EMD Uranium (Nuclear Minerals) Committee

2015 EMD Uranium (Nuclear Minerals and REE) Committee Annual Report

May 20, 2015

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Special Consultants to the Uranium (Nuclear Minerals) Committee:

- **Ruffin I. Rackley**, Senior Geological Consultant, Anacortes, WA
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- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD in 1977)
- **M. David Campbell, P.G.**, Senior Geologist, I2M Associates, LLC, Jupiter, Florida
- **Robert A. Arrington**, VP, Exploration, Texas Eastern Nuclear, Inc (retired), College Station, TX
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- **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

The AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earth) Committee (UCOM) has continued to monitor the nuclear power industry and associated uranium exploration and development in the United States and overseas. Input for this Annual Report has also been provided by Henry M. Wise, P.G., C.P.G. (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration; Steven Sibray, CPG, Vice 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 have also been monitored during the period for this Annual Report, which is a function approved by the UCOM in 2011. On the basis that nuclear (thorium) and REE minerals often occur in deposits together, we provide summary information on current thorium and rare-earth exploration and mining, and associated geopolitical activities.

UCOM is also pleased to remind the reader as a regular feature that the Jay M. McMurray Memorial Grant is awarded annually to a deserving student(s) 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 Chair 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 (AAPG Foundation, 2015).

PUBLICATIONS AND NUCLEAR OUTREACH

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.* Earlier versions include: the 2011 version (here); 2009 (here); and 2007 (here). The 2015 version is in preparation and should be available in late 2015.

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*.

Chapter 9 updates and associated revisions of 2012 have been included in a revised PDF version of the chapter. The text of 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 (93, more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (94, more).

James Conca, Ph.D., a member of the Advisory Group of this UCOM, continues to contribute popular articles to Forbes.com on many nuclear subjects. To review the chronological list of Dr. Conca's contributions to date, see (Ref 95, here).

We have modified the format of the UCOM annual report this year to provide greater coverage with fewer report pages. To accomplish this, we will cover certain topics as we have in the past, such as those that cover the driving forces behind the current uranium industry conditions and activities, e.g., yellowcake prices, data on reserves, and exploration. For the rest of the coverage, we will draw on the I2M Web Portal, which provides links to selected abstracts and reviews of media articles and technical reports with a focus on uranium exploration (96, more), mining, processing, and marketing as well as on topics related to uranium recovery technology, nuclear power economics, reactor design, and operational aspects (97, more), and related environmental and societal issues involved in such current topics as energy resource selection, climate change, and (98, more), since all have direct or indirect impact on the uranium, thorium, and rare earth fields.

Also covered are reviews and current developments in research on thorium (99, more), helium-3 (Ref 100, more), and fusion research, and related environmental and societal issues. Current developments in the rare-earth commodities are also covered (101, more). For the full list of coverage of the various sources of energy and associated topics, in the form of almost 3,000 abstracts and links to media articles and technical reports to date from sources in the U.S. and around the world, see (102, for Index to all fields covered: here). The references have been cited in the form of links in sequential order beginning on page 35 of this report.

EXECUTIVE SUMMARY

- U.S. production of uranium concentrate in the 4th quarter, 2014 was 1,100,111 pounds U_3O_8, down 25% from the previous quarter and up 16% from the fourth quarter 2013.
- U.S. uranium concentrate production totaled 4,905,909 pounds U_3O_8 in 2014. This amount is 5% higher than the 4,658,842 pounds U_3O_8 produced in 2013.
- U.S. production in 2014 represents about 11% of the 2014 anticipated uranium market requirements of about 50 million pounds U_3O_8 for U.S. civilian nuclear power reactors.
- 89% of the U.S. fuel requirements will be met by Canada, Australia, and Kazakhstan, and supplied from other sources, some 377 million pounds U_3O_8 per year.
- China consumes 19 million pounds per year, and produces only about 4 million pounds U_3O_8 annually, while planning to nearly tripling its nuclear power capacity by 2020 in an effort to begin to alleviate problems with air pollution created by mining, importing and burning coal to generate electricity.

- India's installed nuclear capacity is reported now at 5,780 MW, but that is set to nearly double in just the next four years to 10,080 MW.

- India will reportedly initialize a 500 MW prototype fast breeder reactor (PFBR) at Kalpakkam in Tamil Nadu to generate electricity in 2015 or 2016.

- After the Fukushima tsunamis in 2011, uranium prices lost about 60% of their value. But the decline in price appears to have begun to rebound since bottoming near $28 in mid-2014. Since then, the spot uranium price has already gained nearly 40% to reach the current level of around $38.50 but it will remain low while natural gas prices remain low.

- An increase in positive views has been expressed by various media about the nuclear power resurgence over the past six months. To counter this notoriety, however, nuclear adversaries and pro-solar and wind pundits have increased counter claims with spurious and dubious claims about solar and wind accomplishments.

- Prime Minister Narendra Modi is expanding India's world presence by making the first visit to Canada in decades. While there, he recently signed a five-year agreement to buy U_3O_8 in order to fuel India's nuclear reactors. He also has recently visited Mongolia to establish trade relations.

- Despite the Japanese tsunami disaster and associated damage to a nuclear power plant nearby, globally there are hundreds of new reactors either under construction or in planning stages in the world today, and, most, if not all, have completed the recommended safety modifications regarding the need for back-up power in event of potential disasters, like earthquakes, tsunamis, etc.

- Uranium exploration data for 2014 reflected the lower price of uranium and was expectedly down substantially from previous years although this is expected to rebound in 2015.

- Total uranium drilling in 2014 in the U.S. amounted to 1,752 holes covering 1.3 million feet, 67% fewer holes than in 2013 and the lowest since 2004.

- Expenditures for uranium drilling in the U.S. were $28 million in 2014, a decrease of 43% compared with 2013.

- Total expenditures for land, exploration, drilling, production, and reclamation were $240 million in 2014, 22% less than in 2013.

- Total employment in 2014 in the U.S. uranium production industry was 787 person-years, a decrease of 32% from the 2013 total and the lowest since 2006.

- All of the above declines were in direct response to the decline in the price of yellowcake that was related to the shutdown of the Japanese reactors and overall impact of the damage to the reactors caused by Fukushima tsunamis in 2011 throughout the world. The price is expected to rise over the coming months but will remain low as long as natural gas remains widely available at low prices.

- In a landmark decision, Powertech Uranium, now Azarga Uranium, and adversaries of Azarga's planned uranium mining operation in Custer and Fall River counties, South Dakota both view a recent NRC decision as a victory for their respective sides. The licensing board found in Powertech favor on five of the adversarial challenges of the Oglala Sioux Tribe relating to water quality and quantity.

- The NRC revised the Powertech license, instructing the company to make more efforts to find and properly abandon existing drill holes at the site and to respond to an unspecified threat the mining operation would pose to Native American cultural, historic and religious sites in the Powertech well-fields, all of which have positive future implications for the uranium mining industry working with deference in and around lands claimed by Native American tribes.

- Currently known uranium reserves in seven western states are estimated to total nearly 340 million pounds U_3O_8, about one-third of the reserves are in Wyoming. Other known reserves are in Arizona, Colorado, Nebraska, New Mexico, Texas, and Utah, North Dakota, South Dakota, Virginia, and Alaska.

- The uranium deposit at Coles Hill in southern Virginia is the largest known undeveloped uranium property in the U.S., and allegedly the seventh largest in the world. It is estimated to contain some 60 million pounds of uranium in a hard-rock environment but an adversarial government and local NIMBY opposition has halted development to date.

- EIA estimated at the end of 2008 that U.S. uranium reserves totaled approximately 539 million pounds of U_3O_8 on the economic basis of a forward cost of up to $50 per pound U_3O_8.

- At up to $50 per pound U_3O_8, uranium available through in-situ leaching represents about 40 percent of total U.S. reserves, with Virginia uranium availability notwithstanding.

- EIA announced that as of the end of 2014, it has re-estimated uranium reserves to be 163 million pounds U_3O_8 at a maximum forward cost of up to $50 per pound of U_3O_8, claiming the NURE data used in earlier estimates were no longer to be used because of their ambiguity.

- UCOM has concluded that over the past few months the EIA is showing substantial bias against nuclear power in their energy contributions in the U.S. in favor of wind and solar energy recovery installations even though both of the latter are still being funded and operated under large subsidies, while their economic and operational factors are still being tested in the field.

- Small modular reactors (SMRs) have received increased attention by the media, industry, and even both state and federal governments over the past six months, continuing an upward trend in developing SMRs for standby use in case of disasters, for remote areas, including off-world, as well as for operating sector grids in small towns or in large cities where a number of SMRs could be located around the city.

- Currently low price natural gas has shuttered some nuclear power plants in the U.S. while others may be at risk of being closed on strictly economic grounds. In the last year, U.S. utilities have closed or announced plans to close five nuclear reactors in addition to the announced canceled development plans.

- The general consensus held by many is that most of the existing U.S. nuclear plants will not be affected because: a) they provide power without producing carbon emissions, b) coal use will continue to decline as a result of current and future greenhouse gas regulations, c) electricity prices should recover from their current trough, and d) the low variable cost (about $12/MWhr for nuclear, compared to $24 for the most efficient gas plants) heavily favors nuclear on strictly economic grounds.

- Yucca Mountain nuclear waste storage facility may still be put to use for its intended purpose, now that the Senior Nevada Senator's influence has been markedly diminished via the recent elections and his retirement.

- China is leading the world in nuclear power development and is currently building 28 reactors, by far the biggest nuclear program in the world, and is working on several alternative research and development fronts at once, with 23 plants under construction, and more about to start construction.

- China also has a significant research and development program underway to develop a thorium reactor. Several other nations are taking a closer look at thorium-power generation of electricity, especially India, and the U.S. is providing technical assistance.

- Most of mainland China's electricity is currently produced from fossil fuels, predominantly from coal. Two large hydro projects are recent additions: Three Gorges of 18.2 GWe and Yellow River of 15.8 GWe.

- Rapid growth in electricity demand has given rise to power shortages in China, and the reliance on fossil fuels has led to serious air pollution in eastern China and Vietnam.

- Aided by foreign technology acquired during three decades of development (from Westinghouse), China has the highest number of reactors being built with ambitions to export its home-grown models to an overseas market worth hundreds of billions of dollars.

- Russia's state-owned nuclear-energy company, Rosatom, has also made successful inroads into markets around the world. Rosatom has 29 nuclear reactors of Russian design in various stages of planning and construction in more than a dozen countries, the largest number of nuclear reactors being built internationally today.

