Nuclear Power: Winds of Change

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Table of Contents

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by
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Introduction

Since our last report published in early 2005, the winds of change (otherwise known in society as changes in a paradyme) are upon us and have affected the general public as well as geoscientists in the U.S. and around the world. Not only has evidence of global warming stimulated renewed concerns for climate change over the next 50 years and beyond, it has underscored the urgency of reducing the burning of carbon-based fuels worldwide (see the United Nation's IPCC Report, 2007). The debate over climate change has been intense because the stakes are very high. A common view advanced by many climate scientists is that the current global warming rate will continue or accelerate. Hansen, *et al*., (2000) argue that rapid warming in recent decades has been driven mainly by non-CO_2 greenhouse gases, such as chlorofluorocarbons, methane, and nitrous oxide, not by the products of fossil-fuel burning, CO_2 or aerosols. Then there are the naysayers who are convinced that global warming is part of a natural cycle and not related to human activities to any significant extent (Lewis, 2006), and that the public debate is based on a hoax driven by political interests (Dunn, 2007). In any event, regardless of the cause and rate of these changes to the Earth's environment, the necessity of transition to alternative energy sources, such as solar, wind, and nuclear power, has become clear. The role that each of these sources of energy and the technologies that support them can play in the global energy picture of the future has begun to come into focus.

Alternative Sources of Energy

Solar arrays and wind farms appear to have applications in isolated areas, both onshore and offshore, where visual and ecological effects or security issues are not of overwhelming concern. However, because solar panels and windmills for individuals and/or small groups are capital intensive, only the financially well-off will be able to afford the new technology over the next 20 years.

Electric cars and trucks that incorporate new technology using improved electrical batteries were proven in California in the 1990s. Now they are suspiciously absent from the marketplace, although hybrid automobiles are now available and gaining in popularity. The development of hydrogen fuel-cell technology for automobiles is mired down in research controlled by the U.S. auto manufacturers and the oil and gas industry. Prices for these kinds of vehicles are still high because, as with any new technology, the research costs are loaded into the prices of new technologies and are borne by those who can afford them – e.g., the financially well-off and the U.S. armed services. There is little doubt that the high prices now paid for the new technologies will decline as they gain market share over the next 20 years, guiding a transition away from the old, environmentally unfriendly technologies that burn fuel oil and gasoline, natural gas, ethanol, and coal-derived products that may appear on the market. Because the oil and gas industry maintains large investments in economic reserves of oil and gas, coal and lignite, coal-bed methane, oil shale and oil sands, the transition away from the present energy policy is not likely to be rapid and probably will need to extend over the next 20 years. This transition period will only be reduced if the U.S. market place demands it, and, if reduced, will improve our climate and also the overall efficiency of how we use our natural resources.

Other Emission Sources

In addition to the contribution that developed countries make to climate problems through CO_2 emissions, the role of other sources of carbon, CO_2, and CO contributed by remote regions on the Earth is now clear. Satellites in orbit monitor many environmental conditions, one of which is clear-cut burning (Herring, 2007). Just how these sources of habitat-burning and destruction can be controlled in the future is uncertain, but governments are now turning their attention to the problem. For example, the Brazilian government has recently begun a major effort to control the clear-cutting and burning of their forests. These efforts must be supported in addition to efforts to modify industrial and individual patterns of energy consumption, in order to have any significant effect on the overall conditions on the Earth 20 years from now. The time for choices has run out. In fact, we may have waited too long to slow down the climate-change machine without suffering a severe economic and social backlash in the years to come.

New Alliances

As the reality of global warming has gained acceptance over the past two years, discussions and reports have flooded the news media opposing the burning of carbon-based fuels such as coal, oil and natural gas and focusing on the need for cleaner sources of energy. This has brought about a resurgence in consideration of nuclear power based on its reputation over the past 25 years of being a "clean" energy source. An unusual alliance has developed between the nuclear-power industry and many of the national environmental advocacy groups based on the long safety history and relative environmental friendliness of nuclear power, initiating a reversal of unfortunate decisions from the 1970s. The only major area of concern centers around nuclear waste issues.

