

EMD Uranium (Nuclear Minerals) Committee



2014 EMD Uranium (Nuclear Minerals and REE) Committee Annual Report

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Special Consultants to the Uranium (Nuclear Minerals) Committee:

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(Founding Member of EMD in 1977, Secretary-Treasurer: 1977-1979, and Past President: 1982-1983)
- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD in 1977)
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- **M. David Campbell, P.G.**, Senior Geologist, I2M Associates, LLC, San Diego, CA
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(Founding Member of EMD in 1977)
- **Jeffrey D. King, P.G.**, President, I2M Associates, LLC, Seattle, WA
- **Jay H. Lehr, Ph. D.**, Science Director, Heartland Institute, Chicago ([on Nuclear Power](#))

COMMITTEE ACTIVITIES

During the past six months, the AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earth) Committee (UCOM) continued to monitor the expansion of the nuclear power industry and associated uranium exploration and development in the United States and overseas. Input for this 2014 Annual Report* has also been provided by Henry M. Wise, P.G., (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration; Steven Sibray, C.P.G., Vice

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Chair (University) on university activities in uranium, thorium, and rare-earth research; and by Robert Gregory, P.G., Vice Chair (Government) on governmental (State and Federal) activities in uranium, thorium, and rare-earth research, with special input from other members of the Advisory Group.

Thorium and rare earth activities are also updated in this Annual Report, which is a function approved by the UCOM in 2011. On the basis that they often occur together, we provide summary information on current thorium and rare-earth exploration and mining, and associated geopolitical activities.

The EMD Uranium (Nuclear Minerals) Committee is also pleased to remind the reader that the Jay M. McMurray Memorial Grant is awarded annually to a deserving student whose research involves uranium or nuclear fuel energy. This grant is made available through the AAPG Grants-In-Aid Program, and is endowed by the AAPG Foundation with contributions from his wife, Katherine McMurray, and several colleagues and friends. Those students having an interest in applying for the grant should contact the UCOM Chairman for further information and guidance. The biography of Mr. McMurray's outstanding contributions to the uranium industry in the U.S. and overseas is presented ([here](#)).

COMMITTEE PUBLICATIONS

The EMD co-sponsored Journal: *Natural Resources Research* has published the bi-annual *Unconventional Energy Resources: 2013 Review* in Volume 23, Issue 1, March, 2014 ([more](#)). The UCOM 2013 contribution begins on page 62 and is titled: *Uranium, Thorium, and Associated Rare Earth Elements of Industrial Interest*. The 2011 version ([here](#)); 2009 ([here](#)); and 2007 ([here](#)).

The AAPG-EMD Memoir 101: *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space* was released in mid-2013. The EMD's Uranium (Nuclear and REE Minerals) Committee and members of I2M Associates, LLC, contributed the final Chapter 9, entitled: *Nuclear Power and Associated Environmental Issues in the Transition of Exploration and Mining on Earth to the Development of Off-World Natural Resources in the 21st Century*.

Because the 2012 updates to Chapter 9 were omitted during final editing, these updates and associated revisions have been included in a revised PDF version of the chapter. Chapter 9 is preceded by Chapter 9's Table of Contents, and is followed by the author biographies of the chapter, the Memoir 101's Press Release, the book's Table of Contents, ordering information, book preface, and a copy of the front book cover ([more](#)). Forbes.com has highlighted Memoir 101 in a recent article emphasizing the coverage of Chapters 8 and 9 ([more](#)).

NUCLEAR OUTREACH

James Conca, Ph.D., a member of the Advisory Group of this UCOM, has also been contributing popular articles to Forbes.com on many other nuclear subjects. Some of these articles are listed below:

1. “Coal Doesn't Have To Die - We Can Make Furniture Out of It.” ([here](#))
2. “Beyond Earth's Atmosphere - Energy Needs for Space Colonization” ([here](#)).
3. “Like We've Been Saying - Radiation Is Not A Big Deal” ([here](#)).
4. “How Deadly is Your Kilowatt? We Rank the Killer Energy Sources” ([here](#)).
5. “Where would YOU put our Nuclear Waste?” ([here](#)).

I2M Associates, LLC maintains a Web Portal that provides up-to-date articles and reviews of current and historical uranium and related activities in the U.S. and around the world ([more](#)).

I2M also monitors the national and local press and publishes “Confronting Media & Other Bias Against Uranium Exploration & Mining, Nuclear Power, and Associated Environmental Issues,” ([more](#)).

EXECUTIVE SUMMARY

- With world GDP rising by 3.6 percent per year, world energy use will grow by 56 percent between 2010 and 2040. Half of the increase is attributed to China and India.
- Nuclear is increasing by 2.5% per year, but renewables, including hydropower, are now the fastest-growing power generation sector, growing at about 4% per year. Non-hydro renewables are projected to increase by about 10% per year in the next several years almost doubling in the seven years, from 4% of global total power production in 2011 to about 8% in 2018. However, fossil fuels will continue to supply the majority of world energy use through 2040.
- Natural gas is the fastest growing fossil fuel, supported by increasing supplies of shale gas, particularly in the United States.
- China may be changing its energy mix where coal was previously projected to grow faster than petroleum consumption, mostly due to increases in China’s consumption of coal, to nuclear construction and to the slow growth in oil demand in OECD member countries.

- China is attempting to turn away from coal-fired plants that currently produce about 70% of China's power production.
- Given current policies and regulations, worldwide energy-related carbon dioxide emissions are projected to increase 46 percent by 2040, reaching 45 billion metric tons in 2040.
- Japan will re-start many of their nuclear reactors with improved safety factors over the next few years because Japan has no realistic alternative.
- The current status of U.S. reactors include 100 reactors in full operation, 5 under construction, 25 in the planning/permitting stage, and 32 in permanent shut-down or retirement.
- China has 20 operating nuclear power plants (only 1% of total power produced), another 28 under construction, and brought 3 plants on-line in 2013. An additional 50 plants are in the various stages of planning and permitting.
- Current decreases in natural gas prices are leading to increases in the selection of natural gas for power generation.
- Coal use for power generation remains stable in some regions in the U.S. but is declining in other areas as natural gas prices decline and as construction of nuclear power plants increase.
- 2013 U.S. uranium production increased by 16% over that of 2012, the highest production since 1997.
- At present, 83% of U.S. nuclear fuel demand is met by foreign sources, such as Canada, Australia, and Kazakhstan.
- Uranium spot prices will likely remain around \$35.00/pound U₃O₈ but upward pressure is growing because of the future demand from China, Japan, and new construction in Southeast Asia and elsewhere in the world.
- There are currently 20 uranium exploration and mining companies active in the U.S.
- Some mine closures are imminent, especially in Africa for higher cost mines.
- Virginia uranium mining is on hold by state-wide geopolitics and NIMBY reactions by local residents.

- Lawrence Livermore Lab researchers have pioneered the use of near-infrared spectrometry for analyzing the chemical composition of and detecting the origin of uranium and yellowcake samples to interdict smuggled yellowcake and uranium ore.
- China and India are considering the use of thorium technology in their nuclear-reactor designs to reduce the need for uranium over the next 25 years or less.
- Canada continues to produce world-class uranium deposits in the Athabasca Basin in northern Saskatchewan with record high uranium grades above 20% U₃O₈.
- Cameco's Cigar Lake deposit in Athabasca Basin is expected to produce 18 million pounds of U₃O₈ by 2018 or about 9% of the world supply per year.
- Cameco also owns and operates the McArthur River Mine in the Athabasca Basin, which produces about 13% of the world's supply of uranium.
- Australia's Olympic Dam Mine is owned by BHP Billiton and produces about 6% of the world's supply.
- Australia's Ranger Mine is owned by Energy Resources of Australia produces about 5% of the world's yearly uranium supply.
- Other mines in Australia also rank high in production, such as the Beverly and Honeymoon Mines, with the Four-Mile Mine nearing production.
- Kazakhstan mines produce about 36% of the world's yearly supply, most of which goes to Russia and China.
- In Western Australia, Cauldron Energy is having success with its metallurgical testing of its Bennet Well deposit and is preparing for production with increasing U₃O₈ prices.
- Giant uranium producer, Rio Tinto, is having environmental problems with leaching-tank leaks at both the Ranger Mine in Northern Territory (Australia) and at its Rossing Mine in Namibia (SW Africa).
- Junior uranium companies worldwide are having problems maintaining equity capital with the low uranium price, even those with substantial resources.
- Argentina has a number of uranium deposits under development to fuel two existing nuclear reactors, with a third to go on-line in 2014.

- Greenland's Kvanefjeld deposit in the Ilimaussac Complex located in Southern Greenland is under development by Greenland Minerals & Energy, Inc. and contains significant uranium, rare earths, and zinc. The local and national governments are supporting the project.
- Mongolia has substantial uranium resources. Russia mined the deposits until 1995, and then began again in 2008. Russia is negotiating to develop other deposits in the area but is having issues with the political risks involved within the government. The latter are attempting to improve its nuclear mining regulations and laws. French company AREVA has signed an agreement in October, 2013 to develop uranium mines and create AREVA Mines LLC, (66% AREVA & 34% MON-ATOM, the state-owned Mongolian nuclear company).
- In Africa, Gabon, Mauritania, and Zambia have emerged with viable uranium resources; but doing business and fieldwork in such remote regions is challenging, both financially and geopolitically.
- Tanzania has a number of developing uranium deposits. The East African Resources, Inc. (EAR) has arranged financing to fund further exploration on its Mabada deposit. Other deposits are under development by EAR with a South Korean group and by a Russian group (Uranium One).
- India is looking to Central Asia to meet its uranium needs, such as Uzbekistan, Kazakhstan, and Mongolia, as well as Australia. India is also looking to build thorium reactors making use of their abundant monazite sands.
- Reports have surfaced that China now controls the market on up to 15 strategic minerals (e.g., rare-earth elements (REEs), graphite, etc.), while Russia also exerts major control on palladium, platinum group metals, and nickel, as well as uranium via Kazakhstan.
- Thorium is under serious study to replace uranium in reactors via Thor Energy and a consortium involving Westinghouse and others.
- China is increasing research funding to evaluate thorium in an attempt to turn away from coal-fired power plants, which makes up 70% of China's power production, nuclear currently contributes only 1%. India also is looking to building thorium reactors by 2025.
- In the area of REEs, the U.S. (i.e., the State of Alaska) is helping to fund a rare-earth mine (Ucore Rare Metals, Inc.).

- In Canada, the government is considering providing funds to secure REE supplies via Pele Mountain Resources, Inc.
- In Europe, Tasman Metals, Ltd. could be a dedicated supplier of REEs to the European Union.
- The U.S. DOE has identified five elements of the REE group as the most critical: dysprosium, neodymium, terbium, europium, and yttrium. Concerns are that China may be only able to produce enough “heavy” REEs to supply its own needs.
- Ocean-Floor Mining permits by the United Nations continue to increase in the Pacific, Mid-Atlantic, and Indian Oceans.
- Ocean-Floor Resources may contain more than 27 billion tonnes of nodules consisting of around 290 million tonnes of copper, 340 million tonnes of nickel, and even larger resources of REEs.

INTERNATIONAL ENERGY OUTLOOK: 2010-2040

The U.S. Energy Information Agency’s (EIA's) recently released *International Energy Outlook 2013* projects that world energy consumption will grow by 56% between 2010 and 2040, from 524 quadrillion British thermal units (Btu) to 820 quadrillion Btu ([more](#)). Most of this growth will come from non-OECD (non-Organization for Economic Cooperation and Development) countries, where demand is driven by strong economic growth ([more](#)).

International Energy Agency (IEA) claims that nuclear power is increasing by 2.5% per year, but renewables, including hydro, are now the fastest-growing power generation sector, growing at about 4% per year, and will make up almost a quarter of the global power mix by 2018, up from an estimated 20% in 2011. Non-hydro renewables are projected to increase by about 10% per year in the next several years almost doubling in the seven years, from 4% of global total power production in 2011 to about 8% in 2018 ([more](#)). However, the EIA projects that fossil fuels will continue to supply over 70% of world energy use (power plus transportation) through 2040 unless China and India continue their recent interest in new nuclear power plant construction in place of coal plants. Natural gas is the fastest-growing fossil fuel, as global supplies of gas from tight sands, gas from shale, and coalbed methane increase ([more](#)). The AAPG Energy Minerals Division’s 2013 Report in the Journal of *Natural Resources Research* confirms this growth ([more](#)).

The industrial sector continues to account for the largest share of delivered energy consumption and is projected to consume more than half of global delivered energy in 2040. Based on current policies and regulations governing fossil fuel use, global energy-related carbon dioxide emissions

are projected to rise to 45 billion metric tons in 2040, a 46% increase from 2010.

Economic growth in developing nations, fueled by a continued reliance on fossil fuels, accounts for most of the emissions increases. Because of this, burning coal is expected to be rejected as a source of power generation over the next two decades as natural gas, nuclear, and some renewable energy continues to increase ([more](#)). New approaches, such as the direct carbon fuel cell developed in Australia, could change this distribution ([more](#)).

HISTORY OF NUCLEAR POWER INDUSTRY TO 2013

Based on work by Slater-Thompson and Gospodarczyk ([2013](#)), the first nuclear generating units were built in the 1950s, and, as of 2012, nuclear generating units have reached a global capacity of more than 370 gigawatts. Nuclear reactors were first used to generate electricity in 1951 at a small experimental reactor in the United States. Currently, 31 countries have nuclear power programs. From the early 1970s to the early 1990s, nuclear power steadily grew around the world, with brief periods of relatively slow growth following the incident at Three Mile Island (1979) and the foretold disaster at Chernobyl (1986), as the nuclear industry absorbed the lessons learned from both incidents. The latter was cautioned by the West not build a reactor capable of producing weapons-grade plutonium within the confines of a plant producing electricity for the local power grid.

With the exception of the developing economies in Asia, nuclear power capacity remained relatively stable between the mid 1980s until the accident occurred at the Fukushima Daiichi reactors in March of 2011. Following the accident at Fukushima, nuclear industry reactions to the accident varied widely. Italy canceled its plans to build new nuclear power plants. Germany announced the shutdown of all nuclear power plants by 2022. China - where plans for large increases in nuclear capacity had been announced - instituted a temporary moratorium on new approvals for nuclear power construction that lasted 20 months before it was lifted at the end of October 2012.

Many countries, including the United States, have revised or are in the process of revising their safety regulations to address the lessons learned from the accident at Fukushima. In Japan, where all but two of the country's 50 reactors remain shut down, the issuance of new safety standards in July 2013 has led to applications to restart many of those reactors ([more](#)).

Regional Trends:

- **North America.** The first fully commercial nuclear power plant, Dresden Unit 1, was built in the United States. Dresden Unit 1, located in Illinois, had a capacity of 250 Megawatts electric (MWe) and operated from 1960 to 1978. Canada soon followed with its first reactor in 1962. Nuclear capacity grew quickly between 1970 and 1995.

The United States is currently constructing five new nuclear power plants, and in 2012, Canada issued the first site preparation license in 30 years for construction of up to four new nuclear power plants.

- **Europe.** France, Belgium, Germany, Sweden, Italy, and the United Kingdom commissioned nuclear power plants in the 1960s. Since 1995, capacity in Europe has remained relatively stable. Additions of new capacity through construction of new nuclear power plants have often been offset by nuclear power plant retirements. Although Germany is shutting down all of its nuclear power plants, several countries, including France and the United Kingdom, are constructing or have announced plans to construct new nuclear power plants.
- **Eurasia and Asia.** Russia and Japan also built and operated commercial nuclear power plants in the 1960s. Asia has added nuclear capacity in more recent decades. Between 1980 and 2012, nuclear capacity in Asia nearly quadrupled, led primarily by Korea, Japan, and India. More recently, growth in nuclear capacity in Asia has been led primarily by China. Between 2010 and 2012, nine new reactors began operating in this region. Recently, Kazakhstan announced that two nuclear power plants may be built in the Eastern part of the country. The amount of planned, new nuclear capacity in North America and Europe is relatively small in comparison to the planned capacity in countries including Russia, Japan, China, Korea, and India.