- French-owned, Areva, is prominent in the industry, and is now building the first Generation III Plus reactors in Finland, France and even China along with its more than 100 active reactors supplied to utilities around the world.

- U.S. uranium-related university research decreased with very few grants and little federal funding since the Fukushima Daiichi nuclear plant damage resulting from a major tsunami in 2011.

- Recent re-starting of the Japanese nuclear reactors will likely spur renewed interest in academic and industrial research because the uranium market price has begun to rise as nuclear expansion upgrades and replaces aging reactors in the U.S. and throughout the world.

- Current interest in rare earth elements (REE) research has increased despite relatively weak market conditions, until recently. New deposits are being evaluated for development, and new processing technology of the typically complex ore is under development in the U.S., which could lead to less reliance on China as the principal source of REE.

- Russia plans to end imports of rare earths by 2020, and fully provide its own needs by domestic production from the Tomtorsky deposits in Yakutsk, located in the far eastern region as well as from some 30 other prospects in Russia.

- Wyoming Legislature has funded several geological studies conducted by the Wyoming State Geological Survey that include frontier area for REE and uranium exploration.

- UCOM members have concluded that competition between energy sources should be encouraged as long as the selection is based on economics and environmental factors, not on government-funded experiments involving solar and wind technology that have not been proven to be on sound economic and operational grounds.

- Since the Luddites raised the issue of advancing technology without providing employment more than 150 years ago, and the sociologists have been debating the issues involved for as long, solutions must be found soon for industry to contribute to the American society by incorporating more American jobs into the rapid technological developments currently underway in the U.S. and around the world in some countries.

- Current education by the American K-12 schools remain deficient in science and mathematics, while the major graduate schools enroll nearly 50% who meet their requirements for research from overseas, e.g., China, India, Japan, Korea, etc.

- The energy industry is one of the principal engines of society and provides many jobs today in exploration, production, chemical by-products, and support industries including environmental remediation.

INTRODUCTION

After the 2011 Fukushima tsunamis and damage to the Dai-ichi nuclear power plant, uranium prices lost about 60% of their value over the ensuing years. But the decline in the price evident in Figure 1 appears to have run its course by mid-2014. As illustrated in the two charts in Figure 1, since bottoming near $28 in mid-2014, spot uranium prices gained nearly 40% to reach their current level around $38.50.

Figure 1 –Yellowcake Prices since Fukushima Tsunami
(U3O8.biz)

But because nuclear fuel prices represent a very small segment of the total cost to produce electricity by nuclear power relative to other energy sources and because the supply of nuclear fuel is available from an increasing number of production sites today worldwide, new nuclear plant construction is based more on its total plant cost and financing (including insurance costs) and public opinion than with those of other competing energy sources, even if the latter have major impact on the environment. Renewables do not have established records in O&M within a scaled-up grid, without substantial state and federal subsidies.

Natural gas has a poor safety record over the past 40 years when compared to nuclear power, excluding the “cold war” driven Chernobyl disaster, but including both the Three-Mile Island and the Fukushima incidents where no one was killed and no one experienced radiation sickness. Even when the “fuel” costs to drive wind and solar are zero, albeit available at variable wind speeds and receiving radiation only during daylight, the technology required to produce electricity still involves moving parts that must be maintained on a continuous basis.

Based on the many favorable aspects to using nuclear heat to boil water (like when using a magnifying glass focusing sunlight radiation on a piece of paper) to generate electricity to turn turbines that supported the construction and continuous operation of more than 100 plants in the U.S. and nearly 400 plants worldwide over the past 40 years, the main criteria applied today to select the source of energy is based on short-term economics and political whim. Because the nuclear plants have been built in fortress-like designs and cost many millions of dollars to bring on line, and because of such designs almost all of them have lasted decades and have produced electricity both reliably and at low relative cost over years.

Serious debates on energy selection, once reserved for meaningful discussion between professionals within industry and government, have degenerated into public debates by individuals and media who are not qualified to participate in such technical discussions or who have agenda paid for by competing technology groups and even by opposing political groups within government and provide groups. These conditions make it difficult for those attempting to independently assess energy selection to resolve these conflicts without bias.

But bias can be perceived as either based on experience and reliable information or on misinformation and exaggeration. In monitoring the uranium news, UCOM attempts to assess the conditions within the nuclear power industry as it relates to the availability, price, and use of nuclear fuel. But in doing so, this also leads to considerations of factors that affect these conditions, such as the costs of competing fuels, their safety records, public opinions and media coverage, and even as far afield as sociological factors such as the relationship of technology and employment. These factors all come to bear on the availability, price and use of nuclear fuels, i.e., uranium and thorium, for the generation of electricity in nuclear power plants.

There has been a remarkable resilience to the positive views about nuclear powers' resurgence in the U.S. today as the existing plants exceed their design lives, some of which will need to be replaced because of old, but still useable technology (I2M Web Portal (Reference 1, page 39, more)). With the success of the new technology in developing new gas shale deposits in the U.S. and around the world, new natural gas resources are reaching the markets and have driven down the cost of electricity to levels that compete with nuclear. The glut of the new gas is so great that the price has fallen so low that some American shale gas fields are becoming uneconomic to produce. This is evident already by the down-sizing going on today in the oil and gas industry, especially in the smaller companies.

Added to this economic competition, and the renewed interest in new gas-fired power plants based on cheap natural gas, competition also comes from so-called renewable energy resources that the general public, led by the current administration, associated federal agencies, and media, have naively and prematurely accepted as the answer to energy selection in the U.S. To counter this media notoriety, nuclear adversaries and pro-solar and wind pundits have released a continuous barrage of media items promoting the renewables with oftentimes dubious claims and accomplishments without demonstrating sound economics. If the climate is to be a consideration, and if the cost of electricity, without government subsidies, is to be included in an assessment of the best approach to energy selection, then nuclear power continues to prevail, that is, in balance with natural gas between costs and the environment.

ENERGY COMPETITION – FACT AND FICTION

It has become clear to the members of the UCOM over the past few years that EIA, a federal agency managed by the current administration, favors wind and solar energy over nuclear even though both of the former energy sources are still being funded and operated under large subsidies, while their operation and maintenance costs remain under reported (2, more, and 3, more). Serious questions are being raised by independent reviewers on the economic viability of the two energy sources in terms of the generated cost of electricity (4, more).

News items by the local media and blogs supported by solar and wind interests either by commercial, university, or governmental funding expressed agendas that support the bias with no mention of actual costs, especially O&M costs, see (Ref 5, solar) and (6, wind). All this appears in the media while news of both the resurgence and death of nuclear power used for generating electricity compete for the attention of the citizens in the U.S. and overseas (7, nuclear).

Despite the Japanese tsunami disaster and associated damage to a nuclear power plant nearby, globally there are hundreds of new reactors either under construction or in planning stages in the world today. Further, most, if not all, have completed the recommended safety modifications regarding the need for back-up power supplies to keep the reactor cores covered with water in the event of potential disaster, like earthquakes, tsunamis, etc.

URANIUM DEMAND

Eighty-nine percent (89%) of the fuel requirements of the current fleet of nuclear reactors will be met by Canada, Australia, and Kazakhstan, and supplied from other sources, totaling some 377 million pounds U_3O_8 per year. It should be noted that as the uranium price rises, more in-situ uranium mines in the U.S. will come on stream as Japan re-starts their reactors and other countries bring new construction on-line, such as China, India, and a number of others in the next few years. But other deposits now being developed in the world will also come on-line to compete on the world markets, as discussed in the 2011 UCOM Annual Report (26, more).

The U.S., however, is the largest consumer of uranium in the world, currently requiring more than 50 million pounds U_3O_8 annually, yet producing only about 4.7 million pounds domestically. China consumes 19 million pounds per year, and that's expected to reach 73 million pounds by 2030. China only produces about 4 million pounds U_3O_8 per year, while China is planning to build additional nuclear power capacity, nearly tripling by 2020, to alleviate problems with air pollution created by mining, importing and burning coal to generate electricity.

Vietnam receives air pollution blowing out of China. They have committed to building a number of nuclear power plants in the north and in the south of Vietnam (8, more).

Although China slowed coal supplies to Vietnam last year because of their own needs for coal, Vietnam has significant hydroelectric power, but also still needs to burn coal and natural gas to keep the lights on. Their air pollution results not only from China but also from burning coal themselves, from operating a multitude of motorcycles, mopeds, scooters, and trucks in the major cities, and from burning wood (sticks actually) to meet domestic cooking needs in rural areas (9, more).

India also is in the midst of a major build out of nuclear-power generation. A 500-MW prototype fast breeder reactor (PFBR) at Kalpakkam in Tamil Nadu is targeted to produce power in 2015-16 (Ref 10, more). The country's installed capacity is now at 5,780 MW, but that is set to nearly double in just the next four years to 10,080 MW, which also puts pressure on the world uranium demand and price.

For many, uranium has been a forgotten or overlooked sector of the energy market, especially in the wake of the 2011 Japanese tsunami disaster and associated damage to the nuclear power plant nearby. But given the anticipated demand for uranium, Peter Krauth, of *The Market Miracle* suggests that it is time for a significant rise in the uranium commodity price that will drive stock prices up, which in turn will drive new rounds of mergers and acquisitions of uranium properties and the companies holding them, as well as driving new exploration and processing plant development.

And one recent major deal is drawing serious world attention (11, Oracle,). Krauth reports that in mid-April Indian Prime Minister Narendra Modi paid a visit to Canada. While there, he signed a five-year deal to buy 3,000 tonnes U_3O_8 in order to fuel India's nuclear reactors. It's an agreement worth C$350 million dollars, which works out to be just over C$58.00/pound U_3O_8. Oddly enough Narendra's meeting was the first India-Canada governmental visit in 42 years. But more importantly, it was the first nuclear contract between these two nations. He also visited Mongolia recently (12, more).

URANIUM PRODUCTION IN THE U.S.

U.S. production of uranium concentrate in the fourth quarter 2014 was 1,100,111 pounds U_3O_8, down 25% from the previous quarter and up 16% from the fourth quarter, 2013. During the fourth quarter 2014, U.S. uranium was produced at seven U.S. uranium facilities, one less than in the previous quarter (Ref 13, more).

U.S. uranium mill in production (state)

White Mesa Mill (Utah), first operating-processing alternate feed in 4th Quarter, 2014.