In the late 1970s, the United States decided not to recycle (reprocess) spent fuel for fear of weapons proliferation but, instead, to dispose of it in a deep geologic repository that had a 50-year retrievability (in case we changed our minds). This led directly to the Yucca Mountain "problem". But this early decision has been overtaken by events elsewhere in the world, where recycling of spent fuel, as well as U-enrichment, has proceeded forward, making the earlier decision irrelevant but costly (Conca, 2007).

The Department of Energy has recently initiated a Global Nuclear Energy Partnership (GNEP) that addresses recycling, proliferation and the developing world's growing need for energy. Under GNEP, a consortium of nations with advanced nuclear technologies would provide fuel and reactors sized to meet the grid and industry needs of other countries. By participating in GNEP, developing countries would enjoy the benefits of clean, safe nuclear power while minimizing proliferation concerns and eliminating the need to invest in the complete fuel cycle, e.g., recycling and enrichment (Figure 1). In cooperation with the International Atomic Energy Agency, participating nations would develop international agreements to ensure reliable access to nuclear fuel. Therefore, the U.S. or France would supply the fuel to countries like Iran or Indonesia, retrieve it for recycling when it is used, and provide them with new fuel, eliminating their need to develop enrichment programs that could be used to produce weapons-grade material. The development of standardized modular reactors and recycling technologies is the technical challenge of the next ten years.

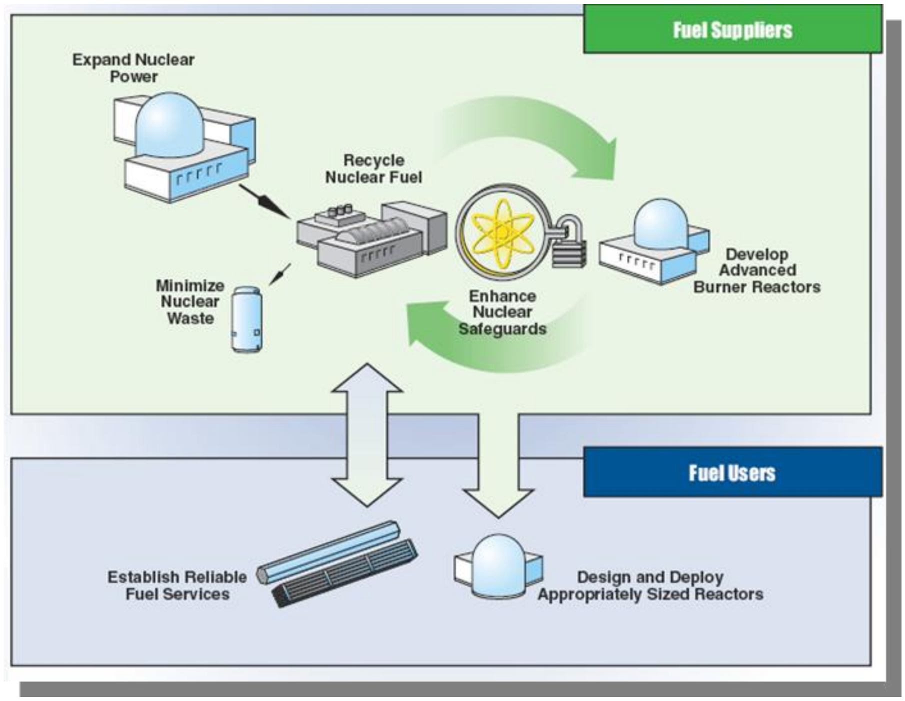


Figure 1 – A Reliable Nuclear Fuel Service Arrangement Between Fuel Suppliers, such as the U.S., and Fuel Users, such as Iran, as Embodied in the New DOE GNEP Program (From DOE, 2007).