There are 69 nuclear power reactors under construction around the world, mostly in Asia where electricity demand is increasing in developing economies. New nuclear capacity is based on projected increased electricity demand in rapidly developing countries coupled with energy security awareness and the desire to limit carbon emissions. More information about future growth in nuclear power is available on a regional basis in EIA's International Energy Outlook 2013 ([more](#)) and on a country-specific basis through IAEA's Power Reactor Information System ([more](#)). The status of the U.S. reactors include 100 in operation, 5 under construction, and 32 in permanent shut-down mode ([more](#)), many of the latter sites of which are in various stages of permitting for new construction.

NUCLEAR OUTAGES AND RETIREMENTS

Outages at operational nuclear power plants were generally lower during the summer of 2013 than in recent years, reflecting the retirement of several units along with a lower number of generators in refueling outages ([more](#)). Beginning in early September, several units began to reduce their output to enter into refueling outages, bringing the total level of capacity in outage closer to the levels seen last year at this time ([more](#)).

Brown ([2013](#)) indicates that because of their low variable cost, nuclear plants nearly always run whenever they are available. Thus, outages are directly reflected in the level of nuclear power generation. Refueling and maintenance outages for nuclear units (as well as fossil-fueled units) typically occur in the spring and fall "shoulder" seasons when demand for electricity is generally

lower. However, a late-summer heat wave in 2013 pushed up demand for electricity in the midwestern and eastern United States. Outages in the electric system that stretches from New Jersey to Chicago and New England likely contributed to the spike in on-peak, day-ahead wholesale electricity prices in these regions on September 11-12, 2013 ([more](#)).

The retirement of four nuclear generators decreased the amount of operational capacity in extended outage, which had elevated outage levels throughout 2012. Although the retirements reduced the amount of operational capacity in outage, they also reduced the total nuclear capacity by almost 3.6 gigawatts, illustrating the significant electrical contribution of only a few nuclear reactors to the national power grid ([more](#)).

COAL-NUCLEAR-NATURAL GAS CONTRIBUTIONS TO THE U.S. POWER GRID

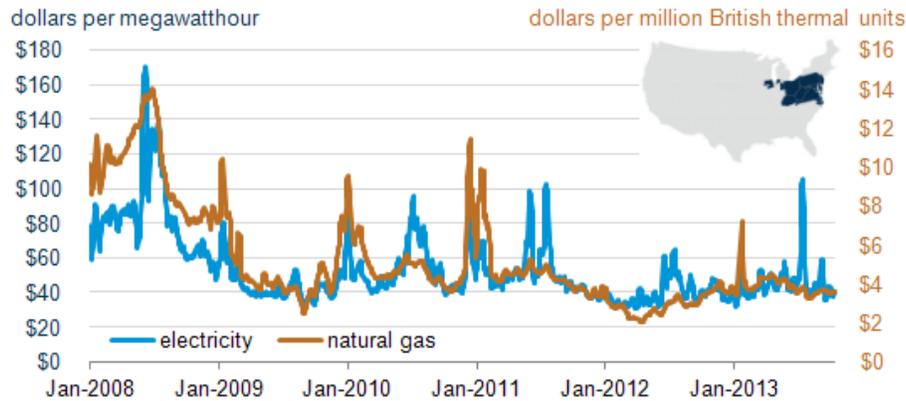
Brown also indicates in late 2013 that in the Mid-Atlantic region, the decline in natural gas prices led to an increase in the use of natural gas for power generation, but the region remains mostly fueled by coal and nuclear sources of electricity ([more](#)). The Mid-Atlantic electric region is represented by the largest single electric system in the nation in terms of customers served. The fuel mix in this region has remained fairly consistent, compared to the larger shifts seen in other regions.

Natural gas power generation increased because of low natural gas prices in 2012 and 2013 (especially in states such as Ohio ([more](#)) and Pennsylvania ([more](#))), but the availability of cheap coal from the Illinois Basin has kept coal-fired units producing nearly half of the output in the region, especially in the western portion (Indiana and Illinois).

Although natural gas-fired units do not make up a majority of the generation units in this region, these units often set the wholesale electricity price. This is because in this particular market, the electricity price is determined by the last unit selected (the marginal unit) to run at a given time, based on fuel and other operating costs. Because natural gas often fuels the last unit selected, the wholesale power price in the Mid-Atlantic electric region generally moves with the natural gas price on any given day (see Figure 1 below).

Figure 1 (Brown, 2013)

Mid-Atlantic spot electricity and natural gas prices



STATUS OF U.S. URANIUM INDUSTRY

4th Quarter 2013 Statistics

U.S. Energy Information Administration (EIA) (2014) reported that U.S. production of uranium concentrate in the fourth quarter 2013 was 1,095,168 pounds U_3O_8 , down 6 percent from the previous quarter and up 14 percent from the fourth quarter 2012. During the fourth quarter 2013, U.S. uranium was produced at seven U.S. uranium facilities, one more than in the last quarter. For a Glossary of nuclear terms, see ([more](#)).

U.S. URANIUM MILL IN PRODUCTION (STATE)

1. White Mesa Mill (Utah)

U.S. URANIUM IN-SITU-LEACH PLANTS IN PRODUCTION

1. Alta Mesa Project (Texas)
2. Crow Butte Operation (Nebraska)
3. Hobson ISR Plant/La Palangana (Texas)
4. Lost Creek Project (Wyoming)
5. Smith Ranch-Highland Operation (Wyoming)
6. Willow Creek Project (Wyoming)

With the Lost Creek Project now producing, Wyoming has three uranium concentrate processing facilities operating in the 4th Quarter, 2013. Uranium concentrate production from Wyoming totaled 883,544 pounds U_3O_8 , (81% of U.S. production), with the remaining 211,624 pounds U_3O_8

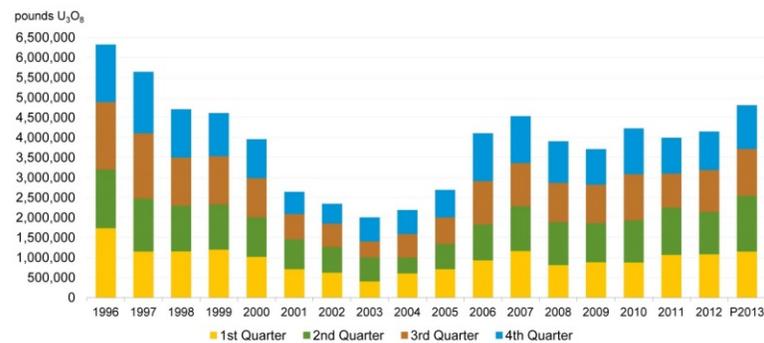
(19%) coming from Nebraska, Texas, and Utah. When possible, EIA will report aggregate state-level data provided individual company data are not disclosed, as is the case for uranium concentrate production from Wyoming this quarter.

Preliminary 2013 Total Production

U.S. uranium concentrate production totaled 4,807,709 pounds U₃O₈ in 2013. This amount is at its highest level since 1997 and is 16% higher than the 4,145,647 pounds produced in 2012. U.S. production in 2013 represents about 10% of the 2013 anticipated uranium market requirements of 50 million pounds at U.S. civilian nuclear power reactors ([here](#)). For production from 1996 to 2013, see Figure 2:

4th Quarter 2013 Domestic Uranium Production Report
 Release Date: January 30, 2014
 Next Release Date: May 2014

Figure 1. Uranium concentrate production in the United States, 1996 - 4th Quarter 2013



P = Preliminary data.
 Source: U.S. Energy Information Administration: Form EIA-851A and Form EIA-851Q, "Domestic Uranium Production Report."

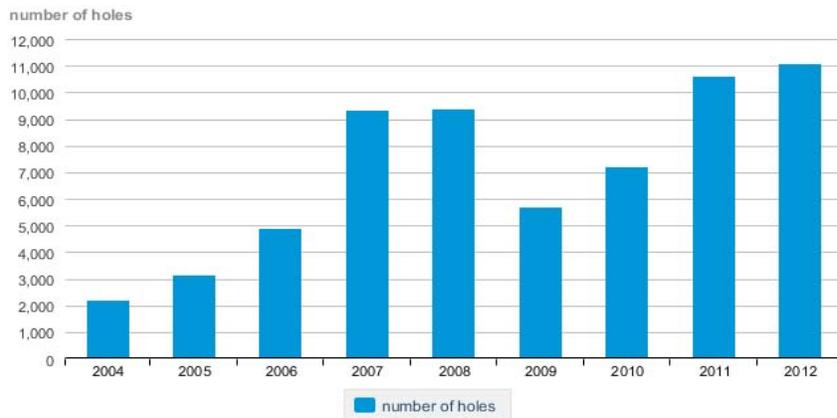
Figure 2 – Domestic Uranium Production – 1996-2013

DRILLING STATISTICS IN URANIUM EXPLORATION

U.S. uranium exploration drilling was 5,112 holes covering 3.4 million feet in 2012, see Figures 3A and 3B. Development drilling was 5,970 holes and 3.7 million feet. Combined, total uranium drilling was 11,082 holes covering 7.2 million feet, 5 percent more holes than in 2011. Expenditures for uranium drilling in the United States were \$67 million in 2012, an increase of 24 percent compared with 2011. Drilling data for 2013 are not available for this report. They will be presented in the UCOM Mid-Year Report in November, 2014.

Figure 3A

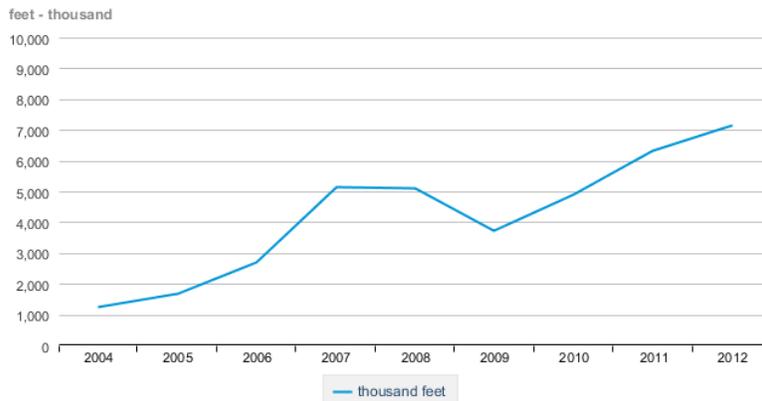
U.S. uranium drilling by number of holes, 2004- 2012



Source: U.S. Energy Information Administration: Form EIA-85 1A - "Domestic Uranium Production Report" (2008-2012).

Figure 3B

U.S. uranium drilling in footage, 2004- 2012



Source: U.S. Energy Information Administration: Form EIA-851A - "Domestic Uranium Production Report" (2004-2012).

FACILITY STATUS (MILLS AND IN-SITU-LEACH PLANTS)

At the end of 2012, the White Mesa mill in Utah was operating with a capacity of 2,000 short tons of ore per day. Shootaring Canyon Uranium Mill in Utah and Sweetwater Uranium Project in Wyoming were on standby with a total capacity of 3,750 short tons of ore per day. There is one mill (Piñon Ridge Mill) planned for Colorado.

At the end of 2012, five U.S. uranium ISL plants were operating with a combined capacity of 10.8 million pounds U_3O_8 per year (Crow Butte Operation in Nebraska; Alta Mesa Project, Hobson ISR

Plant/La Palangana in Texas; Smith Ranch-Highland Operation and Willow Creek Project in Wyoming). Kingsville Dome and Rosita ISL plants in Texas were on standby with a total capacity of 2.0 million pounds U₃O₈ per year. Lost Creek Project and Nichols Ranch ISR Project were under construction in Wyoming. There are seven ISL plants planned in New Mexico, South Dakota, Texas, and Wyoming.

MINING, PRODUCTION, SHIPMENTS, AND YELLOWCAKE SALES STATISTICS

Overall, there were 11 mines that operated during part or all of 2012. Total production of U.S. uranium concentrate in 2012 was 4.1 million pounds U₃O₈, 4 percent more than in 2011, from six facilities: one mill in Utah (White Mesa Mill) and five ISL plants (Alta Mesa Project, Crow Butte Operation, Hobson ISR Plant/La Palangana, Smith Ranch-Highland Operation, and Willow Creek Project). Nebraska, Texas and Wyoming produced uranium concentrate at the five ISL plants in 2012 ([more](#)).

EIA has added new information in their [Table 4](#) and [Table 5](#) that now include County and State location of existing and planned mills and in-situ-leach (ISL) plants. EIA produced their final report on 2012 ([more](#)). They will be presented in the UCOM Mid-Year Report in November, 2014.

U.S. uranium mines produced 4.2 million pounds U₃O₈ in 2012, some 200,000 pounds more than 2011, from 10 mines (underground and in-situ-leach) and one other source. Five underground mines produced ore containing uranium during 2011, one more than during 2010. Uranium ore is stockpiled and shipped to a mill, to be milled into uranium concentrate (a yellow or brown powder). Additionally, five ISL mining operations produced solutions containing uranium in 2011 that was processed into uranium concentrate at ISL plants. An indication that the nuclear industry is anticipating price increases for yellowcake is presented in the marketing report for 2011, which was released in May, 2012 (see [here](#)). The marketing report for 2012 was released in May, 2013 ([more](#)).

The uranium production in the U.S. in the third quarter of 2013 increased 12% to 1,171,278 pounds, compared to 1,048,018 pounds in the same period the previous year, according to the EIA. This represents the highest Q3 level since 1999. Production during the third quarter, however, decreased 16% compared to the second quarter of 2013, which saw a production of 1,394,232 pounds. The third quarter production was 2% higher than the first-quarter amount.

For the first nine months of 2013, U.S. uranium concentrate production increased 16% to 3,712,541 pounds, as compared to 3,187,711 pounds produced in the first nine months of 2012. It is the highest first-three-quarters production level since 1997, when 4,101,513 pounds were

produced, according to the report. The agency expects the U.S. reactors' uranium demand to total 50 million pounds (U_3O_8) in 2013 ([more](#)).

Yellowcake Forensics and Security

A team of Lawrence Livermore National Laboratory (LLNL) researchers has pioneered the use of a long-standing technology, near-infrared spectrometry, for analyzing the chemical composition and determining the origin of uranium samples. In a paper published as the cover story in the September edition of *Applied Spectroscopy*, the Laboratory scientists describe the first reported use of near-infrared spectrometry to study the chemical properties of uranium ore concentrates (UOC), also called yellowcake.

Yellowcake is a uranium concentrate powder obtained from leach solutions, in an intermediate step in the processing of uranium ores. Yellowcake concentrates are prepared by various extraction and refining methods, depending on the types of ores. Typically, yellowcake is produced through the milling and chemical processing of uranium ore forming a coarse powder, which has a pungent odor, is insoluble in water and contains about 80% uranium oxide, which melts at approximately 2,878 °C (5,212.4 °F).

Near-infrared spectrometers were first used in industrial applications in the 1950s and have been utilized for medical diagnostics, combustion research, pharmaceuticals and other uses, but not for studying uranium ore concentrates. The instrument measures the color, intensity and wavelength of light or reflected light.

It is believed that this technology could rapidly provide information on the origin of uranium samples to law enforcement officials who interdict smuggled materials and could be useful in preventing future trafficking from those sources.

For years, one of the primary methods used for determining the different types of uranium has been a simple visual color inspection by researchers. However, visual determination is subjective and no chemical information is provided ([more](#)).