U.S. uranium in-situ-leach plants in production (state):

1. Alta Mesa Project (Texas)
2. Crow Butte Operation (Nebraska)
3. Hobson ISR Plant/La Palangana (Texas)
4. Lost Creek Project (Wyoming)
5. Nichols Ranch ISR Project (Wyoming), start-up production in 2014
6. Smith Ranch-Highland Operation (Wyoming)
7. Willow Creek Project (Wyoming)

U.S. uranium concentrate production totaled 4,905,909 pounds U_3O_8 in 2014. This amount is 5% higher than the 4,658,842 pounds U_3O_8 produced in 2013. U.S. production in 2014 represents about 11% of the 2014 anticipated uranium market requirements of 46.5 million pounds U_3O_8 for U.S. civilian nuclear power reactors (14, more).

EIA (15, more) reported that U.S. uranium mines produced 4.9 million pounds U_3O_8 in 2014, 7% more than in 2013. Two underground mines produced uranium ore during 2014, one less than during 2013. Uranium ore from underground mines is stockpiled and shipped to a mill, to be milled into uranium concentrate (called yellowcake, a yellow or brown powder). Additionally, seven in-situ-leach (ISL) mining operations produced solutions containing uranium in 2014 (one more than in 2013) that was processed into uranium concentrate at ISL plants.

Total production of U.S. uranium concentrate* in 2014 was 4.9 million pounds U_3O_8, 5% more than in 2013, from eight facilities (see Figure 2).

*Yellowcake (a yellow or brown powder) is obtained by the milling of uranium ore, processing of in situ leach mining solutions, or as a byproduct of phosphoric acid production

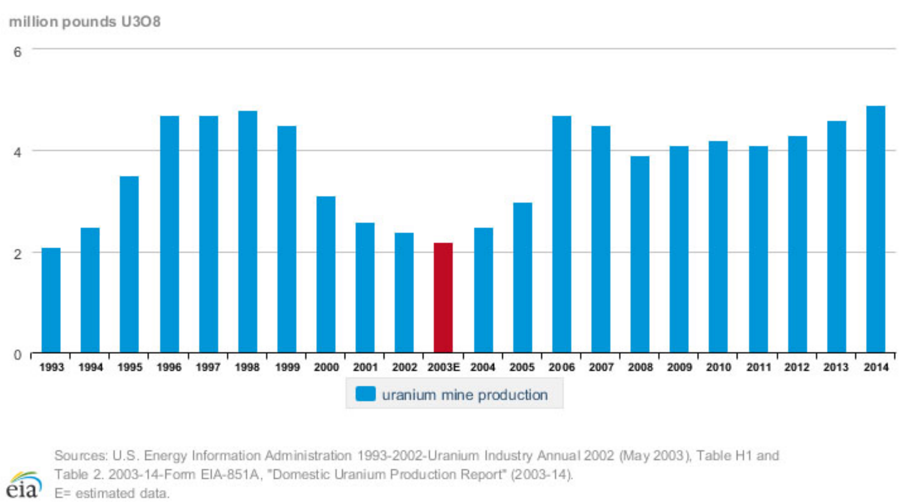

Figure 2 – Domestic Uranium Production – 1993-2014
(EIA – 2015)

The Nichols Ranch ISR Project started producing in 2014. The seven ISL plants are located in Nebraska, Texas and Wyoming.

Total shipments of uranium concentrate from U.S. mill and ISL plants were 4.6 million pounds U_3O_8 in 2014, 1% less than in 2013. U.S. producers sold 4.7 million pounds U_3O_8 of uranium concentrate in 2014 at a weighted-average price of $39.17 per pound U_3O_8.

McFarland (16, more) reports that although most of the uranium used in domestic nuclear power plants is imported, but domestic uranium processing facilities still provide sizeable volumes of uranium concentrate to U.S. nuclear power plants. In 2013, the percentage of uranium concentrate produced was distributed among seven facilities in four states. Wyoming accounted for 59% of domestic production, followed by Utah (22%), Nebraska (15%), and Texas (4%); see Figure 4 for location of sites.

Uranium is processed into uranium concentrate either by grinding up ore mined from an open pit or from underground and then processed into yellowcake, or by using oxygen and liquid mixtures to dissolve the uranium occurring in sandstone from depths of 300 feet to more than 1,200 feet in the subsurface by a process known as in-situ leaching.

Today, most plants use in-situ leaching; Utah's uranium mill serves a separate function involving upgrading the uranium product (see Figure 3). The output of the mill and the leach plants is uranium concentrate, known as U_3O_8 or yellowcake, which is transported to conversion and enrichment facilities for further processing before being fabricated into the pellets used in nuclear fuel to generate the heat water that runs generators to produce electricity.

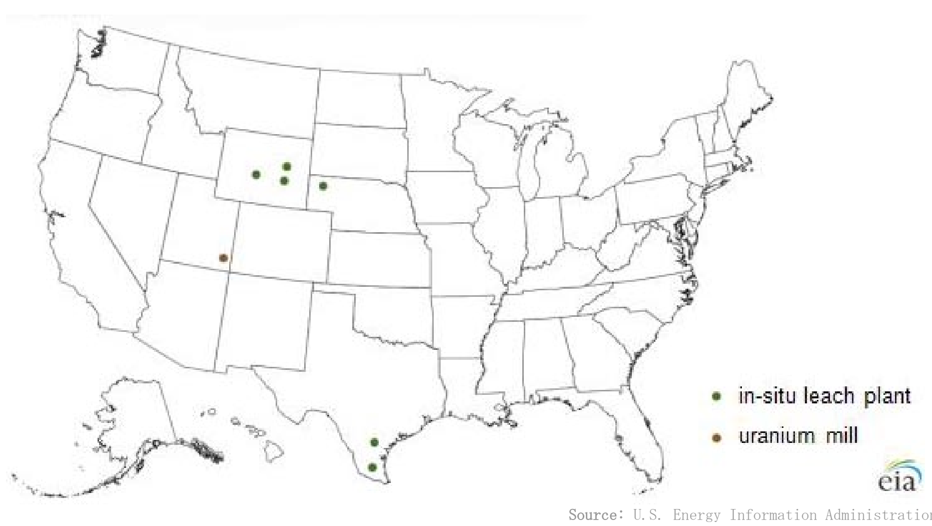

Figure 3 – U.S. Processing Facilities
(EIA – 2015)

URANIUM EXPLORATION IN THE U.S.

Uranium exploration data for 2014 reflected the lower price of uranium and was expectedly down substantially from previous years (see Figure 1). In the meantime, Google search results (17, current) show a multitude of mergers, acquisitions and consolidations, and company downsizing of properties held are moving at a fast pace while the price continues to look for support in the nuclear power industry markets for fuel (18, more). Recent exploration can be monitored on-line (19, here), and by using a more generalized term (Ref 20, here), which would reveal exploration activities for other commodities as well.

As reported by the U.S. EIA (21, more), total uranium drilling in 2014 was 1,752 holes covering 1.3 million feet, 67% fewer holes than in 2013 and the lowest since 2004 (see Figure 4). Expenditures for uranium drilling in the United States were $28 million in 2014, a decrease of 43% compared with 2013. Therefore, total expenditures for land, exploration, drilling, production, and reclamation were $240 million in 2014, 22% less than in 2013.

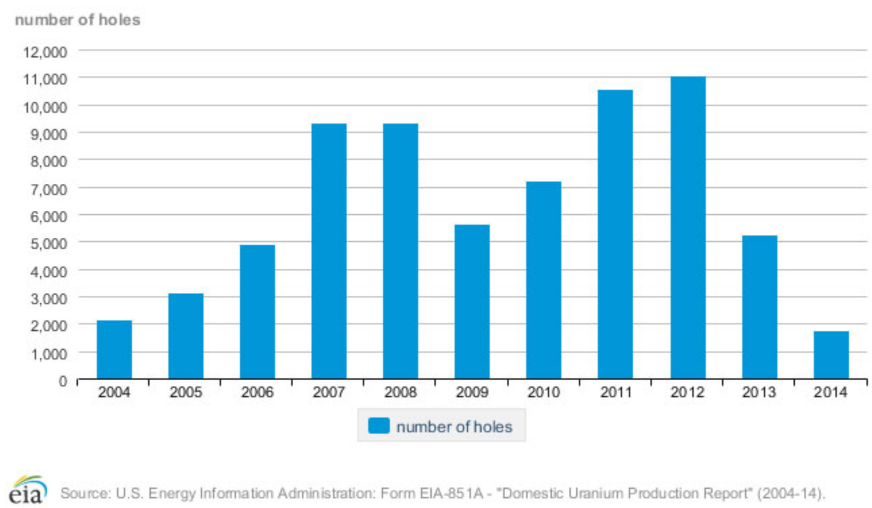

Figure 4 – Uranium Exploration Drilling – 2004 through 2014
(Ref 15, EIA – 2015)

EXPENDITURES IN U.S.

Expenditures for U.S. uranium production, including facility expenses, were the largest category of expenditures at $138 million in 2014 but were down by 18% from the 2013 level, as expected. Uranium exploration expenditures were $11 million and decreased 50% from 2013 to 2014. Expenditures for land were $12 million in 2014, a 21% decrease compared with 2013. Reclamation expenditures were $52 million, a 5% decrease compared with 2013.

All of these declines were in direct response to the decline in the price of yellowcake that was associated with the shutdown of the Japanese reactors and overall impact of the damage to the reactors caused by Fukushima tsunamis in 2011. However, the price is still expected to rise over the coming months (22, more).

SIGNIFICANT FIELD ACTIVITIES IN THE U.S.

In a landmark decision, Cook (23, more) reports that both Powertech Uranium, now Azarga Uranium, and adversaries of a planned uranium mining operation in Custer and Fall River counties, South Dakota saw a recent NRC decision as a victory for their sides. The lengthy decision comes months after the NRC's Atomic Safety and Licensing Board took testimony on a contested license the NRC granted to develop Azarga Uranium's Dewey-Burdock in situ leach uranium operations near Edgemont, SD.

The licensing board found in Powertech favor on five of the adversarial challenges relating to water quality and quantity. It did, however, revise the Powertech license, instructing the company to improve efforts to find and properly abandon existing drill holes at the site to prevent contamination by rainfall draining into the subsurface. Such recently drilled holes have standard procedures in place for appropriate abandonment using cement and bentonite, if needed. The thousands of historical holes are to be sealed when encountered.