In the meantime, reactors are still being built around the world (130 are planned in the next 5 years). It is estimated that nuclear energy will account for as much as 10 trillion kWhrs/year by 2040 necessitating the construction of over 400 new reactors. Because recycling facilities are far behind the need for fuel, demand for yellowcake will continue to climb, as will the price, for many years to come.

Yellowcake Price Drives Uranium Exploration

The resurgence of the nuclear-power industry has stimulated a significant rise in the spot market price of yellowcake (U_3O_8) well beyond that of $50/pound considered likely in 2005 (Campbell, *et al*., 2005). By the end of 2006, the yellowcake spot-market prices rose above $72/pound, more than doubling over the previous 12 months. Although the average price involved in long-term contracts for deliveries in 2005 was less than $15/pound, as the contracts with the nuclear utilities mature, major price re-adjustments upward will certainly occur. See UxC for the spot and other uranium prices (UXc, 2007). The U.S. DOE's Energy Information Agency tracks the important facts on yellowcake usage and consumption (see additional references below).

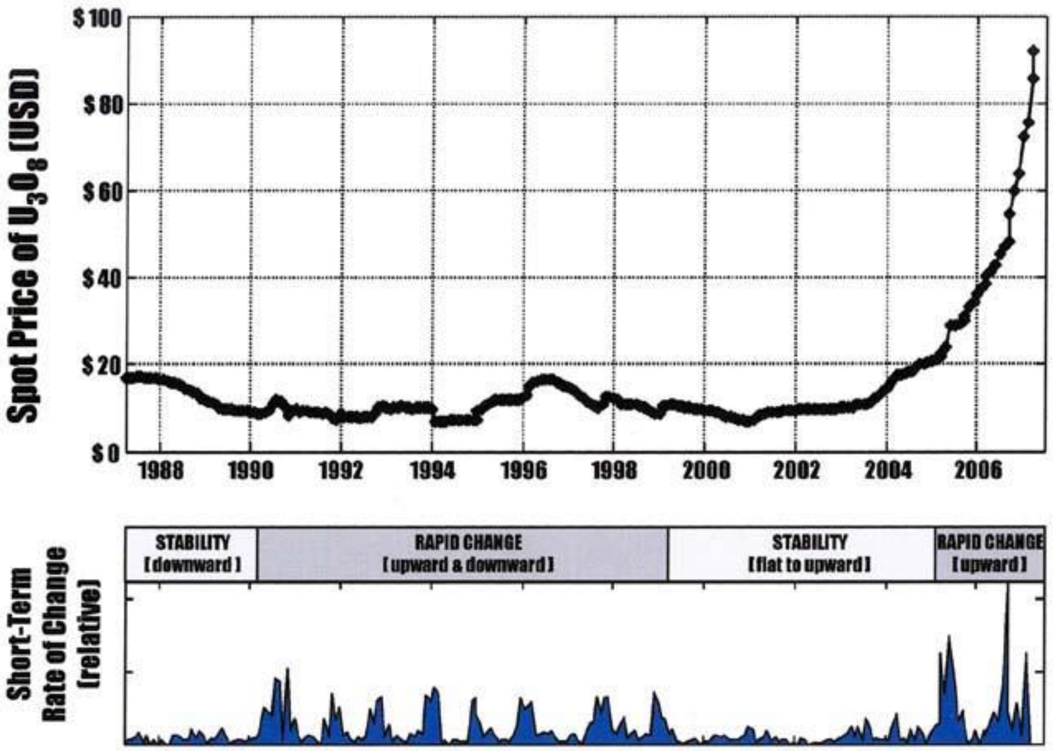


Figure 2 – Spot-Market Price for Uranium: 1987 to 2007

New mineral exploration companies are appearing and drilling activities in South Texas have already reached levels exceeding those of the late 1970s. A shortage of drilling rigs is driving up prices and causing delays in production schedules. Discovery of new uranium deposits is resulting from following extensions of previously known, shallow deposits that were mined