Uranium Purchases and Prices

Owners and operators of U.S. civilian nuclear power reactors ("civilian owner/operators" or "COOs") purchased a total of 58 million pounds U_3O_8 (equivalent definition¹) of deliveries from U.S. suppliers and foreign suppliers during 2012, at a weighted-average price of \$54.99 per pound U_3O_8 . The 2012 total of 58 million pounds U_3O_8 increased 5 percent compared with the 2011 total of 55 million pounds U_3O_8 . The 2012 weighted-average price of \$54.99 per pound U_3O_8 increased 442 percent compared with the 2001 weighted-average price of \$10.15 per pound U_3O_8 , the lowest weighted-average price from 1994-2012.

Seventeen percent of the U₃O₈ delivered in 2012 was U.S.-origin uranium at a weighted-average price of \$59.44 per pound. Foreign-origin uranium accounted for the remaining 83 percent of deliveries at a weighted-average price of \$54.07 per pound. Australian-origin and Canadian-origin uranium together accounted for 35 percent of the 58 million pounds. Uranium originating in Kazakhstan, Russia and Uzbekistan accounted for 29 percent and the remaining 19 percent originated from Brazil, China, Malawi, Namibia, Niger, South Africa, and Ukraine. Owners and operators of U.S. civilian nuclear power reactors purchased uranium for 2012 deliveries from 32 sellers, the same number as in 2011.

COOs purchased uranium of three material types. Uranium concentrate was 50 percent of the deliveries in 2012 and natural and enriched UF₆ was 50 percent. During 2012, 14 percent of the uranium was purchased under spot contracts at a weighted-average price of \$51.04 per pound. The remaining 86 percent was purchased under long-term contracts at a weighted-average price of \$55.65 per pound. Spot contracts are contracts with a one-time uranium delivery (usually) for the entire contract and the delivery is to occur within one year of contract execution (signed date). Long-term contracts are contracts with one or more uranium deliveries to occur after a year following the contract execution and as such may reflect some agreements of short and medium terms as well as longer terms.

In terms of new and future uranium contracts in 2012, COOs signed 34 new purchase contracts with deliveries in 2012 of 12 million pounds U₃O₈ at a weighted-average price of \$55.16 per pound. Thirty one were new spot contracts and three were new long-term contracts.

After the Fukushima disaster, Japan shut down 50 of its nuclear reactors, keeping uranium prices depressed ([more](#)). Uranium reached a high of \$136 a pound in the summer of 2007, see Figure 4. Japan is expected to restart some of the reactors and subsequently boost demand for the nuclear fuel. That along with the expiration of the U.S.-Russian Highly Enriched Uranium Agreement, wherein Russia dismantled Soviet-era nuclear warheads and sold uranium, the re-fueling of Japanese reactors is expected to underpin the price of uranium next year ([more](#)).

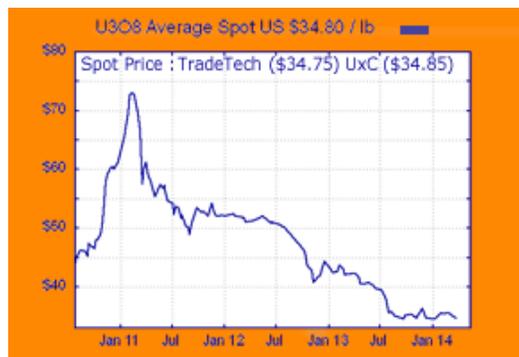


Figure 4 – 2012-2014 Spot Uranium Price

[\(Update April 1, 2014\)](#)

The end of the U.S.-Russia agreement is expected to remove about 24 million pounds of uranium concentrate from Western markets. The U.S. and Russia agreed to a new deal that sets the foundation for nuclear energy cooperation between the two countries. "This agreement supports President Obama's non-proliferation and climate priorities by providing a venue for scientific collaboration and relationship-building between the U.S. and Russian research and technical communities," Energy Secretary Ernest Moniz said. The countries could study the development of an international nuclear research hub, Moniz added ([more](#)).

Peel (2014) of [FN Arena News Group](#) reports that only four transactions totalling 500,000 lbs of U₃O₈ equivalent were conducted in the spot uranium market during the end of March, 2014. Industry consultant [TradeTech](#) notes year to date volumes, at just 7.4 million lbs, are down 32% from the same time in 2013. The ongoing lack of buyer urgency saw *TradeTech's* spot price indicator fall another US\$0.15 to US\$34.60/lb (short-term). *TradeTech's* mid-term price indicators remain unchanged at US\$37.75/lb and US\$50.00/lb for the long-term price.

Peel reports that following the closure of Paladin Energy's (PDN) Kayelekera mine in Malawi, BA-Merrill Lynch now concludes that supply from similar new projects in Africa will likely be

shut down for the balance of the decade. Such projects, including Imouraren in Niger, Trekkopje in Namibia and Mkuju River in Tanzania require a long-term uranium price well above the broker's current estimate to cover the cost of production ([more](#)). This withdrawal of supply will not, however, upset the balance in the shorter term given the extent of Japan's stockpiles, Merrills suggests.

They see a balanced uranium market until 2016. Thereafter, a lack of investment in new deposits could lead to a yearly deficit of nearly 20 million lbs by 2020. Critical to global demand-supply is the restart of Japanese reactors, progress in which has been slower than expected. So far, 17 of Japan's 44 idled reactors have applied to the regulator for restart, representing around an 8.2

million lbs of uranium demand. Merrills expects the first restarts in the second half of 2014 and the Japanese government sees the potential for up to ten restarts by year-end. Brokers have long seen the first Japanese restarts as the impetus for the uranium market to overcome its malaise, but even with the first of these in sight a well-supplied market has meant little price improvement as has been expected after the end of the American-Russian bombs for power in late 2013 (aka the HEU supply agreement).

Merrills has lowered its 2014 spot price forecast by 3.2% to US\$45.00/lb of U₃O₈ and its term price forecast by 4.1% to US\$58.75/lb. The broker's 2015 spot price forecast falls to US\$63.75/lb from US\$66.25/lb while a long term forecast price of US\$67.85/lb is maintained. The uranium stock market is currently awash with optimism for investment opportunities in the uranium industry ([more](#)).

Peel (2014) also reports that despite its downgrades, Merrills remains positive in the long term on uranium’s fundamentals, citing the end of the Russian HEU supply agreement, the renewed commitment to nuclear power from Japan and the aggressive construction of new reactors by China and India as prime drivers. Adding to the equation is a long-term nuclear energy plan now formally adopted by South Korea and Russia’s stated intention to build 28 new reactors by 2030.

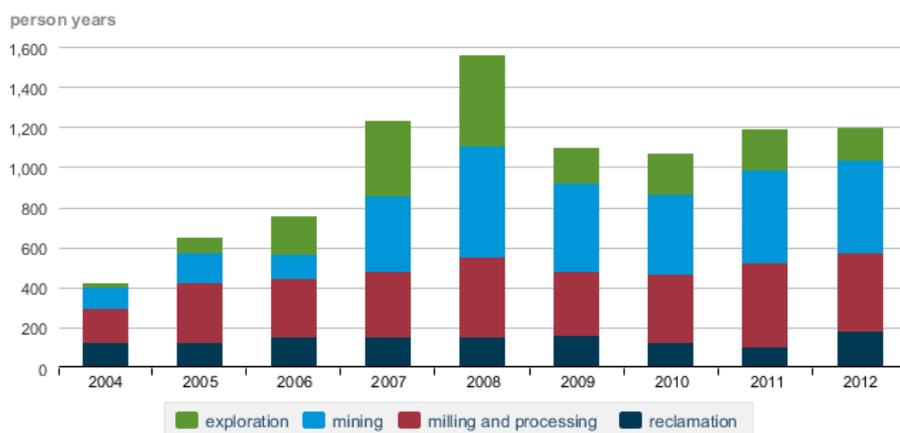
In the shorter term, U.S. power companies have been concerned regarding any current sanctions against Russia as a response to the Crimea annexation might be extended to the export of Russian nuclear fuel supplies. However, U.S. enrichment facilities have assured the market that there is more than enough supply to cover any shortfalls.

EMPLOYMENT IN THE URANIUM INDUSTRY

Data for 2013 will be released in May, 2014. In the meantime, total employment in the U.S. uranium production industry was 1,196 person-years in 2012, an increase of less than one percent from the 2011 total, see Figure 5. Exploration employment was 161 person-years, a 23 percent decrease compared with 2011. Milling and processing employment was 394 person-years in 2012, and decreased 6 percent from 2011. Uranium mining employment was 462 person-years, the same as in 2011, while reclamation employment increased 75 percent to 179 person-years from 2011 to 2012. Uranium production industry employment for 2012 was in 11 States: Arizona, Colorado, Nebraska, New Mexico, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

Figure 5

Employment in the U.S. uranium production industry by category, 2004-2012



Source: U.S. Energy Information Administration: Form EIA-851A - "Domestic Uranium Production Report" (2004-2012).

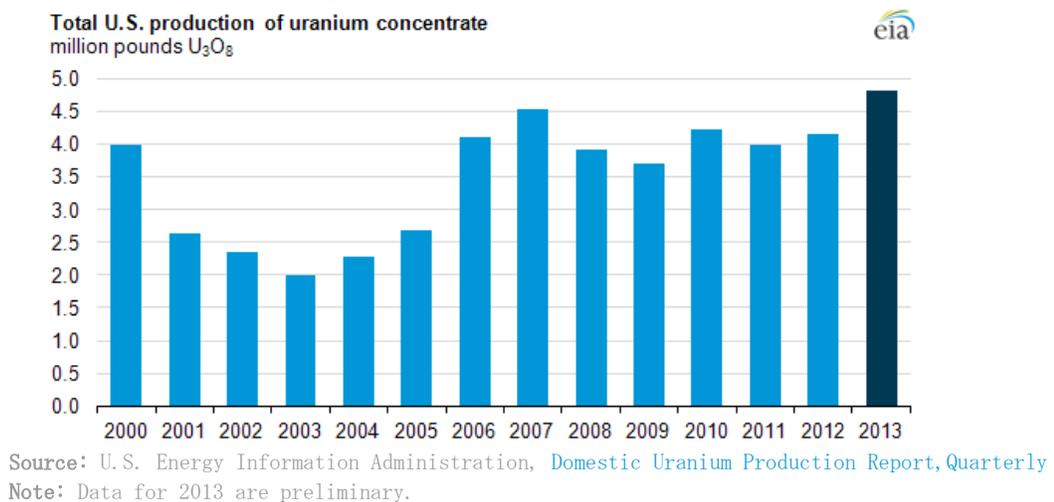
EXPENDITURES IN THE URANIUM INDUSTRY

Total expenditures for land, exploration, drilling, production, and reclamation were \$353 million in 2012, 11 percent more than in 2011. Expenditures for U.S. uranium production, including facility expenses, were the largest category of expenditures at \$187 million in 2012 and were up by 11 percent from the 2011 level. Uranium exploration expenditures were \$33 million and decreased 23 percent from 2011 to 2012. Expenditures for land were \$17 million in 2012, a 14-percent decrease compared with 2011. Reclamation expenditures were \$49 million, a 46-percent increase compared with 2011.

SHORT-TERM OUTLOOK

U.S. uranium concentrate production in 2013 is up 21% since 2011 after the start of three production facilities, one in 2013 and two in 2011. Production has ramped up to partially offset imports from the now-ended Megatons to Megawatts program, which made its last delivery in December 2013 ([more](#)). Production in 2013 totaled 4.8 million pounds, from seven uranium concentrate processing facilities—the highest production level since 1997. For production since 2000, see Figure 6.

Figure 6



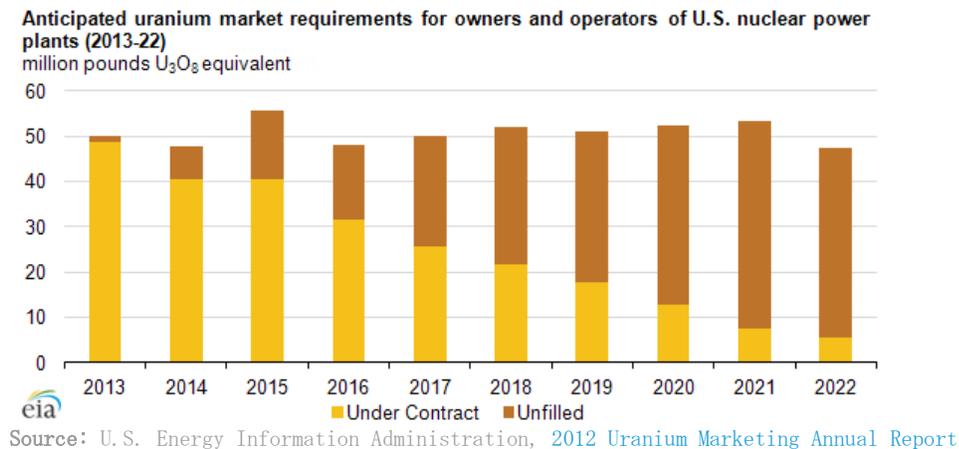
Most U.S. demand for nuclear fuel is met by foreign sources, with 83% of uranium coming from other countries in 2012 ([more](#)). Owners and operators of U.S. nuclear power plants expect to need 48 million pounds of uranium in 2014. These market requirements include the quantity of uranium that is under contract plus additional uranium that companies are planning to purchase to fuel their nuclear power plants, based on plans for maintaining uranium inventories for their future refueling cycles. At the end of 2012, uranium inventories owned by U.S. nuclear power plants totaled 97 million pounds, which is almost two years' worth of uranium. Inventories

represent ownership of uranium in different stages of the nuclear fuel cycle (in-process for conversion, enrichment, or fabrication) at domestic or foreign nuclear fuel facilities. Increased domestic production of uranium concentrate should help fill the market requirements going forward (see Figure 7).

LONG-TERM OUTLOOK

Chandran (2014) just reported that the uranium market received a big boost from a draft of Japan's new Basic Energy Plan. The long-term outlook for uranium market and for producers such as Cameco Corporation, Denison Mines, Paladin Energy, Areva, and Rio Tinto's subsidiary Energy Resources have improved due to supply cuts and anticipated demand for yellowcake ([more](#)).

Figure 7



One of the key drivers for the uranium market in the long term will be China, which already has 20 nuclear reactors in operation and is constructing 28 more. A statement from Chinese President Xi Jinping just recently has highlighted the fact that the world's second-largest economy sees nuclear energy playing an important role in ensuring its energy security.

Uranium Making a Comeback

The spot price of uranium has continued to hover around \$35 per pound, down 50% from the price prior to the Fukushima power plant meltdown in March 2011. Still, the long-term outlook for uranium has certainly improved as nuclear energy is once again being seen favorably, especially by emerging economies such as China, India, and Russia. Even before a draft of Japan's new Basic Energy Plan came out, the outlook for the uranium market had been improving, mainly due to a supply cut from miners such as Paladin and Cameco and anticipated demand. Much of that demand will come from China.

China will be Key Driver

According to the World Nuclear Association (WNA), China is constructing 28 nuclear reactors ([more](#)). That is nearly 40% of the nuclear reactors being constructed globally. In fact, China's nuclear energy growth was something even Cameco noted in its outlook for the industry. The company noted that China brought three nuclear reactors online in 2013.

China's focus on nuclear energy can also be gauged from the fact that the country's top nuclear companies are getting ready for initial public offerings. According to *The Wall Street Journal*, the companies are hoping to raise money to fund future nuclear reactor construction.

China's emphasis on nuclear energy stems from the fact that the country is looking to cut its reliance on coal and tackle its serious pollution problems. Still, in the post-Fukushima world safety is a major concern when it comes to nuclear power plants. But a statement from China's President suggests that the country remains committed to nuclear energy even as it places a great deal of importance on safety.

