But a new greenfields nuclear power plant is still far out on the horizon.

Thus, the demand for uranium and other nuclear fuel products is not expected to diminish. Inventories worldwide have dropped significantly, and their future impact on the market will be minor. Other secondary sources will continue to displace only 15-20% of U_3O_8 requirements.

The fact is clear, more uranium will have to be mined than is currently scheduled! Where will it come from?

As can be seen in the following graph, only about 60% of future scheduled production is truly economic in today's market. Production from Niger is heavily subsidized by France. China, India, Bulgaria, and Ukraine produce uranium for internal needs, and cost is a minor consideration. Russia, through weapons conversion, primary production, inventories and reprocessing, controls almost 40% of the world market for uranium. Much of this control is exercised through an unrealistic economic system still in place from the Soviet era. As Russia slowly moves to a market economy, many of these sources of material may become uneconomic, thus decreasing Russia's strong position in the uranium market. Uzbekistan and Kazakhstan are offspring of the former Soviet system, and retain most of the same "command" economics.

Classification of Scheduled Production



Expansions of existing mining projects can be expected to account for any increase in production to be seen in the next four to six years. Primary production will be increasingly focused on high-grade unconformity deposits in Canada, in situ leach projects in the republics of the former Soviet Union, and by-product output from Australia. Restrictive and costly ground water restoration standards will hamper the expansion of in situ leach production in the U.S.

A large backlog of identified deposits exists. Greater efforts will likely be expended in applying new technology, in situ leaching for example, to these deposits than to exploring for new deposits. Significant expenditures for exploration will be made only when market prices increase substantially (50% or so) from prices seen in 2001 ($9/lb U_3O_8).

Development of new deposits will be a challenge. Few, if any, lending institutions are willing to provide development financing for a uranium project regardless of how attractive the project might be. Most major mining companies are unwilling to participate in uranium production because of potential high-profile controversy. There are no indications that U.S. utilities would even consider, at this time, a direct investment in uranium production.

Will any of the mining areas mentioned at the beginning of this paper see new life? Not anytime soon with today's technology! Conventional mining and milling production from U.S. uranium deposits is unlikely for a decade or more. At Cotter, we are successfully exploring new technologies to recover uranium from non-traditional sources. We are investigating non-traditional methods of recovering uranium from our Western Slope uranium-vanadium deposits. We are always on the lookout for uranium production opportunities. In today's economic and environmental regime, we, like all competitive businesses, must be more and more creative in our thinking. A new approach (and not a small challenge) for mining engineers!