by open-cut methods (see Figure 3). The oxidized tongue shown in Figure 3 is of orange and grayish orange hues. The ore zone is medium gray surrounding the oxidized zone. Prior to mining, the direction of ground-water flow would have been to the right in Figure 3. The red zone shown at the bottom of the figure is the selenium zone and the bluish zone just above is the molybdenum (and vanadium) zone that is common in some Tertiary roll fronts in Texas (see Dickinson and Duval, 1977; and Campbell and Biddle, 1977). In many South Texas deposits, methane and perhaps hydrogen sulfide are the likely reducing agents, while in other areas, lignite and other carbonaceous materials are important constituents in forming the bio-geochemical cell that produces uranium mineralization in Tertiary sediments in Wyoming and elsewhere.

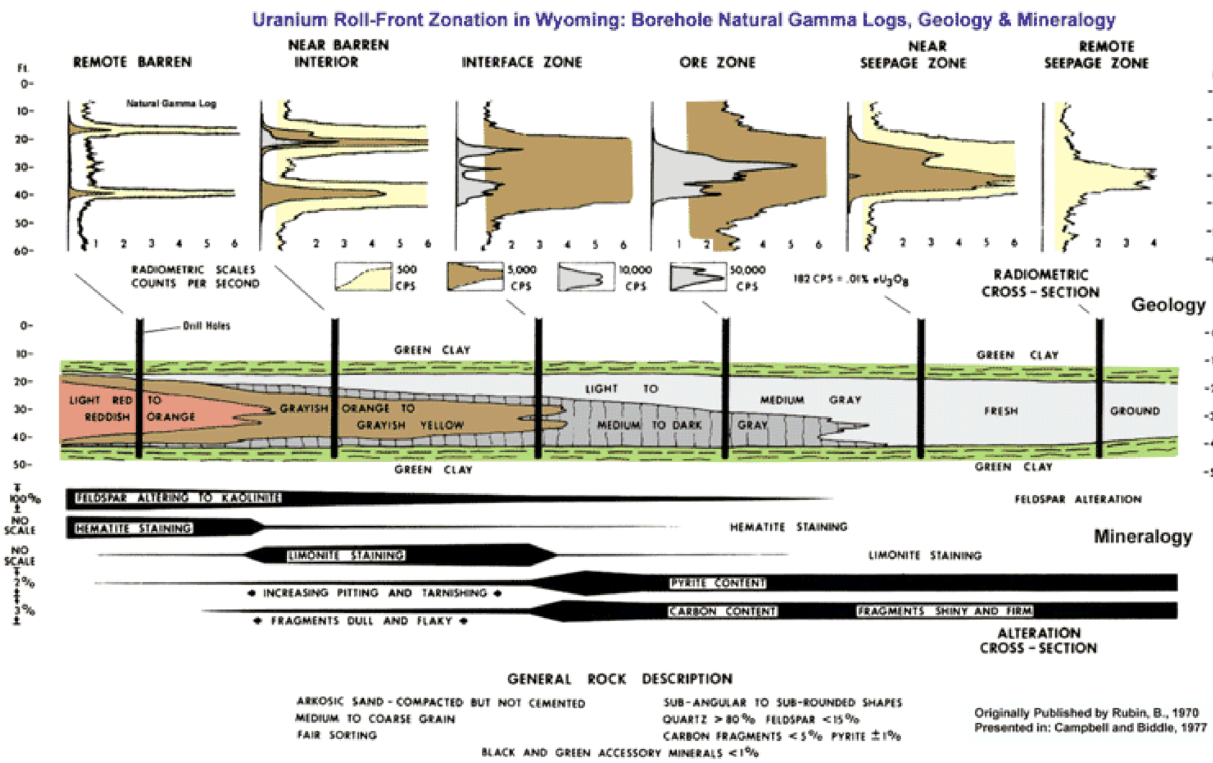
Figure 3 – Roll-Front Exposed in Wall of Open Cut Mine of the 1970s in South Texas (From Dickinson and Duval, 1977)

Using the geologic methods developed in the 1960s and 70s by Rubin (1970), illustrated in Figure 4, and by Rackley and others (1968, 1971, 1975, and 1976), the success rates are going up for uranium mining companies on the American, Canadian, and foreign stock exchanges that employ well-educated, professional geoscientists. Claim-staking activities on Federal and private lands in the U.S. are running at record levels with a disturbing amount of prospective land under control by major Canadian mining companies. These companies may have little interest in committing to production in order to protect their Canadian-based mining activities and associated yellowcake pricing.