China's Commitment

In March, 2014, speaking at the Nuclear Security Summit in The Hague, China's President Xi Jinping said that development and utilization of nuclear energy gave new impetus to the progress of humanity. While President Jinping noted that the development of nuclear energy has its associated risks and challenges, he sees the peaceful use of nuclear energy as important to ensuring security and tackling climate change. His statement, while placing a great deal of importance on safety, highlights China's commitment to nuclear energy ([more](#)).

China National Nuclear Corp. is the parent of Hong Kong- listed CNNC International Ltd. (2302), a uranium producer in Niger. It announced recently that it is in talks to buy a stake in uranium mines owned by Areva, as the world's biggest energy consumer prepares to resume approval of new reactor construction. "We are also discussing opportunities with many countries to cooperate in terms of uranium exploration and mining," Sun Qin, president of China's biggest atomic power plant operator, said in an interview in Seoul.

The Chinese government is "very likely" to resume approval of new nuclear projects in 2014 as the government completes a safety review prompted by the Fukushima disaster. Mr. Sun said it is building at least 27 reactors and has 50 more planned, according to the China Nuclear Energy Association.

China Guangdong Nuclear Power Group Co. is offering to buy Australian explorer Extract Resources Ltd. for A\$2.2 billion (US\$2.3 billion) to gain access to the world's fourth-biggest uranium deposit.

PATH FORWARD

While the debate over safety of nuclear power plants continues three years after the Fukushima meltdown, the future of nuclear energy is certainly secured. The statement from Jinping and Japan's energy plan highlights the fact that nuclear energy will play an important role in securing energy needs in countries that have limited energy resources or are looking to tackle pollution problems. In fact, in Germany, which has closed eight nuclear reactors and plans to shut down the remaining reactors by 2022, there have been calls to delay the phase-out nuclear power plants in order to cut reliance on Russian gas in the wake of the Ukrainian crisis.

Given this scenario, the long-term outlook for the uranium market is continuing to improve although the price remains below earlier expectations. Hall and Coleman ([2013](#)) analyzed the world uranium supply and demand balance in 2012. This analysis indicates that mine development is proceeding too slowly to fully meet requirements for an expanded nuclear power reactor fleet in the near future (to 2035), and unless adequate secondary or unconventional resources can be identified, imbalances in supply and demand may occur.

The above analysis fails to consider the impact of rising U₃O₈ prices on uranium exploration, mine development and production. As the numbers of new nuclear plants continue to increase in 2014, the need for fuel will drive U₃O₈ prices upward. Discoveries of new deposits typically follow and numerous such discoveries have been reported over the past few years. Campbell, *et al.*, 2011 illustrate that IAEA, EIA and USGS estimates are typically conservative by nature, some may even be influenced by government policy ([more](#), page 11).

Vice-Chair Reports

I. URANIUM-RELATED INDUSTRY ACTIVITY

By Henry M. Wise, P.G. (Vice-Chair: Industry)
SWS Environmental Services
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United States Activities

The status of uranium exploration and mining in the U.S. presented here is taken in part from the World Nuclear Association's April, 2014 update ([more](#)). Interest in uranium is resuming in the

USA after some years of minor activity. Whether this is the beginning of a period of substantial and sustained increase in nuclear power plant construction and associated uranium exploration and mining remains to be seen. The following is a review of those companies currently active in the U.S.

Energy Fuels Corporation

In April 2012 Energy Fuels Resources Corporation ([EFRC](#)), a Colorado-based subsidiary of Energy Fuels Inc of Toronto, agreed to take over all Denison Mines' U.S. assets and operations, including the White Mesa mill. This diminished the priority of building the Pinon Ridge mill, and in September 2013 the company put plans for it on hold. In August 2013, Energy Fuels took over Strathmore Minerals. Korea Electric Power Co. (KEPCO) is the largest shareholder in both companies, with 9.1% and 11.7% respectively. It supported the takeover and holds 9.6% of the expanded company.

Denison Mines produced 165 tU in the first half of 2009 through its 2000 t/day White Mesa mill in southeastern Utah (near 'four corners'), from its own and purchased ore (the company is advertising its ore-buying program), as well as doing some toll milling. Production cost for this was \$197 per kgU. The mill has a vanadium co-product recovery circuit. It produced 476 tU over 15 months to the end of 2013, and 700 t of vanadium oxide. Some of its feed stock in 2013 is coming from Cameco's Blind River tailings in Ontario. The company has announced that it will close the mill from August 2014 to late 2015.

EFRC produced from its Arizona 1 and Pinenut mines in Arizona during 2013, and is developing its larger-scale projects including particularly those acquired from Strathmore in 2013. Sheep Mountain WY, Roca Honda NM and the Henry Mountains complex in Utah are seen as the future of the company.

EFRC has several mines in the Uravan Mineral Belt on the Colorado Plateau (straddling the Utah-Colorado border) containing 2100 tU in placer deposits plus vanadium co-product (Uravan = uranium + vanadium). Its mines are mainly in the La Sal, Sunday and East Canyon/Rim zones, about 100 km northeast of its White Mesa mill. In 2007, Denison operated four of these mines: Topaz, West Sunday and Sunday/St. Jude in the Sunday group, and Pandora in the La Sal group. Most are mature operating mines with extensive underground workings, while the Topaz mine is relatively new. Two more of these mines reopened in 2008: Rim and Beaver (La Sal group), which required significant refurbishing to produce some 30 tU/y. There are no plans to bring the other mine, Van 4, into production. Meanwhile EFRC had applied to reopen Whirlwind (including Packrat, Bonanza and La Sal) following Bureau of Land Management and state approval, but put it on standby in 2008. EFRC's nearby Energy Queen mine in Utah was refurbished for 2008 reopening, and is licensed.

In late 2011, the Pandora and Beaver Uravan mines were operating, while the Topaz, Rim, West Sunday and Sunday mines were closed pending market improvement. In October 2012 EFRC said it would place Beaver on standby from early 2013, pending uranium market improvement and would finish mining at Pandora by mid-year due to depleted resources.

EFRC's Henry Mountains deposits in Utah including Tony M, Southwest and Bullfrog have 4900 tU as indicated resources at over 0.2% and inferred resources of 3100 tU, both NI 43-101 compliant. All these are some 120 km west of the White Mesa mill. Denison began production from the Tony M mine in 2007, but late in 2008 put it on a "care and maintenance" basis. The company was intending to spend \$35 million on the adjacent new Bullfrog mine, but it was put on hold in 2008, likely because of low U₃O₈ prices.

EFRC's Daneros deposit in southeastern Utah was the main asset of White Canyon Uranium that Denison bought for \$57 million in 2011. It has been mined since December 2009 and ore is trucked 100 km to Denison's White Mesa mill for treatment and recovery of U₃O₈ product. Ore produced during the development phase was sold to Denison, and from there a 3-year toll treatment agreement came into effect. JORC-compliant resource figures of 447 tU in 0.22%U ore were quoted in August 2010, and production is planned to be 227 tU/yr. In October 2012, EFRC said it would place Daneros on standby from early 2013, pending uranium market improvement.

Denison also had four old mines in the Arizona Strip of north central Arizona, along with some new deposits there, though all these are some 500 km south from White Mesa mill and some may be impacted by the Bureau of Land Management decision to stall developments near the Grand Canyon. The Arizona One underground mine resumed production in 2009, with ore processed at White Mesa. Known resources were depleted early in 2014, so it closed. Denison had applied for licenses for its nearby Pinenut and EZ mines. Pinenut was mined in the 1980s and produced 200 tU then, with a shaft 410 m deep. Inferred resources at Pinenut are 400 tU, and EFRC is bringing the mine into production in 2013 but will close it mid-2014 pending uranium price improvement.

The EZ mine is subject to land use restrictions by the Bureau of Land Management. It has 810 tU as inferred resources. The Canyon mine, which was originally licensed in 1986 and operated for a few years, is fully permitted. It has 630 tU as inferred resources at 0.83% U₃O₈. The development is on hold pending resolution of a dispute with the US Forest Service. The surface facilities are complete but shaft sinking to about 450 metres is not. Ore will be trucked to the White Mesa mill.

EFRC in March 2011, received a Colorado state license to build the new 330 tU/yr Pinon Ridge mill for ore from these mines, plus possible toll treatment, but this was overturned on appeal in June 2012, pending a further public hearing. The state's radioactive materials license was reissued in April 2013, but plans were then put on hold. The company had been seeking \$140 million finance for the mill, which would also produce 1,700 t/yr of vanadium oxide.

EFRC's Sheep Mountain, Wyoming deposit has 11,700 tU measured and indicated resources at 0.1% U₃O₈, including 7,100 probable reserves. In 2009, Titan Uranium Inc bought Uranium Ones's 50% interest in it, and it was then transferred to EFRC in the 2012 merger with Titan. Underground development took place in the 1970s. Titan undertook a prefeasibility study on mining the Congo open pit and underground, with heap-leaching recovery, to produce 580 tU/yr from 5,500 tU probable reserves. In early 2014, EFRC updated the preliminary feasibility study for the whole project, and proposes development in conjunction with Gas Hills, 45 km north. The BLM is preparing an EIS for the project.

Strathmore had been working towards bringing its Gas Hills properties in central Wyoming into production, and in March 2013 announced 2,080 tU at 0.11% U₃O₈ indicated resources and 2,120 tU inferred resources (NI 43-101 compliant). Exploration and possible development was proceeding under a February 2012 agreement with KEPCO, which would contribute \$32 million to the project from 2013, leading to an envisaged joint venture with KEPCO holding 40%. EFRC is planning to develop it in conjunction with Sheep Mountain, 45 km away. Strathmore had been exploring the prospect of developing its Juniper Ridge property in conjunction with Gas Hills, or with EFRC's Sheep Mountain (150 km north), or both. In March 2014, EFRC announced resources of 2,350 tU at 0.05% U₃O₈ at Juniper Ridge, envisaging open pit mining and heap leach.

In New Mexico, Strathmore submitted a mining permit application in October 2009 for Roca Honda (60% owned, with Sumitomo 40%) in the Grants mineral district which has measured and indicated resource of 6,470 tU at 0.34% U₃O₈ and 4,580 tU inferred resources at 0.35% U₃O₈. Annual production is expected to be 1,000 tU at a cost of \$24/lb U₃O₈, and a mine permit decision is expected in 2016. Original plans assumed that a new mill would be built, but the White Mesa mill about 180 km away in southeastern Utah is likely to be used.

The merged company also has other projects in the Grants mineral district, including: Marquez with 3,500 tU as indicated resource, Dalton Pass with ISL potential and 1,000 tU measured & indicated resource, and Nose Rock, deep in hard rock with 1160 tU measured and indicated resource. All the above are NI 43-101 compliant. Church Rock prospect with 4,570 tU as measured & indicated resource, was listed with these but in June 2012 the company retracted the resource estimate, since it was based on a previous owner's 1979 data.

Uranium One, Inc.

Uranium One is now wholly owned by Russia's ARMZ ([more](#)) and, in 2007, acquired US Energy's 1,000 t/day Shootaring Canyon mill in southeast Utah and associated properties in four contiguous states for \$50 million plus royalties. US Energy had been planning to bring the mill back into production at a cost of \$31 million. (Uranium One had also secured the right to buy Rio Tinto's 3,000 t/day Sweetwater uranium mill and associated uranium properties in south-central Wyoming for \$110 million, but in January 2007 Rio Tinto cancelled the deal.) In October 2013 Uranium

One agreed to sell the Shootaring Canyon mill for \$10 million to Black Range Minerals Ltd and also enter into a joint-venture arrangement for all Uranium One's associated "conventional" hard rock leases, where Black Range would progressively increase its equity, but this deal has lapsed due to regulatory problems. Black Range will concentrate on its Hansen project.

Beyond that, Uranium One's interests are in ISL projects. In Wyoming, Uranium One USA had production from its Willow Creek ISL project in the Powder River Basin from 2011. It acquired 500 tU/yr capacity from Christensen Ranch ISL mine through the Irigaray central processing plant when it bought those assets for \$35 million from Areva in mid-2009, and it plans to expand this plant to its licensed 960 tU/yr. In 2007, it announced a toll milling arrangement with Cameco's Power Resources Inc for recovery of up to 540 tU per year at PRI's Smith Ranch-Highland mill, but that appears to be suspended.

Production from its three small mines (Moore Ranch, Peterson Ranch, Nine Mile) and from Christiansen Ranch itself is from loaded resin trucked to Irigaray from satellite plants. Overall Willow Creek produced 362 tU in 2013 at a cost of \$36/lb.

The Nuclear Regulatory Commission issued a license for Moore Ranch in October 2010, to start production in 2012, but development has been suspended. In December 2010, NRC then licensed the Irigaray mill to produce up to 960 tU/yr (it operated at 500 tU/yr in 2011), and for Christiansen Ranch to restart operations (it had been shut down since 2000 and restarted in January 2011). Uranium One's additional projects in the Powder River Basin, including Ludeman, Allemand-Ross and Barge, could also be developed as satellite operations with final processing through the Willow Creek central plant. Uranium One has some 4,000 tU as measured resources (2,235 t at Moore Ranch) and 23,000 tU as indicated resources in the state. It also had plans for production from Antelope and JAB in the Great Divide Basin, but these were deferred due to endangered species concerns.

In 2010, Uranium One sold a number of Utah and Colorado claims and two Utah leases, including the Sage mine, to Colorado Plateau Partners (CPP), a joint venture between Energy Fuels Inc of Toronto (see EFRC above) and Royal Resources Ltd of Australia.

Cameco Resources Inc.

Cameco's US subsidiary [Cameco Resources Inc](#) operates the Smith Ranch-Highland mine in Wyoming's Powder River Basin and the Crow Butte mine in Nebraska, both of them are ISL operations, and produces nearly 1,200 tonnes U between them in 2009 from total reserves of 12,000 tU (15,000 t U₃O₈). The company is planning to increase production from these mines and adjacent properties including Reynolds Ranch to 1,770 tU/y when markets improve. Cameco also has a Gas Hills project in Wyoming which is permitted, but on hold.

Smith Ranch-Highland produced 423 tU in 2012 and 654 tU in 2013 including North Butte. North Butte is a satellite plant in Wyoming which started production in May 2013 and will ramp up to 270 tU/yr. The licensed well-field capacity of both is 1,156 tU. In 2013, Crow Butte produced 270 tU, although licensed capacity is 770 tU.

Uranium Energy Corporation

Uranium Energy Corporation ([UEC](#)) in October 2009 bought the small, but recently-refurbished Hobson mill in southern Texas from Uranium One (it had been shut since 1991). UEC then made Hobson the base and hub of its Texas uranium projects. Hobson had 385 t/yr capacity, but UEC indicates it is now 1,150 tU/yr. In 2011-12, it processed 90 tU. It recovers uranium from loaded resin trucked there from the Palangana ISL mine, to which will be added loaded resin from satellite plants at Goliad, Nichols and Salvo. Production commenced at Palangana in November 2010 – the first U.S. ISL operation to start in five years. By the end of 2011, UEC had obtained all the necessary permits to develop its Goliad ISL project, 64 km from the Hobson mill, for production from mid-2014. Goliad has 2,100 tU and Palangana 410 tU measured and indicated resources grading 0.114% U₃O₈, which are NI 43-101 compliant, at 140 m depth.

Future ISL satellites are Salvo, with 1,100 tU inferred resource grading 0.07% U₃O₈, then Nichols with 500 tU inferred located close to Hobson mill, and Burke Hollow (1,100 tU inferred) and Channen. All four deposits other than Nichols and Palangana are 70-85 km from Hobson. UEC claims the cost is about \$20 per pound over 2010-12 for its ISL production, excluding royalties. However, in September 2013, UEC said it would slow production at Palangana pending future increases in uranium prices, while it focuses on Goliad and Burke Hollow.

