EMD Uranium (Nuclear Minerals) Committee

2014 EMD Uranium (Nuclear Minerals and REE) Committee Mid-Year Report

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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

Since April this year, the AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earth) Committee (UCOM) has 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 Mid-Year 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 Chair (University) who will report on university activities in uranium, thorium, and rare-earth research for the 2015 Annual Report; and by Robert Gregory, P.G., Vice Chair (Government) on governmental (State and Federal) who will report on activities in uranium, thorium, and rare-earth research for the 2015 Annual report, with special input from other members of the Advisory Group. Thorium and rare earth activities are also updated in this 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).

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.* 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*.

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 (more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (more).

During the period covered for this Mid-Year Report (2014), two new articles were contributed by the Chair and members of the Committee's Advisory Group. The current President of EMD, Frances J. Hein, Ph.D., invited the Chair to contribute an article to AAPG's *The Explorer* on the post-Fukushima status of the uranium industry as a contribution of UCOM. A summary article was published in the November issue (here). The expanded article is presented later in this report.

The second article is the result of recent research conducted by the Chair and selected UCOM Advisory Board member's views of the likely role coal could play in the future as it is being replaced by nuclear energy on the basis of the latter's environmental and economic viability. It was published in a recent issue of *The Professional Geologist* of the AIPG, pp. 21-25 (here). An expanded version of this article is also presented later in this report.

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

The I2M Web Portal provides current articles and reviews of current and historical uranium exploration (more), thorium (more), helium-3 (more), and related activities in nuclear power development in the U.S. and around the world (more). Rare-earth commodities are also covered by the I2M Web Portal (more). For the full list of topical coverage, see (here).

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

Uranium and Nuclear Power

- U.S. production of uranium concentrate (yellowcake) in the third quarter 2014 was 1,468,608 pounds U_3O_8, up 34% from the previous quarter and up 25% from the third quarter 2013.

- During the third quarter of 2014, U.S. uranium was produced at eight U.S. uranium facilities, up one from previous quarters with another currently under construction.

- U.S. uranium cumulative concentrate production to date totaled 3,805,798 pounds U_3O_8, up 3% from the 3,712,541 pounds produced during the first nine months of 2013.

- Because of lower U_3O_8 prices over the past decades, most of the uranium used in U.S. nuclear power plants (92%) was imported from Canada, Australia, Kazakhstan, and elsewhere.

- Over the past few months, the price of uranium has begun to rise after years of anticipation after the Fukushima earthquake. Whether the current rise can be sustained remains to be seen. With the loss of Russian uranium, and with the re-start of Japanese reactors, prices are expected to continue to rise.

- At the end of 2013, uranium concentrate (yellowcake) was being produced at seven facilities in four states. Wyoming accounted for 59% of domestic production, followed by Utah (22%), Nebraska (15%), and Texas (4%) of the production.

- Known uranium reserves in seven western states are estimated to total nearly 340 million pounds; 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.

- The largest known undeveloped uranium property in the U.S., and 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 will be mined by underground methods and processed on-site to produce U_3O_8. There is significant political and local opposition to the development of this deposit.

- The latest available detailed data covers spent nuclear fuel 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 2002, which raises the question regarding why more recent data have not be made available via the EIA website.

- At Fukushima, not only has no one died from radiation releases at Fukushima, not a single person experienced radiation sickness. It was only the major physical destruction caused by the tsunami that cost thousands of lives, while the media focus for years afterward remained fixed to a large extent on the so-called "radiation disaster."

- Regarding Fukushima, after many months of sampling the region, general conclusions have been reached by the scientific community that although radiation was released it was not widespread.

- The level of radiation at Fukushima didn't reach dangerous levels except within the reactor area of the plant. It should be noted that technology can now measure extremely low levels of radioactivity, the context of which is often obscured by the media and exaggerated by nuclear adversaries.

- There is now strong evidence that nuclear power is beginning a new expansion period. Japan has realized that they must re-start most of their 54 existing nuclear power plants because they need economic energy supplies (wind, solar, and geothermal sources have not been shown to be economic or scalable). Importing natural gas is too expensive.

- The U.S., U.K., Brazil, Bolivia, India, Vietnam, Poland, Jordan, Egypt, and the UAE have begun planning and construction of new nuclear power plants, and Saudi Arabia and other Middle Eastern countries are considering nuclear as the energy of choice.

- ❖ Germany is re-considering their option for politically and environmentally safe and economically sensible sources of energy, especially in light of the new Russian activities in Urkraine.