Need for Well-Trained Professionals

In the 1970s and 1980s, approximately 2,000 professional geoscientists were working on uranium projects in the U.S. A generation of uranium geologists and engineers has been lost. Presently, only 400 to 500 geologists and only a few qualified hydrogeologists are working in the field. State geoscience licensing in Texas, Wyoming, Washington, and elsewhere has reinforced the upward trend in professional competency and responsibility to the general public in the analysis of uranium reserves and environmental compliance for private mining companies as well as for those on the stock markets. To staff up, it will take some time to train new geologists and hydrogeologists and this will inhibit exploration and yellowcake production schedules as well.

Figure 4

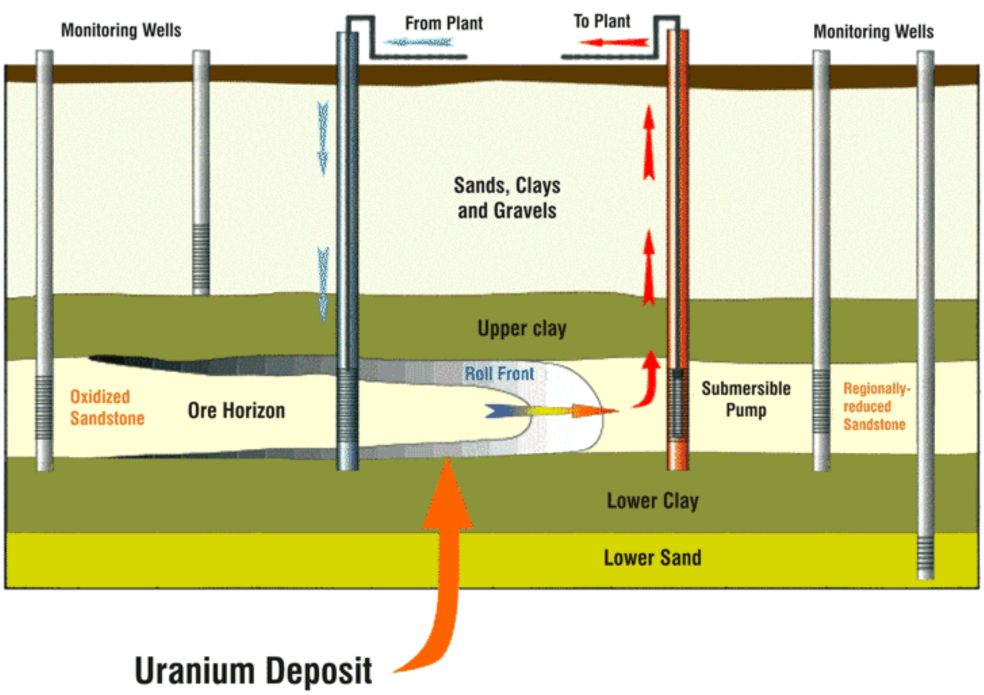


Out with the Old Mining Technology – In with ISL

In the production of uranium, mining no longer requires open-cut surface mines as in the past. New, environmentally friendly, methods have developed substantially since the late 1970s. Mining uranium in Tertiary sandstone deposits in South Texas, Wyoming, Kazakhstan, and elsewhere now incorporates in-situ leaching (ISL) methods that involve water-well drilling technology and common industrial ion-exchange technology similar to household water-softening methods. Because the uranium ore has formed naturally in aquifers often used for drinking-water supplies elsewhere along the trend, the part of the aquifer being mined by ISL methods is prohibited by the State to be used as a source of drinking water. In addition, the area of influence of nearby large-capacity water wells needs to be carefully monitored (by the owners) to avoid drawing the naturally contaminated ground water away from the uranium production area. The leaching agents used in ISL are typically special forms of O_2, and CO_2 and, in some cases, other fluids as well, all of which are non-toxic and are easily recovered by pumping.