Dewey-Burdock Project Manager Mark Hollenbeck of Edgemont said that they were very happy with all the science-based decisions that the Court made. Hollenbeck said that all of the licensing board's decisions upheld the Powertech scientific presentations and data on water quality and hydrology. The licensing board did rule in favor of the Oglala Sioux Tribe on the unspecified threat the mining operation would pose to Native American cultural, historic and religious sites in the well-fields, but these could be easily managed with the cooperation of the Tribe.

HISTORICAL URANIUM RESERVES ESTIMATES IN THE U.S.

Currently known uranium reserves in seven western states are estimated to total nearly 340 million pounds U_3O_8 (24, more); about one-third of the reserves are in Wyoming. Other known reserves are in Arizona, Colorado, Nebraska, New Mexico, Texas, and Utah.

Uranium deposits have also been identified in Alaska, North Dakota, and South Dakota, and in several other states, mostly in the West, as discussed in the 2014 UCOM Annual Report (Ref 25, more). History shows that reserves of almost any commodity are not static; they increase with time as exploration increases, resulting in new discoveries, many of which are drilled producing additional data on defined reserves, assuming certain prices and mining conditions. These issues were evaluated in some detail in the 2011 UCOM Annual Report (26, more).

The largest known undeveloped uranium property in the U.S., and allegedly the seventh largest in the world, is located on private land at Coles Hill in south-central Virginia, near the North Carolina border. The deposit at Coles Hill is estimated to contain some 60 million pounds of uranium in a hard-rock environment, which would be mined by open-pit and later by underground methods and processed on-site to produce U_3O_8. The development of this deposit has been stalled by local opposition.

Christopher (27, more) prepared a rudimentary NI 43-101 report on the project. A more robust geological study of the deposit is provided by Dalhcamp (28, more). It has yet to be confirmed that these reserves have been included in the EIA estimate of U.S. uranium reserves.

EIA (29, more) estimated at the end of 2008 that U.S. uranium reserves totaled 1,227 million pounds of U_3O_8 at a maximum forward cost (MFC) of up to \$100 per pound U_3O_8. At up to \$50 per pound U_3O_8, estimated reserves were 539 million pounds of U_3O_8. Based on average 1999-2008 consumption levels (processed uranium into fuel pellets then inserted into assemblies loaded into nuclear reactors), uranium reserves available at up to \$100 per pound of U_3O_8 represented approximately 23 years of operation (Ref 30, more). At up to \$50 per pound U_3O_8, however, uranium available through in-situ leaching (31, ISL) was about 40 percent of total reserves, somewhat higher than uranium in underground mines in that cost category. ISL is the dominant mining method for U.S. production today. These estimates are likely conservative because proprietary industrial reserve information may be substantially greater than government estimates of economic tonnage and grade of particular deposits.

EIA (32, more) announced that as of the end of 2014, estimated uranium reserves were 45 million pounds U_3O_8 at a maximum forward cost of up to \$30 per pound of U_3O_8. At up to \$50 per pound, estimated reserves were 163 million pounds U_3O_8. At up to \$100 per pound, estimated reserves were 359 million pounds U_3O_8. At the end of 2014, estimated uranium reserves for mines in production were 19 million pounds U_3O_8 at a maximum forward cost of up to \$50 per pound. Estimated reserves for properties in development drilling and under development for production were 38 million pounds U_3O_8 at a maximum forward cost of up to \$50 per pound.

EIA claims that the uranium reserve estimates presented above cannot be compared with the much larger historical data set of uranium reserves published in the July EIA (33, 2010) report on U.S. Uranium Reserves. The earlier reserve estimates were made by EIA based on data collected by EIA and data developed by the National Uranium Resource Evaluation (NURE) program, operated out of Grand Junction, Colorado, by DOE and predecessor organizations. The EIA data covered approximately 200 uranium properties with reserve estimates, collected from 1984 through 2002.

The NURE data covered approximately 800 uranium properties with reserve estimates, developed from 1974 through 1983. Although the 2014 data collected by the Form EIA-851A survey covers a much smaller set of properties than the earlier EIA data and NURE data, EIA believes that within its scope the EIA-851A data provides more reliable estimates of the uranium recoverable at the specified forward cost than estimates derived from 1974 through 2002.

In particular, this is because the NURE data has not been comprehensively updated in many years and is no longer a current data source. However, these data are very useful and suggest that there are many additional uranium properties in the U.S. that deserve additional exploration, the essential question of which revolves around just how many these will be found to contain economic reserves of uranium. If history is any guide to the future, more reserves will be identified as prices begin to rise over the near future and beyond (34, more).

EMPLOYMENT IN THE URANIUM INDUSTRY

EIA (Ref 35, more) estimates total employment in the U.S. uranium production industry was 787 person-years in 2014, a decrease of 32% from the 2013 total and the lowest since 2006 (see Figure 5). Exploration employment was 86 person-years, a 42% decrease compared with 2013. Mining employment was 246 person-years, and decreased 37% from 2013. Milling and processing employment was 293 person-years, a 30% decrease from 2013. Reclamation employment decreased 19% to 161 person-years from 2013 to 2014. Uranium production industry employment for 2014 was in 9 States: Arizona, Colorado, Nebraska, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming.

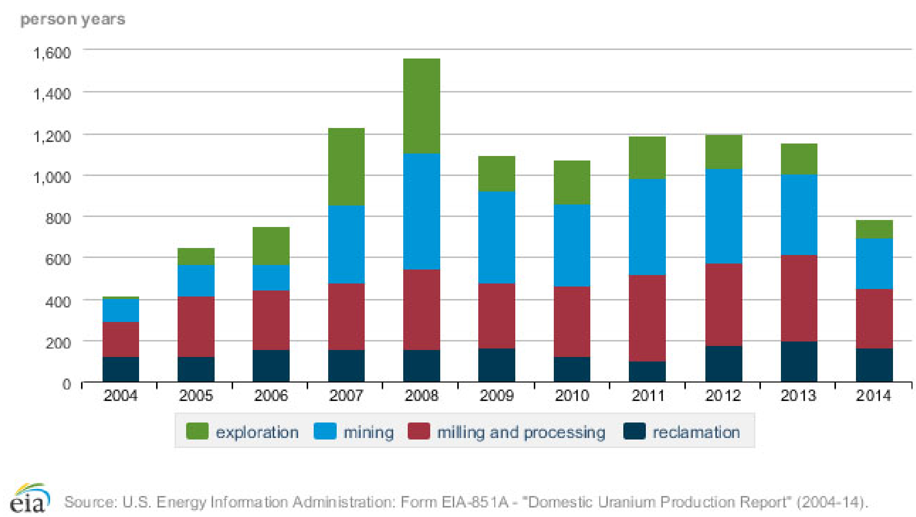

Figure 5 – U.S. Employment in Uranium Industry
(EIA – 2015)

NUCLEAR POWER PLANT OPERATIONS IN THE U.S.

Ninety-nine (99) nuclear reactors are currently licensed in the U.S., and five have been recently closed or are in the process of being shuttered (See Figure 6 for locations). Nuclear plants operate 24/7 and generate 63 percent of America's carbon-free electricity, but competitive electricity markets do not value these attributes and some may be shuttered on economic grounds. Vermont's only nuclear plant is a case in point (36, more).

The premature closure of the Vermont Yankee nuclear energy facility in December, 2014 underscores the shortcomings in electricity markets that threaten to undermine the long-term reliability of the electricity system that offers.

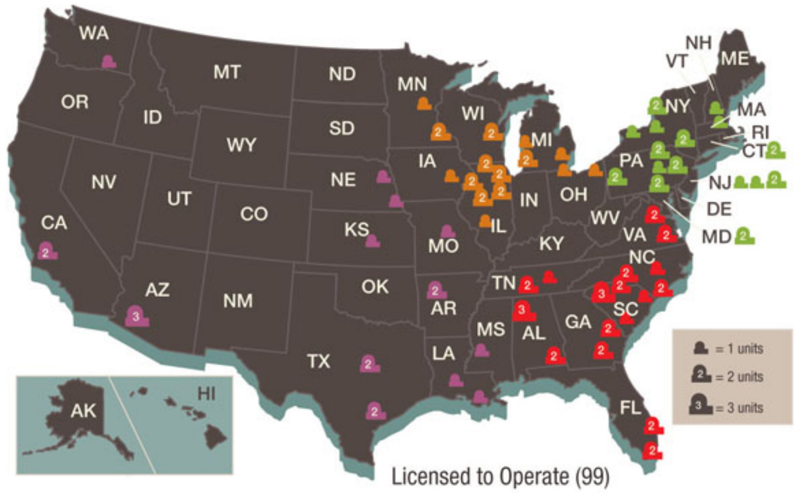

Figure 6 – Currently Operating U.S. Nuclear Power Reactors
NRC (2015)

In December 2014, the Entergy Nuclear Vermont Yankee power plant in Vernon, Vt., closed for economic reasons only. The company's operating revenues at the 604-megawatt plant were squeezed by a combination of sagging electricity demand, low energy prices, and restructured markets that undervalue nuclear energy's contributions. Industry executives warned that more nuclear plants are under financial strain and could close - a prospect that is of concern to all regulators, especially since nuclear power is the preferred energy resource, e.g. capacity factor (see Figure 7).

When a mid-size nuclear reactor in Vermont permanently and prematurely shuts down, it exacerbates instabilities in the energy markets of a community and region already impacted by economic uncertainties in that area. When Vermont lost its only nuclear power plant at the end of 2014, the region's electricity grid lost 604 megawatts of clean, around-the-clock generating capacity - and the area will see an increase in carbon dioxide emissions, a move that runs counter to national goals to reduce these emissions (37, more).

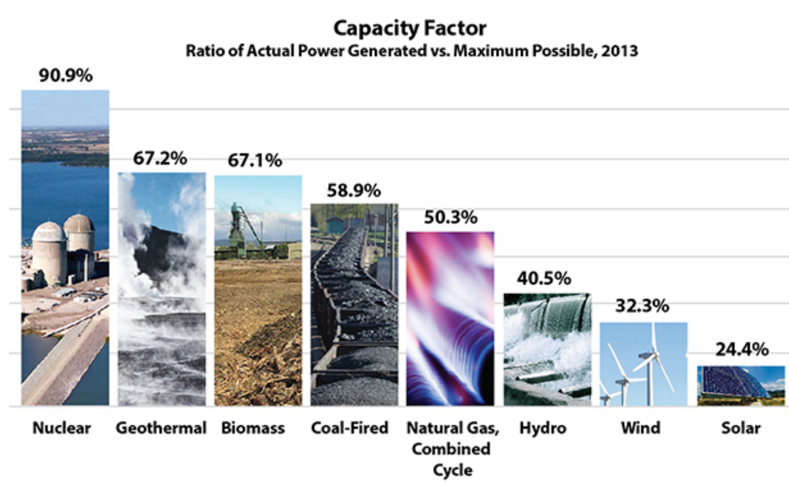

Figure 7 – Comparative Energy Capacity Factors
NEI - (2015)

SHUTTERING AND DECOMMISSIONING OF NUCLEAR POWER PLANTS IN THE U.S.