UEC in 2007 purchased the New River Uranium Project in Arizona with a historic resource estimate of 5,000 tU in shallow low-grade ore. Its Workman Creek deposit there has 1,200 tU inferred resource. For the flagship Anderson project 290 km away, and formerly mined in the 1950s, it announced 6,500 tU NI 43-101 indicated and 4,600 tU inferred resources at 0.04% U₃O₈ (May 2012), most accessible by open pit mining.

In January 2013, UEC reported a NI 43-101 inferred resource for its Slick Rock project in Colorado, of 1,770 tU with 0.21% U₃O₈ cut-off. Vanadium is also present.

In 2009, UEC formed a joint venture with Australia's [Uran Ltd](#) to develop the Grants Ridge project in New Mexico, including nine historic mines that operated from 1970-80s, with average grade 0.15% U₃O₈, to produce 175 tU in total. Uran can acquire a 65% interest by spending \$1.5 million to 2014.

Uranium Resources Inc.

Uranium Resources Inc ([URI](#)) began operations in 1977 in south Texas. It developed and produced over 216 tU from the Longoria and Benavides projects in the early 1980s, then 2350 tU from Kingsville Dome and Rosita through to 1999.

URI commenced production from its Vasquez ISL mine in 2004 at about 50 tU/y and from Kingsville Dome in 2006, both in south Texas. Vasquez peaked in 2006 and is now depleted (30 tU in 2007, 9 tU in 2008). Rosita restarted production in 2008 with oxygen injection but was then closed as uneconomic after 3 tU was recovered. Kingsville Dome produced 67 tU in 2008 and 19 tU in 2009. It was closed in June 2009 due to low uranium prices, and is being remediated along with Vasquez and Rosita.

URI earlier indicated that it did not intend to revive its Texas operations, with total reserves there of only 256 tU, and a joint venture exploration agreement with Cameco there has lapsed. However, in December 2013, URI announced that it remained “committed to developing uranium in South Texas as we aim to leverage our two processing plants in the region” – possibly Kingsville Dome and Rosita.

In New Mexico, URI, in 2007, sought to buy Rio Algom Mining, with uranium properties and a licensed mill site at Ambrosia Lake, where it planned to construct a new mill to serve the Grants mineral belt. However, the deal was cancelled in mid-2008. URI's future potential is in its Grants mineral belt properties in western New Mexico, which hold 39,000 tU, and from which it hopes to produce 2000-3000 tU/yr from ISL.

URI subsidiary Hydro Resources Inc was licensed in 1994 to mine the Crownpoint and Church Rock ISL deposits in New Mexico, and after years of opposition the license was validated by the Nuclear Regulatory Commission in 2006 and then reactivated in 2011. URI planned to produce 385 tU/yr from Church Rock/ Mancos from 2013, as the first of URI's New Mexico properties to develop, subject to further permitting. Nose Rock, Roca Honda and West Largo/ Ambrosia Lake are others in the Grants Mineral Belt.

URI also holds the Copper Mountain leases in Wyoming, with low-grade uranium mineralization in non-sedimentary rock, which was mined to 1971.

Uranerz Energy, Inc.

Uranerz Energy ([UE](#)) received a NRC materials license for its Nichols Ranch ISL operation in the Powder River Basin of Wyoming in July 2011, and its final state approval in October 2012. This will have a number of satellite operations, starting with Hank, with loaded resin being trucked to Nichols Ranch, which is being licensed for 770 tU/yr. Production is envisaged from 2013, and the

initial plant capacity will be 300 tU/yr. The company has NI 43-101 compliant resources of 6,060 tU at about 0.1% U₃O₈ in seven deposits, including measured & indicated resources of 1137 tU for Nichols Ranch itself, 860 tU for Hank, 1100 tU for West North-Butte and 1,655 tU measured and indicated resources at about half the grades of these – 0.048% U₃O₈ – at Reno Creek, 30 km east of Nichols Ranch.

Ur-Energy Inc.

Ur-Energy Inc ([URE](#)) has total about 8,500 tU as NI 43-101 indicated resources in Wyoming, and claims potential for double that. Lost Creek in the Great Divide Basin has 3,300 tU measured and indicated resources at 0.05% U₃O₈ and 1,800 tU inferred (Nov 2013). The company plans to produce 400 tU/yr from the Lost Creek wellfields and about the same from satellite operations. Production from Lost Creek commenced in mid 2013 after construction of a 770 tU/yr mill, following NRC licensing and Bureau of Land Management approval. Early in 2012 Ur-Energy took over nearby leases from Uranium One, adding 1,000 tU to its resource base in the Greater Lost Creek project. The site is close to Kennecott's Sweetwater mill. Bayswater Uranium is farming in to the company's Hauber prospect.

Peninsula Energy Limited

Australian-based Peninsula Energy ([PE](#)) reports JORC-compliant resources (January 2013) of 19,800 tU at 0.041% U₃O₈ for its Lance ISL project on the east side of Wyoming's Powder River Basin, including 4,300 tU as measured and indicated resources, held by the company's subsidiary Strata Energy Inc. It is planning to bring this into production at 580 tU/yr from three production units – Ross, Kendrick and Barber. These will feed into a central processing plant with an expandable capacity of up to 1,154 tU per year (four modules of 288 tU/yr), commencing 2014 from Ross. The plant incorporates a restoration circuit with IX then RO to remediate the water quality of the barren liquor.

State permitting is well advanced, with a permit to mine issued in November 2012. From the NRC, the company has a draft source materials license (SML), and a final supplemental environmental impact statement (SEIS) for both the plant and Ross wellfield in March 2014. It expects final SML from NRC for the Ross production unit by April 2014, with production later in 2014. The Kendrick, Richards and Barber production units to the south of Ross will be brought on line with amendments to Ross licenses. Vanadium may be a by-product of approximately 2,240 t V₂O₅ resources are identified for Ross and Kendrick.

Mestena Uranium LLC

Mestena is a private Texas company. Its Alta Mesa ISL plant in southern Texas is operational with about 385 tU/yr capacity and is one of the newest ISR uranium recovery facilities in the world.

The plant was designed and constructed using state-of-the-art technology and “best” industry practices for uranium ISR. The operation uses conventional ion exchange, precipitation processes, and uses a low-temperature, zero emission rotary vacuum dryer. The facility and well fields are designed for flexibility of operations. Mestena Uranium LLC is the largest private employer in Brooks County with over 125 company and contract employees.

Bayswater Uranium Corporation of Canada

Bayswater Uranium Corporation ([BUC](#)) is a natural resource company engaged in the acquisition and exploration of uranium properties with a secondary interest in base metal properties. The Reno Creek Property, located in Wyoming, is the Company’s flagship project. It holds additional uranium interests in the western United States, Saskatchewan, Labrador, Nunavut and the Northwest Territories. The Company also owns various base metal and diamond interests. During the fiscal year ended February 29, 2012 (fiscal 2012), it sold its interest in all concessions in Niger to Cascade Resources Inc.

The Reno Creek property is an advanced, near-surface uranium project at the permitting/feasibility stage located in the Powder River Basin in northeastern Wyoming. Baywater has received a pre-feasibility study on mining its newly-acquired Reno Creek and Southwest Reno Creek deposits in Wyoming. These have a NI 43-101 measured and indicated resource of 8440 tU @ 0.044% U₃O₈ suitable for ISL, plus a small inferred resource. The project would have five well fields and a central processing plant producing about 750 tU/yr. The Reno Creek Project encompasses approximately 20,900 acres of claims and leases, including 588 unpatented mining claims, seven Wyoming State mineral leases, four fee (private) mineral leases, and nine surface access agreements. It is 30 km southeast of Christiansen Ranch and 50 km north of Cameco's Smith Ranch, and Bayswater plans to bring it into production about 2014.

In early 2014, [Mega Uranium Ltd.](#) indicated that on January 17, 2014, it acquired ownership of 2,759,807 common shares Bayswater Uranium Corp, representing about 11.5 % of the total issued and outstanding common shares of Bayswater, pursuant to a private transaction ([more](#)). These transactions were made for investment purposes and Mega could increase or decrease their investment in Bayswater depending on market conditions or any other relevant factor.

Uranium International Corp, (now Mercer Gold Corporation ([more](#)))

In New Mexico, Uranium International Corp ([UIC](#)) has announced 1,180 tU measured and indicated resource at Dalton Pass, with ISL potential. It also announced a 1,160 tU measured and indicated resource at Nose Rock, deep in non-sedimentary rock. Both are NI 43-101 compliant, in the Grants mineral belt and owned by Strathmore Minerals. UIC has the option of earning a 65% share of each and reports that it has entered into a Letter of Intent with Mercer Gold Corporation

on Colombian claims. Referred to as the Guayabales claims, they cover a highly prospective gold and silver property located in Marmato, Caldas, Colombia. The property has been described thoroughly in a NI 43-101 compliant assessment report dated April 5, 2007. In 2008, the previous Optionor completed 17 holes totaling 2,000 meters of drilling and 1,980 samples. Uranium International plans to evaluate the property and will develop a work program in due course.

Powertech Uranium Corporation

Powertech Uranium ([PUC](#)) is proposing to develop two ISL mines: Centennial in northern Colorado, and Dewey-Burdock in South Dakota – in each case very close to the Wyoming border. Centennial has 4,430 tU in 0.08% U₃O₈ ore and Dewey-Burdock 2,570 tU indicated resources averaging 0.18% U₃O₈ and 1,880 tU inferred resources averaging 0.13% U₃O₈, both NI 43-101 compliant. The company has applied to develop Dewey-Burdock, and an economic assessment early in 2012 suggested 3,240 tU production over nine years, with \$54 million capital investment. A draft license was received in mid-2012 and a full operating license was expected by mid 2013. NRC gave environmental approval in January, 2014, though any license is deferred. Powertech also has 400 tU as indicated resources at its Aladdin project in Wyoming.

Cotter Corporation

Cotter Corporation, a General Atomics subsidiary ([more](#)), is planning a \$200 million rebuild of its Cañon City mill by 2014, when it expects to treat ore from the Mount Taylor mine in New Mexico. Mount Taylor, which has been on standby since 1989, is owned by another General Atomics subsidiary, Rio Grande Resources Corporation ([more](#)).

Black Range Minerals Ltd.

Black Range Minerals Ltd. ([BRM](#)) has acquired the 11,500 tU Hansen deposit grading 0.07% U₃O₈ in Colorado. The company already owns the adjacent Taylor Ranch deposit, about twice the size and grading 0.05% U₃O₈. Hansen was licensed for mining in 1981, but stalled due to low uranium prices. In October 2013 Black Range agreed to take over Uranium One's Shootaring Canyon mill for \$10 million and also associated leases through a joint-venture arrangement, but this deal has lapsed.

Neutron Energy Inc.

Neutron Energy Inc acquired full ownership of the Cebolleta Land Grant in New Mexico which has 8,000 tU resources after mining took place 1975-81, producing about 460 tU. Neutron is a private uranium exploration and development company with assets in the Grants Mineral Belt in northwestern New Mexico. Its properties include the Cebolleta and Juan Tafoya projects, which cover 10,814 acres. Both projects are located on private lands, where the company had planned to

use conventional mining techniques. Neutron also holds a suite of properties that neighbor some URI properties west of Mount Taylor, in the Ambrosia Lake region.

In 2012, Uranium Resources Inc. signed an agreement to acquire Neutron Energy Inc. in a stock-for-stock transaction valued at \$38.1 million ([more](#)). The boards of directors from both companies unanimously approved the deal, but shareholders from URI and Neutron were required. This acquisition represents a significant consolidation of uranium properties in New Mexico and will position URI as one of the largest U.S.-based uranium development companies. It also provides the combined company with significant scale and strategic resources development synergies in the Ambrosia Lake region [of New Mexico] and a previously permitted conventional mill site. URI has 183,000 acres of uranium mineral holdings and 101.4 million pounds of in-place mineralized uranium material in New Mexico. With all the Neutron properties combined, URI would control more than 206,600 acres in New Mexico once the deal closes.

Yellowcake Mining Corporation

Yellowcake Mining Corporation is an exploration-stage company ([more](#)). The company's current plan of operation is to continue to pursue its joint ventures with Strathmore Resources (US) Ltd. to explore, develop and mine the Juniper Ridge, Baggs, Jeep and Sky properties located in Fremont County, WY. It also intends to pursue the acquisition of certain uranium properties located in the area of Gateway, CO, pursuant to its letter of intent with American Nuclear Fuels (Colorado) LLC, subject to the satisfactory completion of its due-diligence investigations and the entry into a definitive agreement between the parties.

The company reports 5,000 tU reserves at its planned Beck mine in the Uravan area of Colorado and agreed in May, 2008 to sell a 50% stake in it to Korea Electric Power Corp (KEPCO). However, in February 2009, KEPCO withdrew, leaving the project low in funds. The company had joint ventures with Strathmore Minerals for Juniper Ridge and a Gas Hills prospect in Wyoming, but these were terminated in 2008. In 2010 Strathmore agreed to sell Juniper Ridge to Crosshair Energy, but this agreement terminated in 2012 ([more](#)).

Bluerock Energy Corporation

In 2008 Bluerock Energy Corp ([more](#)) was continuing to advance production at the J-Bird Uranium Mine, and was conducting other activities:

- Progress mine development at the Cone Mountain Uranium Mine site
- Submit permit applications to process the Patty Ann surface stockpile
- Submit bulk sample and exploration drill permits at the Sunbeam Mine
- As work focuses in on US operations, Bluerock Resources Ltd. has also:
 - ❖ Initiated the sale of its Mongolian assets

❖ Vended noncore base metals projects in British Columbia

Last Operation 2008 Update:

At the J-Bird Uranium Mine, Bluerock shipped uranium ore to the White Mesa Mill. The Company was expecting ore production to increase once the development of the "#2 mineralized zone" in August 2008. Meanwhile, construction of a second development drift, complete with underground drill stations, was progressing as planned.

At the Cone Mountain Uranium Mine, the Company had deployed a Jumbo drill that is capable of 20 feet (6 meters) of advance per shift. The new portal has been framed and stabilized, and development work on the decline was progressing with the first uranium mineralized block, as defined by Atlas Minerals Corp., was scheduled to be intersected in early September, 2008. The Company was planning on submitting the Mine Plan of Operation to the State of Colorado and the Bureau of Land Management (BLM) authorities.

Permits applications had been submitted to the BLM for their approval to begin processing of the Patty Ann surface stockpile. The Company has an LOI with *Uranium One* in respect of the Patty Ann surface stockpile. A reply from the BLM was expected within 30 days as to acceptance or additional requirements for the start of operations. The Patty Ann is an historic uranium stockpile which is expected to be amenable to near-term development and the shipping of ore to the White Mesa Mill.

At the Sunbeam Uranium Mine, bulk sample and Phase II drilling permit applications had been submitted to the BLM and state regulators. The bulk sample program was to allow the Company to reopen the Sunbeam Uranium Mine, assess underground conditions and move towards a production decision. Two mineralized zones were identified in the initial round of the Bluerock 2008 exploration drilling program and these targets were to be followed up with the testing of a third, "historical drillout" later this year.

Bluerock Energy Corporation shipped the first ore from development of the J-Bird mine in Colorado to Denison's White Mesa mill in Utah sometime in 2008. No other information is available.

Laramide Resources Ltd.

Laramide Resources Ltd ([LR](#)) is applying to reopen the La Sal II mine in Lisbon Valley, Utah, bought in 2010 from Homestake with about 1,000 tU. It is about 90 km from Energy Fuels' White Mesa mill, and a two-year toll milling agreement was signed in January, 2013. Laramide also has the La Jara Mesa project in the Grants Mineral Belt of New Mexico, with 4,000 tU resource.