- ❖ Forty-four reactors are under construction in China. The previous plans for hundreds of coal-fired plant have been scraped; Russia and India are gearing up to begin new nuclear power plant construction.

- ❖ With the anticipated demand for uranium fuel, the uranium prices have begun to rise, which naturally sparks off uranium company exploration, mergers and acquisitions, and new mining and processing plants are coming on-line in the U.S., Australia, Canada, Kazakhstan, and an increasing number of locations throughout the world.

- ❖ We have concluded that natural gas and nuclear power will dominate energy sources for decades to come, both of which will likely replace coal, while wind and solar will continue to be tested to determine if they deserve a place in the energy picture (after government subsidies are removed, and whether they can be scaled up to meet the needs in other than remote areas away from national power grids and to meet the operation and maintenance demands of their moving parts.

- ❖ Climate-change issues will re-enforce the domination of the two energy sources; however, there is some recent evidence that with increasing temperatures come increasing methane releases from the deep sediments offshore, which may have an even more serious impact on the climate than CO_2 releases.

When Nuclear Power Replaces Coal for Burning

- ❖ Coal may even become useful in time other than for burning to produce electricity. A new Carbon Age is dawning using re-purposed “clean coal” after all and is no longer just an oxymoron, but many industrial and academic researchers have visions of coal becoming germane economically and environmentally sound in using it for purposes other than burning.

- ❖ Commercial products made of carbon will become widespread in the foreseeable future, both on Earth and off world.

- ❖ As industry has begun to pull carbon dioxide out of the atmosphere and to store it in underground reservoirs, the option is available to not burn the coal of fossilized dead forests. Alternative sources of energy to generate electricity are available.

- ❖ We also have the option to prevent the destruction of the living forests (and their associated eco-systems) that produce much of the oxygen that humans and other organisms need to exist.

- By moving away from burning coal, the transitioning to additional nuclear power systems in the form of either large-scale plants or in the form of small modular reactors that will soon be delivered on a trailer truck or rail-road car, will finally come into their own, driven by the merits of their economy and outstanding safety record.

- The transition from burning coal to other reliable, base-load energy sources (like natural gas, nuclear power, and geothermal energy, when available) will likely be slow because industry cannot change quickly unless companies are placed on an emergency footing by government. However, a large number of coal-fired plants are still in the planning stages for construction in the U.S.

- Competition between energy sources should be encouraged as long as the selection is based on economics and environmental factors.

- The United Nations has formalized bold opposition to burning coal in a recent press release, but the Asia Pacific region is largely dependent at present on coal, rather than wind and solar resources, and even these currently have serious drawbacks.

- Carbon-based materials are poised to replace many products made of less sturdy materials, especially those applications requiring materials that provide superior strength and protection from radiation.

- A shift in the paradigm is afoot it seems where carbon derived from coal may become more important than wood and petroleum products as feedstock to make common products that society uses every day. Carbon formulations can replace wood, some metals, and some plastics.

- The production of carbon for use in consumer products would likely maintain or increase employment in the current coal and graphite industry and in the associated new carbon-based industries that formulate and manufacture new carbon products.

- Graphite is a natural mineral that consists of carbon that forms only two bonds with other carbon atoms. This means it has free electrons, and for that reason it is a good conductor of electricity as well as a very strong material.

- The race is now on to commercialize graphene, the nanoscopic fragments of carbon within coal, graphite and other carbon products, including diamonds, as an integral part of a new nanotechnology industry. China is leading the race at present. American companies have entered the race as well, especially since there are substantial security implications and other increasingly important applications of graphene, e.g., in electronics, medical, and other fields.

- ❖ Not only are many products already derived from reformulated coal useful in the world today, but by moving away from burning coal, the transitioning to additional nuclear power and geothermal systems in the form of either large-scale plants or in the form of small modular reactors that will soon be coming down the road on a trailer truck or rail-road car, will finally come into their own, driven by the merits of their economy and outstanding safety record.

- ❖ The transition from burning coal to other reliable energy sources (like natural gas, nuclear power, and geothermal energy) will likely be relatively slow because industry cannot change quickly unless companies are placed on an emergency footing.

- ❖ 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 within the current system of capitalism.

- ❖ In the big picture, coal has been used since the days of the cave man. Coal (in making steam) drove the industrial revolution. It is useful today, and will be more so in the foreseeable future in driving a new, repurposed carbon industry, but just not for burning.

Thorium to Replace Uranium as a Nuclear Fuel?