Currently, as indicated above, low-price natural gas has shuttered some plants and left others at risk of being closed on strictly economic grounds. In the last year, some U.S. utilities have canceled development plans, according to the *Morningstar Utilities Observer* report for November, 2014. McMahon (Ref 40, more) has monitored the speculations that prolonged low gas prices could drive more plant closures given the high maintenance capital investment requirements required for only shuttering.

Despite slimmer margins for nuclear operators in a low natural-gas price environment, McMahon suggests that his speculation may be unwarranted, outside of some select situations. Nevertheless, McMahon concludes that most existing nuclear plants will not be affected because: a) they provide power without producing carbon emissions, as reported by Morningstar, b) coal will suffer with current and future greenhouse gas regulations, c) power prices should recover from their current trough, and d) the low variable cost (about $12/MWhr for nuclear, compared to $24 for the most efficient gas plants) heavily favors nuclear on strictly economic grounds.

With little significant emissions, combined with coal closures, likely gas price increases, and improving power prices, these combine to support nuclear viability, but the low variable cost is far and away the primary reason that most nuclear plants are not at risk of closure despite a difficult market environment, as inferred by analyst Mark Barnett (40, more).

Paul Voosen (41, more) reports that with nuclear plants being built to last and to be dependable while emitting few greenhouse gases, the U.S. fleet of nuclear power plants will likely run for another 50 or even 70 years before it is retired - long past the 40-year life span planned decades ago - according to industry executives, regulators and nuclear scientists. This is the benefit of the high cost of construction and financing.

With nuclear providing 24/7 electricity that will become more cost-effective if a price is placed on heat-trapping carbon dioxide emissions, utilities have found it is now viable to replace turbines or lids that have been worn by radiation exposure or wear. Many engineers realized that nearly all plant parts, most of which were not designed to be replaced, can be swapped out. But for whatever reason, when a plant must close, management, in cooperation with the NRC, must choose from three decommissioning strategies: DECON, SAFSTOR, or ENTOMB (42, more).

Under DECON (immediate dismantling), soon after the nuclear facility closes, equipment, structures, and portions of the facility containing radioactive contaminants are removed or decontaminated to a level that permits release of the property and termination of the NRC license.

Under SAFSTOR, often considered "deferred dismantling," a nuclear facility is maintained and monitored in a condition that allows the radioactivity to decay; afterwards, the plant is dismantled and the property decontaminated by replacing soil and transporting contaminated soil and debris to a regulated landfill or storage facility designed for such material, such as the WIPP (43) and Yucca Mountain (44) facilities.

Under ENTOMB, radioactive contaminants are permanently encased on site in structurally sound material such as engineered concrete. The facility is maintained and monitored until the radioactivity decays to a level permitting restricted release of the property. To date, no NRC-licensed facilities have requested this option.

The licensee may also choose to adopt a combination of the first two choices in which some portions of the facility are dismantled or decontaminated while other parts of the facility are left in SAFSTOR. The decision may be based on factors besides radioactive decay, such as availability of waste disposal sites. Decommissioning must be completed within 60 years of the plant ceasing operations. A time beyond that would be considered only when necessary to protect public health and safety in accordance with NRC regulations.

When a power company decides to close a nuclear power plant permanently, the facility must be decommissioned by safely removing it from service and reducing residual radioactivity of the reactors to a level that permits release of the property and termination of the operating license (See Figure 8 for sites undergoing decommissioning). The Nuclear Regulatory Commission has strict rules governing nuclear power-plant decommissioning, involving cleanup of radioactively contaminated plant systems and structures, and removal of the radioactive fuel. These requirements protect workers and the public during the entire decommissioning process and the public after the license is terminated (Ref 45, more).

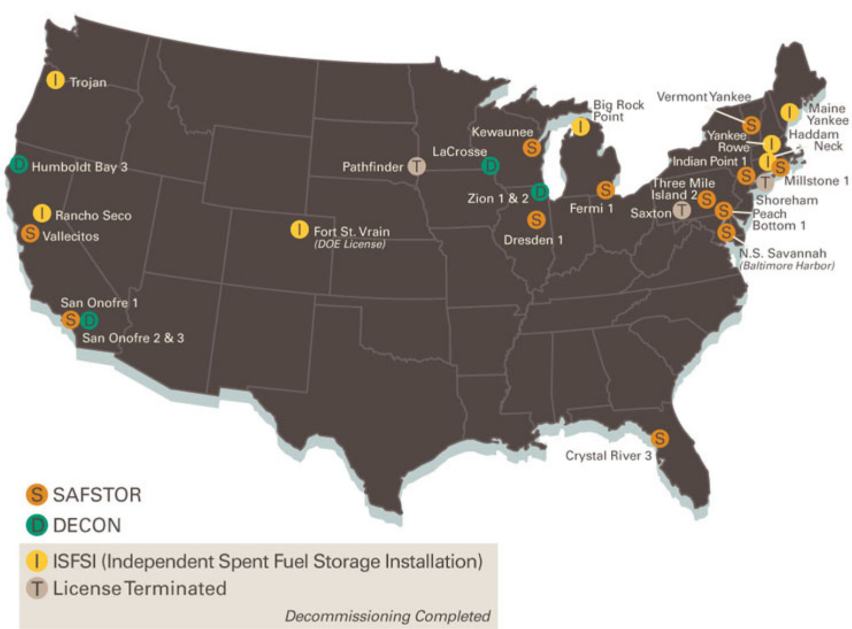

Figure 8 - Decommissioning U.S. Nuclear Power Plants
(NRC – 50, more)

SMALL NUCLEAR REACTORS (SMRS)

Small Modular Reactors (SMRs) are getting increased attention over the period, continuing an upward trend in developing SMRs for standby use in case of disasters, for remote areas, including off-world, as well as for operating sector grids in small towns or in large cities where a number of SMRs would be located around the city. Numerous research and development programs are underway on SMRs by many companies in the U.S. and overseas.

For additional, updated information and media items on SMRs to date, see (media: 38, more). For technical information on the development and current status of SMRs, see (technical: 39, more).

SPENT-FUEL STORAGE

Spent nuclear fuel data is collected by the EIA for the Office of Civilian Radioactive Waste Management (OCRWM). The spent nuclear fuel (SNF) data include detailed characteristics of SNF generated by commercial U.S. nuclear power plants. From 1983 through 1995 these data were collected annually. Since 1996, these data have been collected every three years. The latest available detailed data covers all SNF discharged from commercial reactors before December 31, 2002, and is maintained in a data base by the EIA. But this information is all that is available as of 2002 (46, more), which raises the question regarding why these data have not be made available via the EIA website.

It seems to UCOM that the I2M Web Portal is more up-to-date than the EIA is willing to make widely public on the nuclear waste storage issues (47, here). Turns out that the Yucca Mountain facility may still be useful for its intended purpose, which is to store nuclear waste from the nation’s nuclear power plants now that the Senior Nevada Senator’s influence has been markedly diminished via the recent elections.

Bi-partisan support and Republican efforts to reinstate the Yucca Mountain facility to meet its intended purpose are getting some support from a number of sources, now that the principal opposition will be gone soon. Even though the ‘store in place” plan is viable, the nuclear power plants are not getting what they have been paying decades for and what has been mandated by law, a secure place to store the nuclear waste (48, more). The history of the growing support and the opposition against opening the Yucca Mountain facility are being continuously monitored by the I2M Web Portal (49, more).

NUCLEAR POWER CONSTRUCTION OVERSEAS

Nuclear power plant construction is expanding rapidly in China, India, and more than 10 other countries. The principal focus for this report is China, India, and Russia.

China Leading the World, for Now

China is leading the world in nuclear power development. WNA (Ref 50, more) reports that China is currently pursuing the biggest nuclear plant building program in the world and is working on several research and development fronts at once. This is to break what it calls a dependence on imported fuel, but also to fight serious pollution in China that is damaging their population of billions. To mitigate the issue, China is pursuing a wide ranging program. For example:

- Mainland China has 26 nuclear power reactors in operation (see Figure 9), 23 under construction, and more about to start construction (see Figure 10),
- Additional reactors are planned, including some of the world's most advanced, to give more than a three-fold increase in nuclear capacity to at least 58 GWe by 2020, then some 150 GWe by 2030, and much more by 2050,
- The impetus for increasing nuclear power share in China is increasingly due to air pollution from coal-fired plants,
- China's policy favors a closed fuel cycle,
- China has become largely self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle, but is making full use of earlier western (US) technology while adapting and improving it,
- China's policy is to 'go global' with exporting nuclear technology including heavy components in the supply chain,
- China also has a significant research and development program underway to develop a breeder reactor and a thorium reactor,

Most of mainland China's electricity is currently produced from fossil fuels, predominantly from coal. Two large hydroelectric projects are recent additions: Three Gorges of 18.2 GWe and Yellow River of 15.8 GWe.

In 2012, gross electricity generation was 4,994 TWh* (not including Hong Kong) on IEA figures, this being 3,785 TWh from coal, 86 TWh from gas, 97 TWh from nuclear, 872 TWh from hydroelectric, and 147 TWh from non-hydroelectric renewables (wind and solar). Net export to Hong Kong was 10 TWh, adding to its 39 TWh generation (27 TWh from coal, 11 TWh from gas).