Virginia Energy Resources Inc.

Virginia Uranium Inc., ([VER](#)) in association with Virginia Energy Resources Inc, has a proposal to mine the Coles Hill uranium deposit in Pittsylvania county which has 3,260 tU as measured resource and 42,800 tU as indicated resource at 0.05 % U_3O_8 (NI 43-101 compliant). An associated conventional mill would be near Chatham. A detailed state review reported on the project, but the Governor at the end of 2013 announced that he would veto any enabling legislation.

Uranium has been reported in groundwater and in stream water for many years, see Figure 8. This suggests that uranium mineralization within the rocks of the state would be anticipated. One such occurrence is the Coles deposit in southern Virginia. Its size and grade indicate that it may be an economic ore body. However, the general public fears the development of this deposit on the basis of exaggerated claims ranging from health issues to groundwater contamination. The fight is now clearly geopolitical and is being waged in the local news media:

Pro-Uranium Mining: “Uranium offers clean path to economic revival,” ([more](#)).

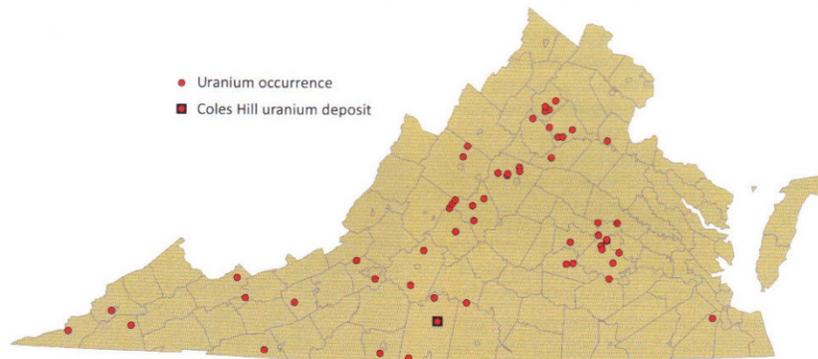


Figure 8 - Uranium Occurrences in Virginia

Oppose Uranium Mining: “Virginia Beach Uranium Mining Impact Study Mining,” ([more](#)).

Canadian Activities

Upward pressure on uranium prices is intensifying as the widely forecast uranium supply crunch draws closer. A worldwide nuclear reactor construction boom and Japanese plans to restart reactors this summer means demand is climbing while production delays and the end of the US/Russian Megatons-to-Megawatts program have reduced supply by an estimated 84 million lbs. per year.

With increasing demand and a vulnerable supply, world attention is focusing on the source of the world's richest uranium deposits: Canada's Athabasca Basin, where *Fission Uranium* has just drilled its best off-scale results to date at its Patterson Lake site - its high-grade, shallow depth uranium discovery ([more](#)). Fission's drill results are among the best ever encountered in the Athabasca Basin, with one recent hole (Hole 129) labeled by analysts as the top hole in the uranium industry because of its grade, thickness and shallow depth. It was calculated by one analyst that even with the current uranium spot price, Hole 129 was equivalent to 117 meters of 5 oz/t gold, i.e. 150 g/t. Assays for the hole include large intersections with grades nearly 380 times the world average for uranium. The company announced new drill results, including one (Hole 187) that far surpasses the amount of off-scale mineralization for Hole 129 ([more](#)).

Fission's success has led to a flood of exploration activity by other companies in the previously underexplored South West area of the Athabasca Basin and just recently *NexGen* announced a uranium discovery at a property adjacent to that of Fission Uranium ([more](#)). Other companies active in the region include Fission's spin out - Fission 3.0 Corp., Fission JV partners, Brades Resource and Azincourt Uranium, as well as others, such as Areva, Cameco and Aldrin.

Major mines in the Athabasca Basin include Rabbit Lake (186 million lbs. U₃O₈ produced), Cigar Lake (22.3% U₃O₈), McArthur River (16.5% U₃O₈), Maclean Lake (50 million lbs. U₃O₈ produced) and Cluff Lake (60 million lbs. U₃O₈ produced). Kivalliq Energy Corporation has also made significant discoveries in the area ([more](#)).

Lakeland Resources also announced its exploration activity in the Athabasca Basin in context with other companies throughout the basin. Their video summarizes expectations in the region ([more](#)).

Denison Mines ([more](#)) and Cameco are dominant miners in the region ([more](#)). Cameco's Cigar Lake mine is expected to be one of the largest uranium mines in the world, with peak production of 18 million pounds per year by 2018. For 2014, the McClean Lake mill is expected to produce between 2 and 3 million pounds of uranium. Based on its anticipated full production figures, Cigar Lake is expected to account for 9 percent of global mine supply ([more](#)).

One of the three mines with the highest production of uranium in the world today is the McArthur River Mine in the Athabasca Basin in Canada.

McArthur River Mine

The McArthur River mine is an underground uranium mine owned by Cameco. The mine is located in Saskatchewan, about 50 miles from the Key Lake mill in the Athabasca Basin; it produces 13 percent of the world's uranium ([more](#)).

McArthur River is the highest-grade uranium deposit in the world, with a proven and probable mineral resource estimate of 264.5 million pounds of U₃O₈ at an average grade of 16.36 percent

[\(more\)](#)). The McArthur River deposit was discovered in 1988, and mine construction began in 1997. In 1999, production began, with full commercial production achieved in 2000. The production of 18.7 million pounds of U_3O_8 (yellowcake) takes place at McArthur River, and the ore is processed at the Key Lake mill.

Underground mines account for 37 percent of U_3O_8 production. At these mines, ore is brought to a mill after extraction to be crushed and ground. It is then leached with sulfuric acid to dissolve the uranium oxides. Uranium is subsequently separated through ion exchange and is then dried and packed, most commonly as yellowcake.

Australian Activities

The two other mines of world class are in Australia.

Olympic Dam Mine

The Olympic Dam Mine is owned by BHP Billiton and is an underground mine that produces 6 percent of the world's U_3O_8 . Olympic Dam is primarily a large iron oxide-copper-gold deposit that produces copper, uranium, gold and silver. The mine is located at Roxby Downs, in South Australia, which is about 350 miles north of the city of Adelaide.

An interesting fact about the Olympic Dam mine is that it is the largest-known single deposit of uranium in the world. Uranium production is a by-product of copper from the mine. Current operations at the underground mine use sublevel open stoping (i.e., where the roof rock requires no artificial support). The deposit was discovered in 1975 and the mine was opened in 1988 by WMC Resources. In 2005, BHP took over WMC Resources and became the owner of the mine. Mine expansion plans are currently shelved.

Processing procedures at Olympic Dam have recently improved, with uranium recovery from solution increasing to 97 percent from 90 percent. All uranium produced at the mine is exported.

Ranger Mine

Also in Australia, the Ranger mine, owned by Energy Resources of Australia, is an open-pit mine that produces 5 percent of the world's uranium. Located in the middle of Kakadu National Park, about 143 miles east of Darwin, the deposit was discovered in 1969 ([more](#)). Production began in 1980 following negotiations between the Commonwealth Government and the Northern Land Council, which represents the interests of Aboriginal landowners. Ownership of the mine is fairly complicated, with 31.61 percent of the concern traded publicly. Energy Resources of

Australia, a subsidiary of Rio Tinto is also owned in part by Cameco, Cogema and a holding company representing Japanese utilities, among others. Uranium recovery at the mine ranges

between 91.5 and 93 percent. It is the second-largest uranium mine in the world, and the only one of the top three mined via open-pit.

Uranium oxide sales by Energy Resources of Australia are all exports to energy utilities ranging from Japan and South Korea to Germany and France ([more](#)). There are several uranium ore bodies at the mine, one of which was mined out by the end of 1995 and the latter of which is under development.

Other Mines in Australia

The Beverly and Honeymoon Mines in South Australia also rank high in Australia's uranium production, with the Four-Mile Project nearing production ([more](#)).

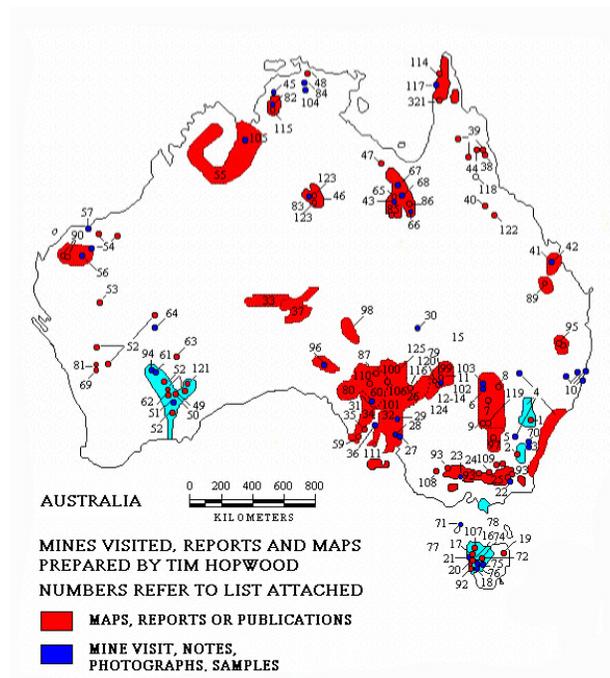


Figure 9 - All Mines in Australia, including Uranium Mines

(Click on Figure for list of Mines)

Prepared by Hopwood ([more](#)), the above map (and associated link) provides a summary of all mines for a range of commodities in Australia, along with other mines elsewhere in the world, see Figure 9.

Western Australia

In preliminary laboratory testing, Cauldron Energy reports that it has recovered over 96% uranium with low acid use at the company's Bennet Well deposit in Western Australia, see Figure 10. Significantly, the high uranium recoveries show the ISR method would be effective and a

relatively cheap production method - and that the recovery of U_3O_8 would be economic at even the current low commodity prices ([more](#)).

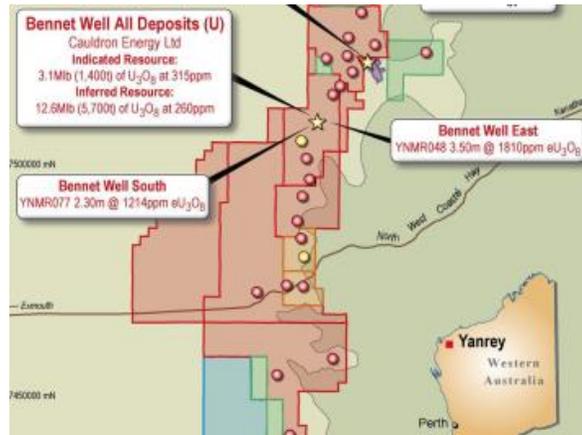


Figure 10 - Cauldron Energy Properties

(Click on Figure for detailed information)

Toro Energy is another uranium company preparing for production. It based in Perth, Western Australia. Toro's flagship and wholly-owned Wiluna uranium project is located southeast of Wiluna in Central Western Australia. Toro's wholly owned Theseus Project is a recent discovery with results to date indicating the potential for a high-grade mineralized system. The Company also owns uranium assets in the Northern Territory and in joint venture in Namibia, Africa ([more](#)).

South Australia

Indicative of current economic conditions impacting junior uranium exploration companies worldwide, [UraniumSA](#) is confident it will continue its work at its Blackbush deposit near Whyalla. UraniumSA's half-yearly financial report indicated a net loss, sparking concern about the future of the project.

Exploration funding for any company not in production relies primarily on equity capital markets and at present market sentiment is not supportive of junior exploration companies. UraniumSA management indicated that the tide will change and UraniumSA will be there to capitalize on its outstanding Blackbush uranium deposit and related exploration potential within the Samphire project ([more](#)).

Northern Territory

Rio Tinto has come under scrutiny for its uranium practices after it was made known that two of its operations experienced similar spills within a week of each other. And with environmentalists concerned over the similarities between the incidents, they should not be taken lightly.

The first incident occurred on December 3, 2013, when one of the 12 leaching tanks at the Rossing processing facility in Namibia experienced a serious leak resulting in a large quantity of radioactive slurry being spilled. The company also said that the spill has thus far resulted in no environmental impact.

At Rio Tinto's Ranger Mine in Northern Territory (Australia), another incident occurred less than a week later when a worker at Rio's subsidiary, *Energy Resources of Australia* (ERA), reported that a leaching tank had failed at the Ranger Mine, leaking roughly 1 million liters of acidic uranium slurry into the ground. ERA maintains that containment systems in place at the mine will prevent the slurry from escaping into the surrounding Kakandu National Park.

The Australian government has suspended all processing operations at Ranger since the announcement, and Industry Minister, Ian Macfarlane, has informed ERA that it cannot resume processing activities until it has demonstrated the integrity of the plant's systems to regulators. ERA is focusing on clean up and recovery ([more](#)).

Exploration Potential in Northern Territory

Uranium mining and exploration has made a significant contribution to the economic development of the Northern Territory since the first discovery was made in 1954 at Rum Jungle. Production from deposits in the Northern Territory to the first quarter of 2006 totaled 120,064 t U₃O₈ and about 301,000 t U₃O₈ is classified as resources ([more](#)).

Lally and Bajwah, (2006) report that the uranium occurrences in the Northern Territory can be grouped into four main styles of mineralisation: Proterozoic unconformity-related; vein-type; Westmoreland-Murphy-type; and sandstone-type.

Almost all mined deposits, and most of the currently known resources, are of the Proterozoic unconformity-related type and occur within Palaeoproterozoic rocks of the Pine Creek Orogen, near the unconformity with overlying platform cover sandstones of the McArthur Basin. Deposits vary in size from a few tonnes to more than 100,000 tonnes of contained U₃O₈, with grades generally in the range 0.2-2% U₃O₈. Large deposits of this type, in the *Alligator Rivers Uranium Field*, account for 96% of past production and 95% of known resources in the NT.

In addition to uranium, these deposits may also contain economic quantities of gold, platinum and palladium (e.g., *Jabiluka*, *Coronation Hill*). Genetic models for the formation of these deposits are still the subject of some discussion. Most researchers favor a model in which oxidized fluids from the overlying platform covering sandstone successions carried soluble U⁶⁺, were reduced by reaction with suitable lithologies in Pine Creek Orogen rocks, resulting in the deposition of insoluble U⁴⁺ in the form of uraninite. The location of deposits was controlled by a combination of structure and lithology, and contacts between carbonate and metapelite units represent the most favorable conditions.

Unconformity-related uranium deposits are the main exploration target in the NT, because of the potential for large-tonnage, low- to medium-grade resources. However, a large proportion of the most prospective areas are included within the boundaries of Kakadu National Park and are therefore quarantined from exploration, for now.

Vein-type deposits are small and generally contain less than a few hundred tonnes of U_3O_8 . Most occur in Palaeoproterozoic rocks of the Pine Creek Orogen, although occurrences are also known in the Tennant and Arunta regions. Production was limited to small-scale mining operations in the 1950s and 1960s, and this type of deposit does not contribute significantly to resources in the NT.

Westmoreland-Murphy-type deposits occur within the lower McArthur Basin succession, on the northern side of the Murphy Inlier, straddling the NT-Queensland border. Production from two small operations in the 1960s totaled 35 t U_3O_8 . The largest known deposits of this type are in Queensland and occur where dolerite dykes cross-cut sandstone. Other styles of this deposit type occur at contacts between rocks of different oxidation states, and appear to have formed by reduction of oxidized uranium-bearing fluids. Small occurrences of uranium mineralization occur in similar geological settings in Katherine River Group rocks, near the western margin of the McArthur Basin, and appear to have been formed by similar processes.