- ❖ Thor Energy continues to provide funding for research on whether or not thorium is a viable alternative to uranium in nuclear energy. Firms from the U.S., Australia and the Czech Republic are also working on thorium reactor designs and other elements of fuel technology using the metal.

Rare Earth Activities

- ❖ The Chinese government has started to stockpile rare earths again and that there is a lot of pressure building for higher prices. The big six Chinese firms that have been designated to consolidate the industry there have reported pretty poor financial results and continue to face an escalating cost structure - their environmental costs are going up. Their labor costs are going up. They are mining lower grades.

- ❖ Japan Oil, Gas and Metals National Corporation (JOGMEC) are conducting geological exploration for rare metals in the Chatkal-Kurama rare-earth zone of Uzbekistan. Targets are tantalum, niobium, lithium, beryllium, rubidium, cesium and REEs.

- ❖ Not only does Canada control world-class high-grade uranium deposits, Canada may also soon supply 20 per cent of the critical needs for REEs by 2018.

- ❖ Africa (Zambia and Malawi) has emerged as a major REE producer.

STATUS OF U.S. URANIUM INDUSTRY

3rd Quarter 2014

U.S. production of uranium concentrate in the third quarter 2014 was 1,468,608 pounds U_3O_8, up 34% from the previous quarter and up 25% from the third quarter 2013.

During the third quarter 2014, U.S. uranium was produced at eight U.S. uranium facilities.

U.S. Uranium Mill in Production (State)

1. White Mesa Mill (Utah)

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)
6. Smith Ranch-Highland Operation (Wyoming)
7. Willow Creek Project (Wyoming)

During the 3rd quarter, 2014, Strata Energy's Ross CPP (central processing plant) was under construction in Wyoming.

Uranium Prices

Over the past few months, the price of uranium has begun to rise after years of anticipation after the Fukushima earthquake. Whether the current rise can be sustained remains to be seen. With the loss of Russian uranium, and with the re-start of Japanese reactors, prices are expected to continue to rise. The price rise shown in Figure 1 appears to be a re-bound as opposed to a slow recovery. This suggests that the price may be subject to periodic rises and falls depending on the prevailing news affecting nuclear power and energy needs, electricity demands, and other factors over months.

There is a short-term supply problem in the uranium industry. However, in the long term, the general consensus is that supply will not be able to keep up with demand growth. The point at which the expected demand was to outstrip supply was considered by many to be in terms of a year or two, but this may be shortening. Japan's activities have introduced some uncertainty and have impacted the price in recent months, as well as some market makers' positive outlook for the price going forward.

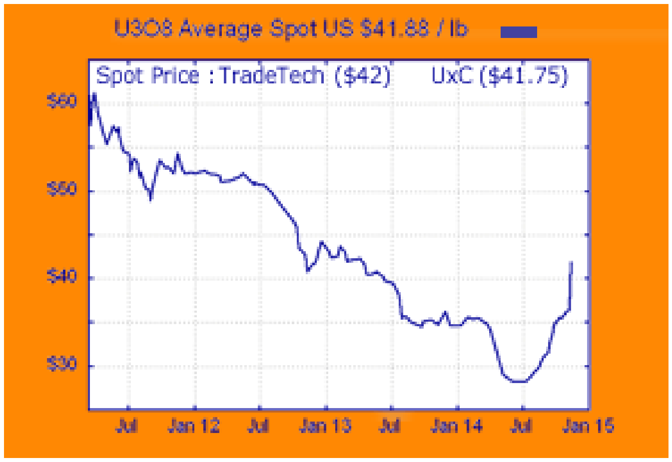

Figure 1 –Yellowcake Prices since Fukushima
(after U3O8.biz)

The three main reasons for continued global growth of uranium mine production are the persistence of long-term fixed-price sales contracts, the intransigence of government producers who believe that security of supply is more important than mine economics, and byproduct uranium production. Secondary supply sources also remain robust, plus other factors (more).