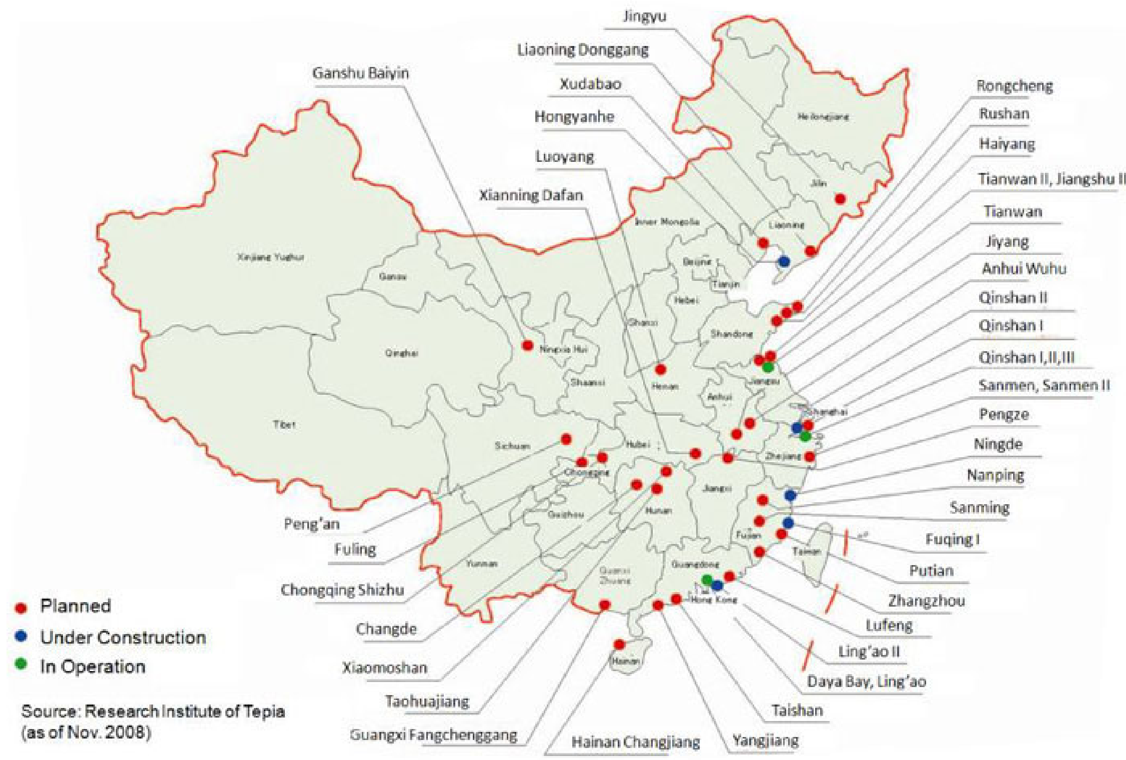

Figure 9 – Location of Nuclear Power Plants in China
WNA (Ref 53, 2015)

Aided by foreign technology acquired during three decades of development (from Westinghouse and elsewhere in the U. S. and UK), China has the largest number of reactors being built with ambitions to export its home-grown models to an overseas market worth hundreds of billions of dollars. Premier Li Keqiang told an annual parliamentary meeting recently that China aims to increase its share of global sales in a range of advanced industries, including implementing major projects in nuclear power (51, more).

Rapid growth in demand for electricity has given rise to power shortages in China, and the reliance on fossil fuels has led to serious air pollution. The economic loss due to pollution is put by the World Bank at almost 6% of GDP. Chronic and widespread smog in the east of the country is attributed to coal burning.**

For a review of current media items and reports on nuclear activities involving China, see (media: 52, more) and (technical: 53, more).

* 1 TWh = 1 tera-watt hour per year = 1,000 gigawatt hour per year = 1,000,000 megawatt hour per year
** Official measurements of fine particles in the air measuring less than 2.5 micrometers, which pose the greatest health risk, rose to a record 993 micrograms per cubic meter in Beijing on 12 January 2013, compared with World Health Organization guidelines of no higher than 25.

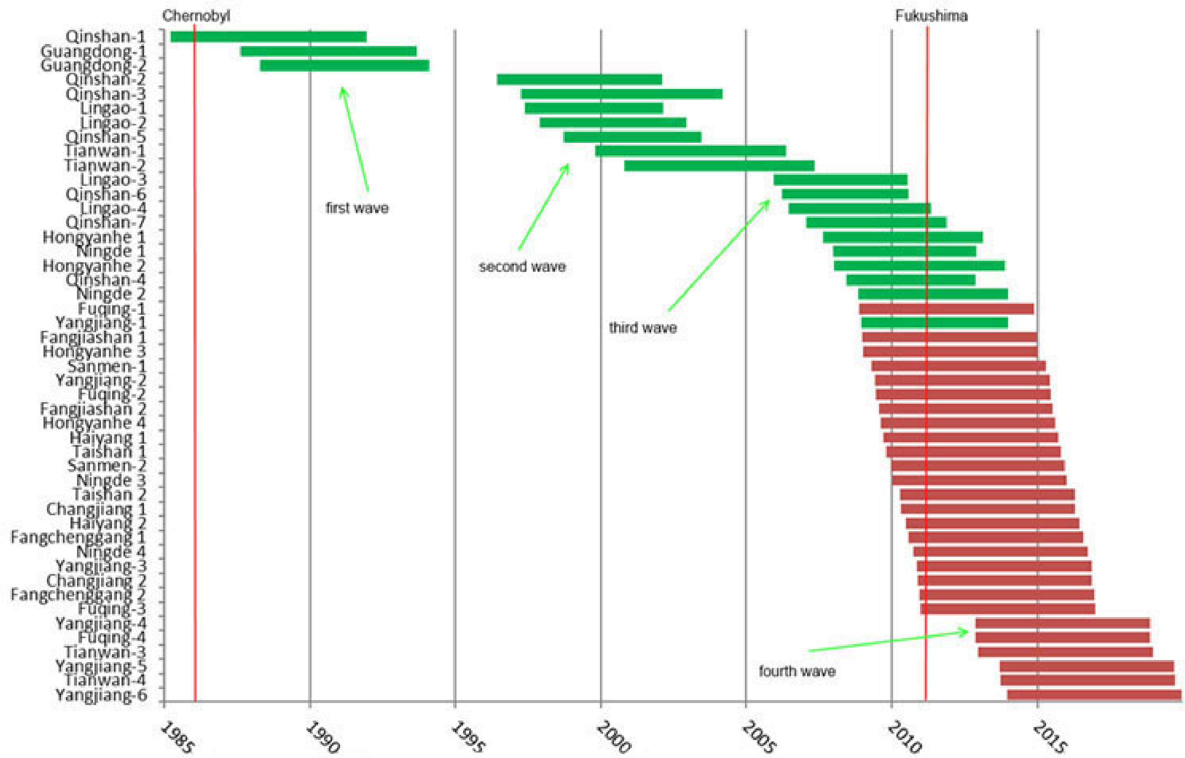

Figure 10 – Timetable Nuclear Power Plant Construction in China
WNA (Ref 55, 2015)

India is increasing its Nuclear Power Generation

India has a flourishing and largely indigenous nuclear power program and expects to have a 14,600 MWe nuclear capacity on line by 2020. It aims to supply 25% of electricity from nuclear power by 2050. Because India is outside the Nuclear Non-Proliferation Treaty due to its weapons program, it was for more than 34 years largely excluded from trade in nuclear plant or materials, which has hampered its development of civil nuclear energy until 2009 (technical: 54, more).

Due to earlier trade bans and marginal indigenous uranium deposits, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. However, since 2010, a fundamental incompatibility existed between India's civil liability law and international conventions that limited foreign technology provision.

India has a vision of becoming a world leader in nuclear technology due to its expertise in fast (breeder) reactors and thorium fuel cycle. Their current nuclear power complex consists of 11 nuclear power plants containing 21 operating nuclear reactors. Six reactors are under construction, 22 reactors are planned, and 35 reactors have been proposed (ref 55, more), see Figure 11 for locations.

India currently has 14 uranium mines, all but one is an underground mine. Production is not sufficient to fuel India's current plants so it has been receiving imported fuel from Russia and its Uzbekistan mines for a number of years.

Figure 11 – Nuclear Power Plant Construction in China
WNA (56, 2015)

More recently, India has developed new sources of supply from Namibia, Mongolia, Canada, and Australia (technical: 56, more). For a review of current media items and technical reports on nuclear activities involving India, see (media: 57, more).

Russia is Still a Nuclear Power

In Russia, 10 nuclear power plants are in operation with 31 operating reactors that produce about 15 percent of the country's electricity needs (58, more). In 2004, these reactors produced 21.7 MWe. Seven of the reactors have recently been granted a prolonged engineering lifetime for 15 years, from their 30-year intended term of service up to 45 years. Half of Russia's reactors are considered to be of a high-risk design by Western experts, as they did regarding the Chernobyl reactors before the early 1980s.

Eight of Russia's 10 plants are in the European part of Russia, East of the Ural Mountains, two others are east of the Urals - one in Far Eastern Siberia. Civilian nuclear power plants in Russia are owned and operated by the state-owned Rosenergoatom Company (see Figure 12, plant locations).

Not only China, but Russia has also been exporting their nuclear designs by building power plants in other countries as well. Thoburn (59, more) reports that Russia has been using state-owned companies as instruments of national power. President Vladimir Putin's natural-gas wars with Belarus and Ukraine made headlines and threatened to leave substantial parts of Europe in the cold. But Moscow's activities in other energy-related areas have been less noticed.

Figure 12 – Russian Nuclear Power Plants
Anon (58, 2015)

Recent revelations about the concerted Russian effort to buy up uranium resources in the U.S. (aka *Uranium One*, (60, more), and across the globe will also be publicized widely. State-owned nuclear-energy company, Rosatom, has made successful inroads into the nuclear power plant construction markets around the world. It is Rosatom - not France's Areva or the United States' Westinghouse - that has 29 nuclear reactors of Russian design in various stages of planning and construction in more than a dozen countries, the largest number of nuclear reactors being built internationally today.

In contrast, Areva, though largely owned by the French government, has not sold one reactor since 2007, although remains prominent in the industry. With its more than 100 active reactors supplied to utilities around the world, Areva is now building the first Generation III + reactors in Finland, France and even China (61, more).

For a review of current media items and reports on nuclear activities involving Russia, see (technical: 62, more) and (media: 63, more). Because of the proximity to Russia, here is the relevant information for the Ukraine, see (technical: 64, more) and (media: 65, more). Also for Kazakhstan, see (technical: 66, more) and (media: 67, more).

THORIUM ACTIVITIES

Ideas for using thorium have been around since the 1960s, and by 1973 there were proposals for serious, concerted research in the U.S. But that program came to a halt only a few years later. Why? The cause for the halt was the development of nuclear weapons.

The 1960s and '70s were the height of the Cold War and weaponization was the driving force for all nuclear research. Any nuclear research that did not support the U.S. nuclear arsenal was simply not given priority according to David Warmflash (here) and (Ref 70, more).