It is the responsibility of the mining company (and required by state regulatory agencies) to install strategically located ground-water monitoring wells to periodically sample for fluids that may have escaped the hydraulic cycle. The cycle entails injection and recovery of uranium-saturated fluids for making yellowcake from ion exchange resins in the plant on the surface. The typical cycle is illustrated in Figure 5, below.

Figure 5
Typical In-Situ Leaching System
(Modified from: South Dakota Department of Environment and Natural Resources, 2006)



To a large extent, in-situ mining of uranium is both a natural resource development project and a natural, contaminant-remediation project. Although uranium ore is a natural energy resource, it is also a bacterial waste product that was formed within the bio-geochemical cell of the roll front. Both rely heavily on, and are driven by, hydrogeological processes including: hydraulic conductivity, hydraulic gradient, sediment and ore-zone porosity, and hydrochemistry of natural and injection fluids (both within the ore zone and at proximal and distal parts of the aquifer). Protecting upper and lower aquifers from incursions of the production fluids requires understanding the hydrogeological conditions in and around the production site.

The mine's hydrogeological staff is responsible for monitoring the behavior of the fluids and associated hydrochemistry during the in-situ leaching of the uranium ore zones and for monitoring the data generated from sampling the surrounding monitoring wells. Regulatory personnel work with the mine's staff to ensure that the mine meets the regulations written to protect the aquifers outside the production areas.

Energy-Source Competition: The Environment vs. The Oil & Gas Industry

As long-term plans continue to expand the use of nuclear power for the generation of electrical power in the U.S., the price of yellowcake will continue to rise. At this writing, the spot price passed through $91/pound of yellowcake. It is widely suspected that the price of uranium will continue to rise for the next few years until the perspective of a uranium shortfall is realized. This will occur when new production comes on line and current operations are expanded to increase production, likely within the next 5 to 10 years. If the world greatly expands the use of nuclear power by building many more plants than have been announced to date, the pressure on production and price will be tremendous beyond 2020. However, recent efforts by the international community in recycling and enrichment of nuclear wastes may play significant roles in stabilizing production and fuel prices in the future.

It is interesting to note that the major oil and gas companies, who in the 1970s held major stakes in uranium exploration and production, are sitting it out so far this cycle. Perhaps just as the majors likely encouraged the U.S. automotive industry to sit out on the development of the electric car. Therefore, one might presume that we can expect competition between nuclear power and 1) natural gas, 2) coal and lignite, 3) oil shales, 4) oil sands, and 5) other oil- and gas-based fuels that might be burned to generate power for the electrical grid in the U.S. Because Texas has abundant coal-lignite resources, The Center for Energy and Economic Development (CEED) is pressing hard for coal (lignite) development and use in electrical power generation in Texas (see CEED reference below). If the pressure continues on limiting the development of the so-called ”dirty” energy sources, they will soon fade into obscurity within 20 years because their time of usefulness may have passed even before some of them could be brought into production. Standard energy resources, such as natural gas, will serve to back-up energy needs for decades to come. Furthermore, there is a growing sentiment that if the major oil and gas companies wish to remain leaders of the global energy field, they will have to re-enter the nuclear-power industry – both at the plant level to play a strong role in hydrogen production and distribution and at the exploration level to influence the availability of reactor fuel and associated yellowcake prices (Lea, 2007).

This economic and environmental competition between energy resources can only be good for the American people and for the industries that support it. However, as the winds of change in our way of using energy impacts society as well as industry and the specter of climate change continues to rise on the horizon, nuclear power used to generate electricity will play a greater role in energy usage for many years to come.

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