Sandstone-type deposits are restricted to Paleozoic (Devonian-Carboniferous) continental red-bed sedimentary successions in the Ngalia and Amadeus basins. Deposits of this type represent about 5% of uranium resources in the NT. Uranium mineralization occurs at a redox boundary that formed either by flushing oxidizing groundwater through reduced sandstone beds (Amadeus Basin deposits), or by interaction with detrital organic matter (Ngalia Basin deposits). The *Angela* deposit, in the Amadeus Basin, is the largest deposit of this type and contains 10,250 t U_3O_8 grading 0.1% U_3O_8 .

Surficial (calcrete) and metasomatite/intrusive-type uranium occurrences are also known in the NT, but have attracted little exploration interest. However, the forecast demand in uranium may stimulate exploration interest in these styles of mineralization.

OVERSEAS ACTIVITIES OF PARTICULAR NOTE

Hall and Coleman ([2013](#)) analyzed the world uranium supply and demand balance, but do not consider the number of new deposits that have been recently discovered all over the old. Some of those are discussed below:

South America

Argentina

- Argentina has two nuclear reactors generating nearly one-tenth of its electricity, and another reactor finishing construction.
- Its first commercial nuclear power reactor began operating in 1974.
- Operation of the country's third reactor is expected in 2014.
- Construction has started on a small locally-designed power reactor, CAREM-25.

Electricity consumption in Argentina has grown strongly since 1990. Per capita consumption was just over 2000 kWh/yr in 2002 and rose to over 2600 kWh/yr in 2007. Gross electricity production in 2011 was 130 TWh, comprising 66.6 TWh from gas, 31.9 TWh from hydro, 19.6 TWh from oil, 3.3 TWh from coal, and 6.37 TWh from nuclear. In 2012, nuclear power provided 5.9 billion kWh of electricity – about 4.7% of total electricity generation, and less than some previous years. The government plans for 15-18% of electricity from nuclear power once intended capacity comes on line. It planned to invest \$42 billion in nuclear power by 2013, but in mid-2013 had spent 15% of this.

Argentina's electricity production is largely privatized, and is regulated by ENRE (*Ente Nacional Regulador de la Electricidad*). Installed capacity is about 35 GWe, about 11% of which is from producers and private generators ([more](#)).

Greenland

Kvanefjeld, Ilimaussac Complex

The World Nuclear Association ([2014](#)) recently updated its information on the new Greenland project and the salient features are summarized below. Located in Southern Greenland, the Kvanefjeld project is the main REE deposit with major potential for uranium production, with Sorensen and Zone 3 orebodies in the same Ilimaussac complex. It was investigated intensively over 1955-86, then dropped for commercial reasons. Greenland Minerals & Energy acquired the project in 2007 then with a JORC-compliant resource then of 43,000 tU at 0.022% U with 6.5 million tonnes of REO at 1.07% in Lujavrite. About 3.6% of REOs are terbium, dysprosium and yttrium, i.e., 'heavy'.

The full Kvanefjeld uranium resource (JORC compliant) is now estimated at 101,000 tU indicated resources at 0.023 %U, 120,000 tU inferred resources, both with 0.015% U₃O₈ cut-off, and 10.3 million tonnes of REO including 0.37 million tonnes of heavy REO. The company has demonstrated over 90% co-recovery of REOs via effective beneficiation of concentrates followed by atmospheric sulfuric acid leach and solvent extraction recovery. This will lead to hydrogen reduction of uranium minerals and beneficiation followed by acid leach for REOs including yttrium. The Kvanefjeld deposit also has 2.25 Mt zinc as potential by-product.

Pre-feasibility study suggested annual production of 1,000 tU with about 40,000 t REO as well as zinc concentrate, from a large open pit mine. Project cost is expected to be \$1.53 billion. A definitive feasibility study is proceeding to mid-2013, concurrently with pilot plant trials, environmental impact assessment and social impact assessment. In August 2012, tests showed that flotation beneficiation would allow the concentrate to be exported for straightforward hydrometallurgical treatment if desired. The mine and concentrator part of the feasibility study was completed early in 2013 and the company is now finalizing the environmental and social impact assessment and preparing an application to the government to proceed with the project. Construction could commence in 2015 with first production in 2018. Subsequent expansion to 6 M million tons per year is envisaged.

The current proposal is for the mine and concentrator with flotation circuit to produce a REE-U concentrate plus zinc and fluor spar by-products. The concentrate comprising 8.5% of the milled ore and containing 15% REO and 0.25% U would be exported to a dedicated refinery to produce 23,000 tonnes of mixed rare earth carbonate (15% of this heavy REO) and 425 tU per year in stage 1. Start-up costs for a 3 million tons per year plant are estimated at \$810 million - \$450 million for mine and concentrator and \$360 million for the refinery. Unit production costs are low for REOs and an incremental cost of \$37/lb U₃O₈ for the uranium initially, falling to \$31 if the production rate doubles. The company is seeking partners for the offshore refinery. The metallurgical flowsheets for both concentrator and refinery were finalized in 2013.

There is considerable further mineral potential in the immediate area – up to 600,000 tU according to IAEA estimates. As well as Kvanefjeld and adjacent Steenstrupfjeld, Zone 2 (6 km north) and Zone 3 were identified in 2011 within the project area. In March 2012, the company announced Zone 2 (now Sorensen) inferred resources in the same geology of 62,440 tU at 0.015% cut-off grade (average grade 0.03%) and 2.67 Mt REOs. In June, initial Zone 3 inferred resources of 24,300 tU and 1.1 Mt total REO were added. This took the project total to 221,600 tU, 2.24 Mt zinc and 10.3 Mt REO including 370,000 t heavy REO with 840,000 t Y₂O₃. Zone 3 has the same geology and its similar mineralisation outcrops extensively, with higher grade portions near surface.

A year after the Greenland government allowed the company's feasibility studies to include uranium; in December 2011, it amended the company's exploration license to include uranium.

The company could then apply for a mining license including uranium, with a view to first production in 2016, followed by a long-mine life. The company is conducting detailed discussions under confidentiality agreements with several international consortia regarding development scenarios and their funding.

In November 2012, the Greenland government voted unanimously to support the project, including uranium, and in October 2013 it repealed the long-standing policy banning uranium development. It noted that it is Denmark's responsibility to ensure that international conventions, such as non-proliferation, are respected. Denmark is pursuing this, and both states expect to have a cooperation agreement for the mining and export of uranium finalized in 2014. The IAEA Additional Protocol for Greenland entered into force in March 2013.

Mongolia

According to the 2012 Red Book, Mongolia has 74,000 tU in Reasonably Assured Resources plus Inferred Resources, to US\$ 130/kg U. Geological indications reported in the Red Book suggest that uranium resources could be 1.47 million tU.



Figure 11 - Uranium in Mongolia

- Uranium was produced from the Dornod deposit in Mongolia by Russian interests to 1995, see Figure 11.
- Mongolia has substantial known uranium resources and geological potential for more.
- Since 2008 Russia has re-established its position in developing Mongolian uranium.
- There is currently no uranium mining in Mongolia

The country is considered by the World Nuclear Association (WNA) to have relatively high political risk associated with investment ([more](#)). One aspect of this was the existence of an eminent domain provision for strategic minerals which involved the possibility of claw-back at the

discretion of the government, applied where new exploration covered areas which were previously explored or developed, such as Dornod and Gurvanbulag. Originally, this was understood to involve compensation if it were invoked, but this provision was abolished in the July 2009 Nuclear Energy Law. The potential for large uranium deposits remains. For example, French company AREVA, present in the country since 1997, has carried out exploration leading to the discovery of two new orebodies in the Dornogobi province; these two ore bodies, Dulaan Uul and Zoovch Ovoo have resources estimated at 60,000 tons U.

Kazakhstan

The Special Inter-District Economic Court for the City of Astana (Republic of Kazakhstan) on March 26, 2014 issued an order having the effect of invalidating the original transfers in 2004 and 2005 from Kazatomprom to the Company's Betpak Dala and Kyzylkum joint ventures of the subsoil use contracts for the Akdala, South Inkai and Kharasan uranium fields. The ruling relates to events which occurred two to three years before Uranium One acquired its interest in the two joint ventures. Both joint ventures intend to vigorously defend themselves in the Kazakhstan courts and plan to file notices appealing the order. Neither Uranium One nor its shareholders are parties to the proceedings. Kazatomprom, the Company's Kazakh state-owned joint venture partner in Kazakhstan, has, however, assured the Company and its shareholders that their legal rights and economic interests will be fully preserved.

Africa

The *Uranium Investing News* ([2014](#)) recently reported on the history and future of uranium mining in Mauritania, Gabon and Zambia, three more African countries. While none of them are top producers of uranium at the moment, they have potential that has attracted many companies, from juniors to established multinationals.

Uranium deposits in the Mounana area of Southern **Gabon** were discovered in 1956 by French Atomic Energy Commission geologists, and mining began there in 1960. In 1999, however, operations at Mounana were halted “due to a lack of economically recoverable reserves.”

Mauritania is considered by UIN as a relatively promising country for uranium production. One key company operating there is Aura Energy, an Australian company that the Mauritanian government has welcomed on an official level. Its Reguibat project is a “greenfields” calccrete uranium discovery with a current resource of 49 million pounds.

In its recent annual survey, the Fraser Institute identifies Mauritania as a top African country for mining. However, the nation ranks fairly low on the World Bank's Ease of Doing Business index ([more](#)).

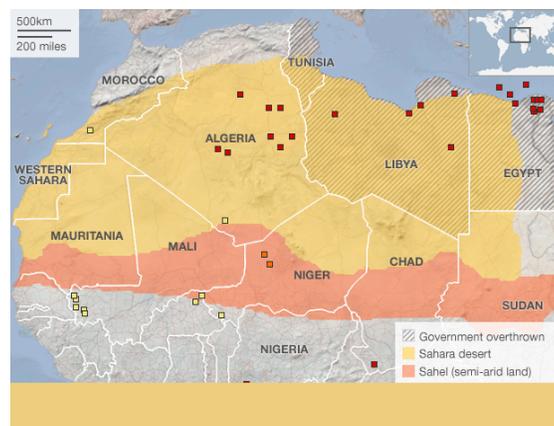
Zambia has issued uranium mining licenses since late 2008, the WNA notes, and has been a member of the International Atomic Energy Agency since 1969. Operating in the country is privately owned Equinox Minerals, which controls the \$762-million Lumwana project in Northwest Zambia. It produces copper and uranium from separate deposits in the same area and has an indicated uranium resource of 3,800 tonnes and an inferred uranium resource of 2,570 tonnes.

Chirundu, which is near the border with Zimbabwe, is another major project in Zambia. It has 4,300 tonnes of measured, indicated and inferred resources and is 100-percent owned by African Energy Resources (AER).

Zambia ranked 94th among 185 countries on the World Bank's Ease of Doing Business 2013 index; however, it scored highly on some measures like getting credit and paying taxes. It is still difficult for producers to deal with construction permits, get electricity to sites and engage in cross-border trade ([more](#)).

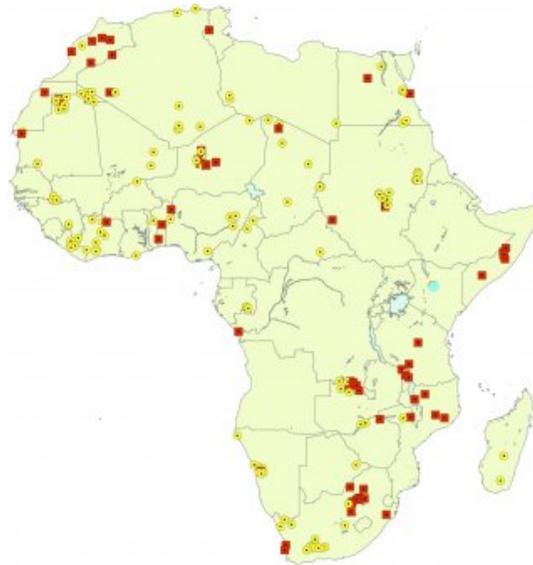
Other African Uranium Resources

Uranium exploration is also being actively carried out in Botswana, Central African Republic, Chad, Democratic Republic of Congo, Gabon, Guinea, Malawi, Mali, Mauritania, Morocco, Namibia, Niger, Tanzania, Zambia, and Zimbabwe, and Chad, in West and Central Africa, see Figures 12A and B. The following was summarized from a synopsis by the World Nuclear Association ([more](#)).



Figures 12A - Natural Gas, Uranium and Gold Mines and Prospects in Africa

Figure 12B – Uranium and Gold Mines and Prospects



Tanzania

Of particular interest are the activities of East Africa Resources's (EAR) in Tanzania. The company has completed a placement of 34,050,005 shares from the recent rights issue shortfall at \$0.01 each to raise \$340,500 for use in furthering the exploration of its Madaba uranium project in the Selous Game Reserve, Tanzania ([more](#)). The National Environmental Management Council (NEMC) of Tanzania has recommended a Preliminary Environmental Assessment, as it has decided that the project does not require a full assessment. This decision will significantly reduce the time and work required to secure access to conduct a uranium exploration program at the project.

EAR is currently focusing its attention on gaining access to the Madaba project with the goal of beginning exploration there in the middle of 2014. The company is also involved in a joint venture with KORES over Mkuju South, adjacent to Uranium One's Mkuju River deposit of 32,750 tonnes at 439 ppm uranium. KORES is currently considering investing an additional \$1.5 million in this project, with a decision expected soon.

EAR is capitalized at under \$3 million, and also controls the nearby Datlaa "gold rush" project, where it discovered artisanal miners extracting gold whilst EAF was surveying for uranium prospectivity. Tanzania has not been explored in any detail since the 1970s when the EDR occupied the country. Currently, the Geological Survey of Tanzania is organized to provide considerable support in exploration and development of natural resources within the county ([more](#)).

Uranium Resources Elsewhere in the World

India

“India has one of the most aggressive growth plans for nuclear energy in the world,” said Tim Gitzel, Cameco’s president and CEO. “The completion of the Canada-India [NCA](#) now gives us the ability to supply Canadian uranium to this important future growth market, which will mean more jobs, more investment and more development here in Canada.”

Australia is not the place that India is looking to get its uranium - India is in talks with Uzbekistan as a possible source of uranium. India has been evaluating prospects in Central Asia to help meet its uranium needs. The country already has standing contracts with Kazakhstan and Mongolia, according to the *Times of India*. From Uzbekistan, India is hoping to import about 2,000 tonnes of uranium by 2014. India’s Department of Atomic Energy explained that India “is not focusing on Central Asia only, but the region happens to have proven reserves of uranium.” At this point, India is trying to secure uranium wherever it can ([more](#)).

China and Russia

Armistead ([2014](#)) reports that around 10 to 15 strategic minerals come from China almost exclusively, (see Figure 13). Russia, on the other hand, has major controls on palladium, platinum group metals and nickel, as well some of the agricultural fertilizers, such as potash. Russia also has a critical supply of uranium; it produces about 3,000 tons of uranium, close to double United States production of uranium. Not only that, but Russia has strategic ties with Kazakhstan, which produces about 20,000 tons of uranium per year - over 36% of global supply, (see Figure 14).

These resources are at risk of a critical supply shortfall to the West. It's even more the case now as tensions between the West and Russia increase. There is greater risk of China or Russia turning off the natural gas pipelines to Europe or cutting exports of the rare earths and graphite to the world ([more](#)).

China may attempt to restructure the rare earth industry, implementing the quota system for rare earth as a control based on concerns over environmental protection and resources. The nation's apparent path is not integration of the rare-earth industry that it controls at present, but on the transformation of rough processing into deep processing, said an unnamed senior executive of an Inner Mongolian rare earth company ([more](#)).