Conventional nuclear power using a fuel-cycle involving uranium-235 and/or plutonium-239 was seen as meeting two objectives with one solution: reducing America's dependence on foreign oil, and creating the fuel needed for nuclear bombs. Thorium power, on the other hand, didn't have military potential. And by decreasing the need for conventional nuclear power, a potentially successful thorium program would have actually been reported by some as threatening to U.S. interests in the Cold War environment.

Today, however, the situation may be very different. Many global leaders are concerned about proliferating nuclear technology. And that has led several nations to take a closer look at thorium-power generation of electricity, especially China and India, and the U.S. is providing technical assistance (71, more).

Hayes (72, more) indicates that China, India, and a few others are actively pursuing research on a thorium-based nuclear fuel cycle for electricity production. This is based largely on the fact that India has not yet identified abundant uranium resources, but does have substantial thorium ores.

Ambrose Evans-Pritchard (73, more) even reports that the nuclear race is on, again. China is upping the ante dramatically on thorium-nuclear energy. Scientists in Shanghai have been ordered to accelerate plans to build the first fully-functioning thorium reactor within ten years, instead of 25 years as originally planned. He suggests that this is definitely a race. China faces fierce competition from overseas and to get there first will not be an easy task, says Professor Li Zhong, a leader of the program. He said researchers are working under warlike pressure to deliver.

This urgency may actually serve to close the era of fossil-fuels, and may inhibit the political regimes that have trouble adapting in a modern society. The U.S. and others, however, risk being left behind by relying on the old uranium reactor technology that was originally designed for U.S. submarines in the 1950s.

As reported in the technical and public press over the past few years, thorium shows promise as an economically viable fuel source someday, but the potential use of it in the U.S. does not appear to be likely in the near term, which seems to imply that there are other, more serious issues with its rapid development. However, nuclear giant, Westinghouse, a unit of Toshiba, is part of an international consortium with Thor Energy (74, more), a private Norwegian company, to fund and manage further assessments of using thorium to replace uranium to generate the heat in nuclear power reactors.

To review the current reports, media items, and other information selected from the thorium database, see (Ref 75, more).

RARE EARTH ACTIVITIES

There are two parallel themes to consider when discussing the topic of rare earth elements. One deals with the exploration and mining of REEs, and the other is the economic processing of the ores to provide a marketable product stream. Gerden (76, more) reports that there have been some recent developments in the former by Russia. They have announced they are in the final stage of a company plan to focus on the development of the world class Burannoey deposit of the Tomtorsky rare earth element trend, where reserves are estimated at 20 million tonnes of ore, valued at US$8 billion (either in place, or on some unspecified basis of costs), with the development of other deposits in the trend when required. Operational lifetime of the Burannoey project alone is estimated at 40-50 years.

A joint venture of Rostec (a Russian state corporation established to promote development, production and export of hi-tech industrial products for civil and defense sectors), and ICT Group, one of Russia's leading investment holdings. The volume of investments in the project is estimated at 145 billion rubles (US$4.5 billion).

Successful implementation will make Russia one of the world's largest producers and exporters of rare earth metals when it reaches full operation. During Soviet times, the production of rare earth metals in the country was at the level of 8,500 tonnes per year. Production took place in more than 30 regions of the USSR. However, since the collapse of the USSR in 1990 and the number of political and economic crisis in the country, the production of REE's in Russia has almost stopped, while Russia became a net importer.

There have also been breakthroughs in processing that could reduce China's current control of the REE prices and product, at least of those elements of the REE group that are highly sought after, but also very expensive (77, more).

The company Rare Earth Salts (78, more) announced that it has a defined path to near-term commercialization of its rare-earth separation technology. Company CEO Allen Kruse has said that their low-cost technology will allow rare-earth companies to directly compete with domestic Chinese pricing. The RES technical team claims to have demonstrated some of the lowest operating costs and highest efficiency in the industry with their environmentally friendly process, projected the cost to be below $4 per kilogram.

They reported that their separation technology is the missing piece to the industry being successful in the Western World once again. It will allow current rare-earth concentrate producers and prospective producers to directly compete with, and be profitable at, Chinese domestic pricing.

The functional independence of the Rare Earth Salts' Separations Technology with various rare-earth concentrate feedstocks is another key advantage by RES. Their technology allows them to reportedly combine concentrates from multiple partners and feedstock types without sacrificing separation effectiveness (78, more).

To review the current reports, media items, and other information selected for the rare-earth database, see (media: 79, more) and U.S. Geological Survey research: (Ref 80, more).

SOCIAL ISSUES IMPACT ENERGY SELECTION

Members of UCOM monitor the national and local press and some contribute to the publication "Confronting Media & Other Bias against Uranium Exploration & Mining, Nuclear Power, and Associated Environmental Issues," which contains a narrative on objectives and reviews of selected media articles (81, more).

The objectives are to alert the general public to the vagaries of the some reporters employed by local news media and news media in general around the country. They encourage the general public to take notice of how some local public servants, activists, and some news media are sowing the seeds of misinformation, creating unnecessary controversy and mistrust around the U.S. This includes the dissemination of biased articles related specifically to inhibiting the expansion of nuclear power and associated uranium exploration and recovery, and of confusing climate change issues (82, more).

UCOM members have also begun to monitor the research that endeavors to determine the reasons behind what appears to be abnormal behavior of various groups within the U.S. and elsewhere, especially as it relates to the issues surrounding the selection of energy resources, climate change (83, more) and employment with technological advancements (84, more).

Campbell (Ref 85, more) concluded in the 2014 Mid-Year UCOM Report (86, page 16, more) that competition between energy sources should be encouraged as long as the selection is based on economics and environmental factors, but not on government-funded experiments that have not been proven to be on sound economic and operational grounds. But media and commercial bias wrapped up in the American Capitalism will continue to try to frighten the public, to stampede the public, and to turn the public toward one extreme technologically or politically or the other in making our decisions on energy sources and other current issues like climate change. Like it or not, this is a characteristic of a democratic society protected under the U.S. Constitution and the Bill of Rights.

But this assumes that competition is undertaken for the benefit of vested interests who would also contribute to the common good, not necessarily just for the common good. This also assumes that a democratic society will be enlightened and well-educated regarding important matters affecting the common good.

But new forms of monitoring public opinion are developing (87, here), and the old prejudices, fears and agendas will be affecting the general public as well (88, here). Unless, that is, society learns how easily otherwise well-meaning individuals can become technologically and politically memed by opposing and polarizing interests through ignorance or agenda bias that benefit the few and cause the cost of energy to rise for many (89, more).

But like the balance needed between industry and the environment, the balance also needs to be understood between the common good and those who are the engines of our society. Although confronted by risk, they place their confidence in science and technology, and in the rational selections that are realized. The real challenge of the future is to incorporate and integrate the society's primary resource, its people, into the technological solutions. The former cannot exclude the latter or our society will sooner or later become overloaded and the democratic systems will no longer function as anticipated (Ref 90, here) and (91, more).

From a historical perspective, this may be why democratic systems have not lasted but a few hundred years; natural self-interest in opposition to the common good suggests that social capitalism may be incompatible within a social democracy. New approaches and modifications to the existing attitudes are clearly needed in industry, the government, and in the people of America (taxpayers and consumers alike) who are willing to work and who are the actual engines that make our society function. Sociological research can only point the way.

Since the Luddites raised the issue more than 150 years ago and the sociologists have been debating the issues involved for as long (92, more), solutions must be found soon for industry to contribute to the American society by incorporating more American jobs into the rapid technological developments currently underway in the U.S. and around the World in some countries. The lack of viable solutions opened the door in the past to Karl Marx's left wing and later a right-wing counter solution to Adolph Hitler.

Although there will be no simple solution, the challenge to all Americans then is to begin now to develop new approaches to this apparent conflict of attitudes within the people of industry and the government who encourage or allow jobs to go overseas, and build a new economy within the U.S., in partnership with other like-minded nations, into a system that encourages real contributions and lasting progress in technology that also offers employment in the decades ahead. But at the same time, current education by the American K-12 school systems remain deficient in science and mathematics, while the major graduate schools (geology and engineering) enroll nearly 50% of those who meet their requirements for research from overseas, e.g., China, India, Japan, Korea, etc.

The energy industry is at the forefront of providing employment of highly trained personnel from American graduate schools and remains one of the principal engines of society providing many jobs today in exploration, production, chemical by-products, and support industries including environmental remediation (93, more). However, problems have developed over the past 10 years of losing these well-trained individuals today to their countries of origin where in years past they stayed in the U.S. to become American citizens (94, more).

URANIUM & RARE EARTH UNIVERSITY RESEARCH

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

Uranium-related university research decreased with very few grants and little funding since the Fukushima Daii-chi nuclear plant damage resulting from a major tsunami in 2011. Recent re-starting of the Japanese nuclear reactors will likely spur renewed interest in research because the uranium market has begun to increase as nuclear expansion expands buy upgrading existing plants in the U.S. and throughout the world. Current interest in rare earth element (REE) research has attracted more interest despite relatively weak market conditions until recently.

The Society of Economic Geologists Foundation (SEGF) and the SEG Canada Foundation (SEGCF) recently announced the Student Research Grant awards for 2014. Of the 68 grants awarded, only one was awarded for uranium-related research and nine were awarded for research on REE or carbonatites deposits.

The one award for uranium-related research was on gold-uranium-carbon associations in the Witwatersrand Basin, South Africa. Notable was the absence of any grants for uranium research in Canada from the SEGF and the SEG awards, at least. The 10 grants totaled US$22,250.

SEG Foundation - Hugh E. McKinstry Fund - 2014 Recipients

The Foundation supports "study, research and teaching of the science of economic geology or for related projects," with preference given to field and laboratory-related research by graduate students, as follows:

Name	Award Amount	University	Degree	Project Area
Sam Broom-Fendley	US$3,850	University of Exeter - Camborne School Of Mines (UK)	Ph.D.	Targeting heavy rare earth elements in carbonatite complexes.
Amaia Castellano	US$2,500	University of Barcelona (Spain)	Ph.D.	Bailundo and lLongonjo carbonatites, Angola.
Zachary Dodd	US$2,000	Kansas State University (USA)	M.Sc.	Petrogenesis and REE in the alkaline Pilot Knob intrusion, WY, USA.
Jae Erickson	US$3,500	Colorado School of Mines (USA)	M.Sc.	REE mineralization and Formation of the Iron Hill (Powderhorn) Carbonatite Complex, CO, USA.
Brandon Ives	US$2,000	Missouri State University (USA)	M.Sc.	Geophysics of REE deposits, SE Missouri, USA.
Vaida Kirkliauskaite	US$1,900	Vilnius University (Lithuania)	M.Sc.	REE mineralization, Southern Lithuania.
Ryan Mulhall	US$3,000	Colorado School of Mines (USA)	M.Sc.	Primary ore mineralogy of the Mountain Pass Carbonatite, California, USA.
Paul Woods	US$1,000	South Dakota School of Mines and Technology (USA)	M.Sc.	Breccia, Bear Lodge, WY, USA: Implications for emplacement of carbonatite and REE mineralization.
Tremain Woods	US$2,500	University of Witwatersrand (South Africa)	M.Sc.	Gold-Uranium-Carbon associations in the Witwatersrand Basin, South Africa.

In addition, there are a number of researchers who are currently active on uranium and/or rare earth projects. These include:

Michael J. Blessington, University of Nebraska – Lincoln, completed a Master of Science Degree on "A Niobium Deposit Hosted by a Magnetite-Dolomite Carbonatite, Elk Creek Carbonatite Complex, Nebraska, USA" Available: http://digitalcommons.unl.edu/geoscidiss/62

Virginia McLemore, New Mexico Institute of Mining and Technology, published "Rare Earth Elements Deposits in New Mexico", SME ME Online Exclusive, 10 p., HTTP://ME.SMENET.ORG/READER.CFM?WEBARTICLEID=1206 . She has already published a number of reports and abstracts on REE in New Mexico that will be included in the UCOM Mid-Year report in November, 2015.

Laurie Christine O'Neill, University of Texas, Austin, completed a Master of Science Degree on "REE-Be-U-F Mineralization of the Round Top Laccolith, Sierra Blanca Peaks, Trans-Pecos Texas"

John DeDecker, Colorado School of Mines, is working on an industry supported uranium related Ph.D., "Alteration associated with basement faults in the Athabasca Basin, Saskatchewan".

There were four Master of Science graduate students at the Colorado School of Mines whose research involves the geology of REE. These students and their projects are as follows:

Michael Berger, "Characterization of alkaline igneous rocks and alteration at the Pajarito Mountain REE-Zr deposit, Mescalero Apache Indian reservation, new Mexico"

John Bristow, "Concentration and mobilization of rare earth elements in the Boulder Creek Batholith, Boulder, Colorado"

Ryan Mulhall, "Relationship of North Fork, ID and Sheep Creek, MT carbonatites to the Proterozoic rift of western Rhodinia and the Lemhi Pass District"

Mandi Reinshagen, "The transition between hypogene and supergene REE ores, Bear Lodge, Wyoming"

URANIUM & RARE EARTH STATE/FEDERAL GOVERNMENT RESEARCH

By Robert W. Gregory, P.G., (Vice-Chair: Government), Wyoming State Geological Survey, Laramie, WY

The New Mexico Bureau of Mines and Geology has been engaged in a study of the REE potential in the Caballo and Burro Mountains of southern New Mexico. Their study has focused on early Paleozoic (Cambrian-Ordovician) magmatic occurrences. Areas having undergone hydrothermal alteration are of particular interest as they may exhibit secondary concentration of REE. Graduate and undergraduate students at New Mexico Tech have contributed to the study, which included field mapping, sampling, and a range of geochemical and geochronological analyses. They hoped to have the final report completed in the summer of 2014.

During the last three years the Wyoming Legislature has funded several studies conducted by the Wyoming State Geological Survey (WSGS) including rare earth elements (REE). The WSGS released a report in June, 2013 which examined known and potential REE occurrences and deposits. Report of Investigations 65 (RI-65) covers reconnaissance surveys statewide and highlights areas of anomalous concentrations over five times the average crustal abundance.

RI-65 was authored by W. M. Sutherland, R. W. Gregory, J. D. Carnes, and B. N. Worman and is available at the WSGS website (http://www.wsgs.wyo.gov/). The WSGS is again studying REEs in a follow-up study to the above-mentioned survey, and this second phase study will be completed in June, 2016.

The Wyoming Legislature also has funded several projects conducted by the University of Wyoming's School of Energy Resources (SER), covering an array of uranium-related topics, particularly those pertaining to in-situ recovery (ISR). Below are summaries of some of those studies, some of which are ongoing. The titles are as they appeared at a SER-hosted research symposium (April 21, 2015) at the University of Wyoming, followed by the names and affiliations of the principal investigators.

For updated information on these and other studies funded by SER, visit their website (68, here).

These include:

Kevin Chamberlain and **John Willford**, Topic: Enhancing Bioremediation of In-Situ Uranium Aquifers through Uranium and Carbon Isotope Tracing of Biologic Activity; University of Wyoming.

This project studies the effect of introducing *tryptone*, an enzymatic digest of casein, to enhance the productivity of anaerobic bacteria. The productivity of bacteria in turn leads to a reduction of the soluble hexavalent form of uranium to the insoluble tetravalent form, thus reducing the dissolved uranium content in the post-mining aquifer. The study tested other potential additives to promote bacterial reduction but tryptone was shown to be the most effective. A 53% to 68% decrease in the concentration of soluble uranium was observed. The study used uranium and carbon isotopes as metrics for monitoring uranium reduction. This project is on-going and a field trial is currently underway at the Smith Ranch-Highland uranium mine in Converse County, Wyoming.

Kevin Chamberlain and **John Willford**, Topic: A Column Study for Enhanced Bioremediation of In-Situ Uranium Aquifers with Varying Levels of Total Dissolved Solids, University of Wyoming.

Concurrent to the above-mentioned study, the aim of this project is to stimulate growth of microorganisms by adding organic nutrients and observing the reduction of hexavalent uranium in a continuous system. This was a long-term laboratory column study to demonstrate efficacy and to determine optimal tryptone concentrations with total dissolved solids (TDS) and soluble uranium concentration where biostimulation could prove most effective. Varying amounts of tryptone were added to varying amounts of TDS. Uranium isotope ratios were measured to monitor the extent of reduction and carbon isotope ratios were measured to monitor organic versus inorganic activity.

Paul Reimus, Topic: Field Evaluation of the Restorative Capacity of the Aquifer Down Gradient of a Uranium In-Situ Recovery Mining Site During Mining Operations, Los Alamos National Laboratory.

This study conducted two types of tracer tests to evaluate an aquifer's ability to attenuate the transport of uranium down-gradient from a mined area following the completion of ISR extraction. The results indicated significant heterogeneity. Additionally, three single-well injection/withdrawal tests were performed on an unmined field. The ongoing study will employ uranium isotopic analyses in an attempt to distinguish between uranium tracers and ore zone uranium.

Susan Swapp, **Carol Frost**, and **Ron Frost**, Topic: The Mineralogy and Provenance of Wyoming Uranium Roll Front Deposits and their Significance to In-Situ Recovery Mining Processes, University of Wyoming, with Robert Gregory and Fred McLaughlin, Wyoming State Geological Survey.

This study examined roll front mineralogy of both host rocks and their uranium ores of two deposits in two separate foreland basins in Wyoming. The Lost Creek deposit, in the northeastern Great Divide Basin and the Willow Creek deposit, both currently producing by ISR methods, are distinct with respect to ore mineralogy, and to a lesser extent, that of the host rocks as well. At Lost Creek, reduction of hexavalent uranium is inferred to be the result of ferrous iron released during the breakdown of biotite, as there is a prevailing lack of other apparent reductants. At Willow Creek reductants are abundant in the form of pyrite and organic matter, and ore minerals often include vanadium-bearing minerals along with uranium-bearing phases. Some areas of uranium ore at Willow Creek is already in the oxidized and insoluble state and thus does not respond as favorably to conventional oxidizing ISR techniques.

Thomas Borch and **Thomas Johnson**, Topic: Critical Evaluation of Restoration Goals Based on Improved Geochemical and Toxicological Characterization of Baseline- and Post-Mining Site Conditions, Colorado State University, with James Stone, South Dakota School of Mines and Technology.

This study aimed to determine the toxicity of constituents on health effects, characterize uranium geochemistry from baseline conditions as compared to a mined area, and construct predictive mathematical models to integrate hydrologic and geochemical data.

Jodi Schilz, Topic; Testing the Chemical and Biological Efficacy of Cupric Oxide Nanoparticles from Uranium In-Situ Recovery Produced Water, University of New Mexico.

This study investigates the contaminants in ISR production bleed water (PBW), such elements as: arsenic, vanadium, uranium, and other heavy metals. Cupric oxide nanoparticles (CuO-NPs) have been shown to remove arsenic and selenium from contaminated groundwater but have not been attempted on mining mixtures such as PBW. Batch and flow-through reactors were employed in this study to assess their ability to decontaminate PBWs. Results indicate that CuO-NPs were effective at removing most vanadium and some uranium but have pH limitations with regard removing arsenic, vanadium and other contaminants. Further studies aim to optimize the effectiveness of CuO-NPs, which do show promise in metal mixture decontamination.

Kyle McDonald, Trihydro Corporation, Topic: A Novel One-step Process for Uranium Production Bleed Water to Filter Trace Metals Using Cupric Oxide Nanoparticles, with Brandon Reynolds, Wyoming State Engineer's Office, Katta Reddy and Tex Taylor, University of Wyoming.

This study examines the effectiveness of cupric oxide nanoparticles (CuO-NPs) in removing trace amounts of arsenic, vanadium, and residual uranium from ISR production bleed water (PBW) using a flow-through adsorption column in the field. The CuO-NPs are affected by lower pH (~6.5) but regeneration indicated that they can be reused.

The University of Wyoming's School of Energy Resources (SER) has also partly funded a number of graduate thesis programs including:

Charles Nye (2015) which compares and contrasts two mine units at the Willow Creek ISR operation in Johnson and Campbell Counties, Wyoming. Mr. Nye made a comprehensive study of the roll fronts with respect to petrography, geochemistry, and hydrologic factors.

The U.S.G.S. has numerous research projects in progress (http://geology.usgs.gov/postdoc/profiles/) but only one involving the uranium mining process; it is part of their Uranium Life Cycles studies. The project is headed by Dr. Tanya Gallegos and aims to develop environmentally suitable methods to help optimize aquifer restoration after ISR uranium extraction has ceased.

By evaluating ore formation processes and characterizing the geochemical changes that occur during ISR, the goal is to reverse those changes. Reestablishing reducing conditions may be aided by introducing nanoparticles of synthetic mackinawite (an iron sulfide) into the aquifer. The aim is to promote reducing conditions and lead to uranium precipitation or adsorption onto mackinawite nanoparticles.

Additional uranium research subjects investigated by the U. S. Geological Survey are available for review (69, more).

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