Figure 13 – Chinese Coal and Known Major Mineral Resources

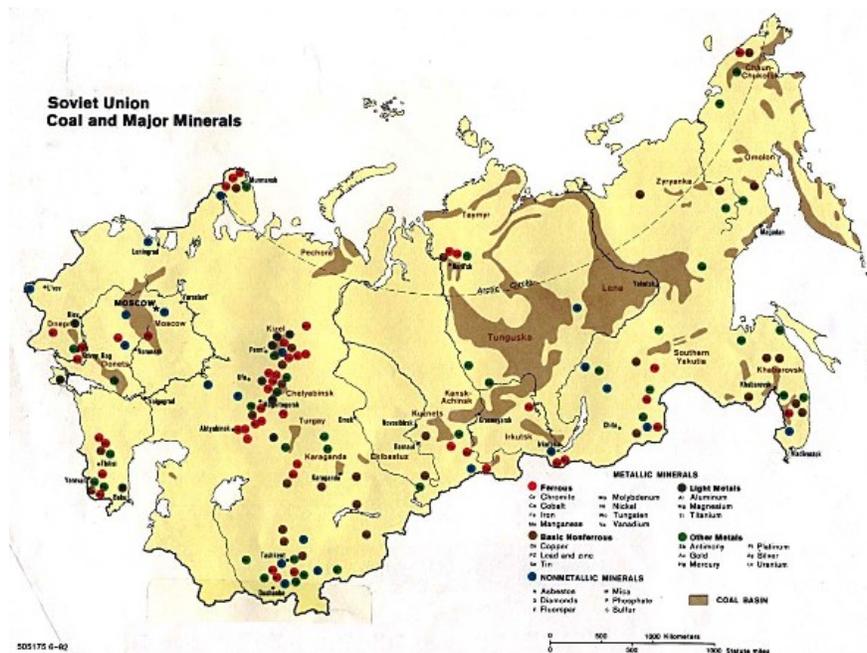


Figure 14 – Russian Coal and Known Major Mineral Resources

(Click on Figure for detailed information)

II. URANIUM-RELATED UNIVERSITY RESEARCH ACTIVITY

By Steven S. Sibray, C.P.G., (Vice-Chair: University)
University of Nebraska
Lincoln, NE

The U.S. Department of Energy is paying for the three-year \$5 million study. It's led by University of Michigan but includes six other universities; plus national laboratories and international partners in the United Kingdom and France.

Research Awards and Grants

The Society of Economic Geologists Foundation (SEGF) and the SEG Canada Foundation (SEGCF) recently announced the Student Research Grant awards for 2013. Of the 66 grants awarded, two were awarded for uranium deposit research and six were awarded for research on deposits of rare earth elements (REEs). One award was for research on U-REE mineralization associated with mid-crustal Iron Oxide Copper Gold (IOCG) deposits. The nine grants totaled US\$14,750 and CAN\$11,300.

Also see the M. McMurray Memorial Grant, page 2 of this report.

Below is an update from Colorado School of Mines (CSM courtesy of Dr. Monecke):

- 1) Jena Long, MS student, funded by Cameco, project: Geology of the Buss Pit roll-front uranium deposit, Gas Hills, Wyoming,
- 2) Julie Leibold, PhD student, funded by Cameco, defended in summer 2013, project: Geochemistry and mineralogy of the alteration halo associated with the Three Crow roll-front uranium deposit, Nebraska, U.S.

There are several students at CSM working on REEs, including:

- 1) Mandi Reinshagen (MS student, advisor Dr. Hitzman),
- 2) Michael Berger (MS student, advisor Dr. Hitzman),
- 3) Jae Erickson (MS student, advisor Dr. Pfaff),
- 4) Jon Bristow (MS student, advisor Dr. Wendlandt), and
- 5) Ryan Mulhall (MS Student, advisor Wendlandt).

The titles of the theses are listed ([here](#)).

III. URANIUM-RELATED GOVERNMENT RESEARCH ACTIVITY

By Robert W. Gregory, P.G., (Vice-Chair: Government)

Wyoming State Geological Survey
Laramie, WY

Uranium-related research at government agencies in 2013 has been limited in scope. The University of Wyoming Department of Geology and Geophysics (UW-GG), in cooperation with the Wyoming State Geological Survey (WSGS) continues its research into the uranium ore-forming processes and the geology and geochemical changes that take place during extraction and processing. The aim is to develop environmentally sustainable methods that will benefit the recovery and restoration processes associated with in-situ recovery of uranium (ISR).

USGS Research

According to Dr. Gallegos, the U.S. Geological Survey (USGS) continues research entitled “Impacts of Uranium Mining/Milling on Groundwater and Remediation with Mackinawite.”

Certain sulfides, either natural or introduced, can aid the groundwater restoration process by hastening the necessary reduction required to stabilize minerals such as uraninite. The iron sulfide mackinawite, and possibly similar minerals, may prove useful in precipitating uranium and other metals in order to return the uranium and associated metals solubilized during the in situ mining process to an immobilized state and no longer in solution.

In future research, Dr. Gallegos hopes to explore other areas such as 1) characterizing core samples from an ISR operation to determine elemental associations with uranium, 2) laboratory simulation of ISR to extract uranium and characterize solids in the system, and 3) simulate remediation using mackinawite and its effectiveness on fixing uranium and other metals ([more](#)).

Hall and Coleman ([2013](#)) analyzed the world uranium supply and demand balance. To evaluate short-term primary supply (0–15 years), the analysis focused on Reasonably Assured Resources (RAR), which are resources projected with a high degree of geologic assurance and considered to be economically feasible to mine. Such resources include uranium resources from mines currently in production as well as resources that are in the stages of feasibility or of being permitted. Sources of secondary supply for uranium, such as stockpiles and reprocessed fuel, were also examined. To evaluate long-term primary supply, estimates of uranium from unconventional and from undiscovered resources were considered.

Wyoming Geological Survey Research

In cooperation with active Wyoming uranium mining operators, the WSGS and the UW-GG have acquired several hundred feet of well-controlled samples of pre-mineralized, mineralized, and

post-mineralized host sandstones and plan to study associated groundwater. Investigators on this project are Susan M. Swapp, Robert W. Gregory, B. Ronald Frost, Carol D. Frost, Jonathan F. McLaughlin, Davin Bagdonas, and Charles Nye.

They are using field emission scanning electron microscopy (FESEM), powder x-ray diffraction (XRD), wavelength dispersive x-ray analysis (WDS) on an electron probe micro analyzer (EPMA), x-ray fluorescence (XRF), stable isotope mass spectrometry, and traditional wet chemical analyses at UW-GG to characterize host rocks, ground water, and uranium minerals in these deposits. These data, together with radiogenic isotopic data for accessory minerals acquired using instrumentation at Stanford University will enable the research group to recognize potential source areas for the uranium in individual deposits. Identification of uranium mineralogy will facilitate a more thorough and effective ISR mining process, and a better understanding of uranium source rocks and controls on deposit formation. This will also improve the methods of exploration and initial evaluations for new deposits. The study is supporting two graduate students' thesis projects and will end in June, 2014.

In June, 2013, this Vice-Chair presented a talk at the Wyoming Geological Association's Annual Field Conference in Casper on Cretaceous-aged uranium deposits and pending mining operations. One such operation by Peninsula Energy, Ltd. plans to be producing yellowcake by the end of 2014 from the Upper Cretaceous Lance Formation in northeast Wyoming.

Arizona Research

An Arizona Geological Survey report by Spencer and Wenrich ([2011](#)) in their study of uranium in the Colorado River, both naturally-occurring, and what may result from mining of breccia pipes and/or an accidental spill found that the effect would be "trivial"; only a fraction of one part per billion (ppb). For example, the addition of 300 kilograms (660 pounds) of uranium over one year would increase uranium in river water from 4.00 ppb to 4.02 ppb. Given that the EPA maximum contaminant level for uranium in drinking water is 30 ppb, this increase would be trivial. Furthermore, it would be undetectable against the much larger natural variation in river-water uranium content.

Research on Rare Earth Elements

The WSGS has received additional funding from the Wyoming Legislature to continue research into rare earth element (REE) deposits and anomalous occurrences. This second phase of REE research will continue through June, 2016.

In May of 2013, WSGS geologists Wayne M. Sutherland, Robert Gregory, along with contract geologists Brett Worman and Jacob Carnes completed a reconnaissance survey of potential rare earth element (REE) deposits and anomalous occurrences. Follow-up studies on known sites with

anomalous REE values were visited and resampled, not only for REE but also other potential minerals of potential economic value. Additionally, the group sampled dozens of sites around Wyoming which may have potential for REE occurrences based on what is known about existing deposits in Wyoming and elsewhere. The study also involved data mining at WSGS and beyond, as well as testing of geologic samples collected in conjunction with past WSGS investigations.

The project was completed in May, 2013 and is summarized in WSGS Report of Investigations RI-65, available through the website ([more](#)). All field and geochemical data were compiled into an interactive database which is also now available to the public by way of the website. The Wyoming Database of Geology (WyoDOG) will be updated to include our recent findings and results of REE investigations along with field data, maps, references, photographs, and other information.

STATUS OF THE THORIUM INDUSTRY

The question of whether thorium is useful for energy production was answered in 2013, when a private Norwegian company, **Thor Energy**, began to produce power at its Halden test reactor in Norway using thorium. Nuclear giant Westinghouse, a unit of Toshiba, is part of an international consortium that Thor Energy established to fund and manage the experiments ([more](#)).

One of the consortium's members is none other than Westinghouse, an established player in nuclear energy; the company provides viewpoints on the research. But Thor Energy is not the only company engaged in researching whether or not thorium is a viable alternative to uranium in nuclear energy. Firms from the US, Australia and the Czech Republic are also working on thorium reactor designs and other elements of fuel technology using the metal. However, Thor Energy was the first off the block to begin energy production with thorium.

Unlike uranium, thorium can't split to make a nuclear chain reaction - in scientific terms, it isn't fissile. However, if it is bombarded by neutrons from a fuel that is fissile, like uranium-235 or plutonium-239, it's converted to uranium-233, itself an excellent nuclear fuel. After the process begins, it's self-sustaining - fission of uranium-233 turns more thorium nearby into the same nuclear fuel. There are complexities including the mechanics of molten-salt versus pressurized-water reactors in burning thorium, but the reaction described above is the main appeal of thorium, and its principal promise.

Thorium vs. Uranium

Thorium is an appealing alternative to uranium to many countries. It is both less expensive and more abundant than uranium, whose price is expected to rise yet more as backlash from the Fukushima disaster dies down, according to Energy and Capital ([more](#)). There are other benefits of thorium as well. During a thorium-powered nuclear reaction, most of the thorium itself is

consumed, which leads to less waste, most of which is rendered non-hazardous in 30 years.

China's Problem and Thorium

In response to China's pollution concerns, Premier Li Keqiang declared a "war on pollution" to the national legislature in early March, 2014, promising to take significant measures to tackle the problem. Those measures include turning away from coal-fired power stations, which in 2013 accounted for roughly 70 percent of China's electricity. Nuclear power, on the other hand, currently accounts for roughly 1 percent of China's electricity demand and offers a "solution for massive coal replacement and thorium carries much hope," Li said. India too is looking to build thorium nuclear reactors by 2025.

Why Thorium?

According to figures from the World Nuclear Association ([2014](#)), China currently has 20 operating nuclear power plants and another 28 under construction - that amounts to nearly 40 percent of the world's total. In 2013 alone, China is expecting to add 8.6 gigawatts of nuclear power capability to its electric grid. However, even with that addition, uranium-fueled nuclear power still accounts for only 2 percent of China's electricity.

Beyond this year, the country has developed an extremely ambitious nuclear program lined up, with plans to generate almost 60 gigawatts of nuclear energy by 2020 and up to 150 gigawatts by 2030. Despite headlines regarding a Chinese economic slowdown, the country has been fairly busy acquiring many available commodities, including uranium, and identifying thorium resources throughout the world ([more](#)).

STATUS OF THE RARE EARTH INDUSTRY

Company Activities

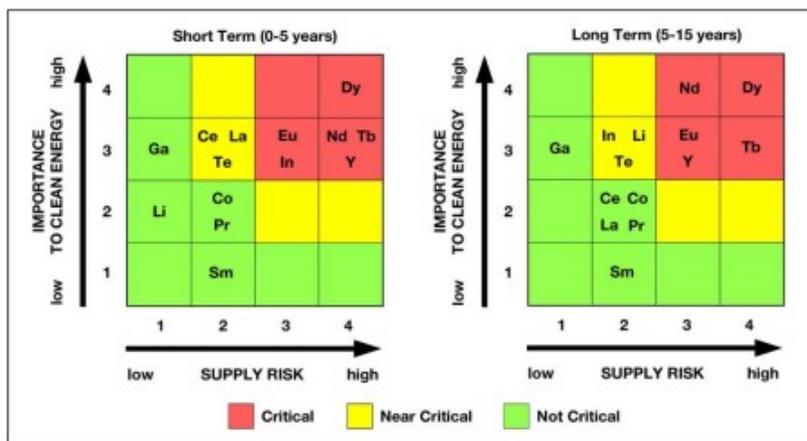
Many junior miners have made strategic advancements with some jurisdictions in the rare earth sector. For instance, the state of Alaska made a proposal to help fund a rare earth mine in Alaska controlled by Ucore Rare Metals Inc. ([more](#)). In Canada, there's a push in the Parliament to look for secure supplies, an effort which may benefit Pele Mountain Resources Inc. ([more](#)). In Europe, Tasman Metals Ltd. could be a strategic supplier of technology metals to the EU, which may be very concerned about supply as tensions increase with Russia over Crimea ([more](#)).

Value of Heavy Rare Earths

The U.S. Department of Energy has identified dysprosium, neodymium, terbium, europium and yttrium as the most critical rare earths ([more](#)). They have defined “criticality” as a measure that combines importance to the economy and risk of supply disruption (see Figure 15).

Currently more than 95% of production of rare-earth metals is based in mainland China and predictions from the European Union raise concerns that, in the long term, China may only be able to produce enough heavy rare-earth metals to satisfy its own needs. This may trigger a significant supply shortage for the rest of the world.

Heavy rare earths are an integral part of the both clean energy technology and data storage; both of these areas are expected to increase substantially in the next five years. The “big four” of dysprosium, yttrium, terbium, and europium are the most important.



Sources: US Department of Energy, Technology Metals Research

Figure 15 - Criticality Index

(click to enlarge figure)

As indicated in the above Vice-Chair’s report on REEs in Wyoming, the WSGS Report of Investigations RI-65 is now available through the website ([more](#)). All field and geochemical data were compiled into an interactive database which is also now available to the public by way of the website. The Wyoming Database of Geology (WyoDOG) will be updated to include our recent findings and results of REE investigations along with field data, maps, references, photographs, and other information.

Ocean-Floor Mining

Jamasmie ([2014](#)) recently reported that since 2001 the United Nations’ International Seabed Authority has issued 30 exploration permits for the Pacific, Mid-Atlantic and Indian Oceans.

However, there has been a rush of late, with another seven ready to be issued. Last year, the United Nations published an update to its plan for developing a regulatory framework for deep sea mining, saying private firms would be allowed to apply for mineral, oil and gas extraction licenses as soon as 2016 ([more](#)).

Hugo Swire, Minister of State, UK Foreign and Commonwealth Office, told the UK House of Commons in January, 2014: “We are at the threshold of a new era of deep-sea mining,” He added that a recent assessment of the Pacific Ocean has estimated that over 27 billion tonnes of “rock nodules” may be lying on its floor. The nodules may contain more than 290 million tonnes of copper, 340 million tonnes of nickel and an undetermined, but very large tonnage of rare-earth elements ([more](#)), among several other minerals of importance to society. For additional information on rare-earth activities in the U.S., Canada, and elsewhere, see ([here](#)).

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