2014 Total Production (as of 3rd Quarter)

At the end of September 2014, U.S. uranium concentrate production totaled 3,805,798 pounds U_3O_8. This amount is 3% higher than the 3,712,541 pounds produced during the first nine months of 2013. For production from 1996 to 2014, see Figure 2:

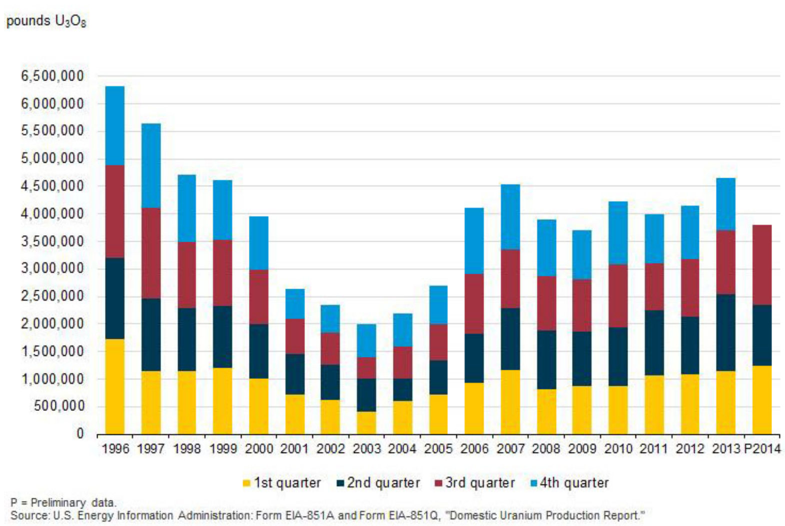

Figure 2 – Domestic Uranium Production – 1996-2014

McFarland (2014) reports that although most of the uranium used in domestic nuclear power plants is imported, domestic uranium processing facilities still provide sizeable volumes of uranium concentrate to U.S. nuclear power plants. In 2013, uranium concentrate was produced at seven facilities in four states. Wyoming accounted for 59% of domestic production, followed by Utah (22%), Nebraska (15%), and Texas (4%), (see Figure 3).

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.

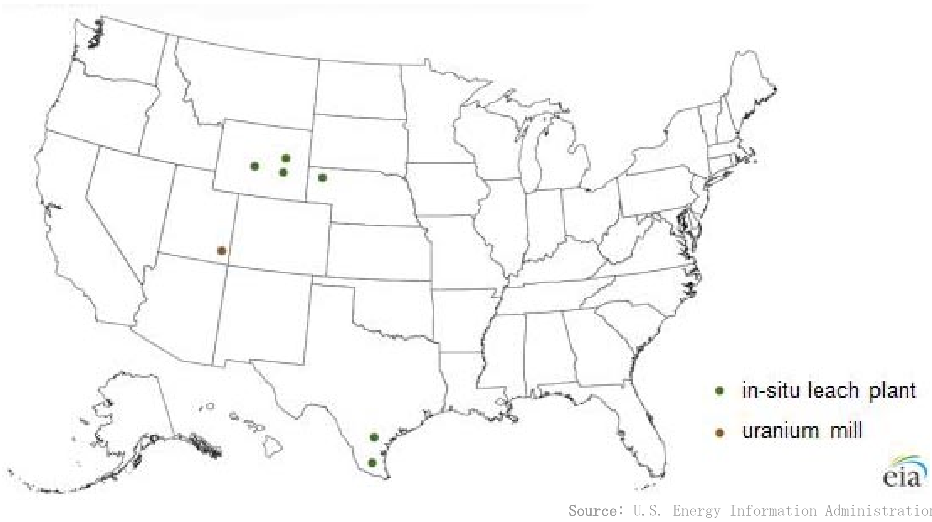

Figure 3 – U.S. Processing Facilities

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 heat water that runs generators to produce electricity.

In 2013, U.S. processing facilities produced 3.8 million pounds of uranium concentrate, a 12% increase from 2012 and equal to about 11% of the uranium used by the nation's 100 operating nuclear power reactors. The rest of the uranium used to fuel reactors came from other nations, including uranium received as part of the joint U.S.-Russian Megatons to Megawatts program (more), which ended during the 4th quarter of last year (more).

Uranium has been produced in the western United States since World War II, but in the past 25 years, uranium concentrate has been available at competitive prices on international markets. Last year (2013), 92% of the uranium used in U.S. nuclear power plants was of foreign origin, e.g., Canada, Australia (more).

Decades ago, uranium mines in western states shut down because the lower grades and lower demand caused by the Three-Mile Island incident allowed the mines in Canada and Australia to offer U_3O_8 at lower prices because of their higher grade deposits and lower cost to produce, which led to a cartel-like arrangement similar to OPEC kept the price below in-situ production costs.

As indicated in the 2014 UCOM Annual Report, Canada's continuing development of their especially high-grade and large tonnage uranium deposits, with even new discoveries in Ontario and Newfoundland, suggest that Canada will likely be the #1 uranium producer in the world for decades to come (more). Known foreign uranium resources were discussed in some detail in the previous 2013 UCOM Mid-Year Report (more).

U.S. yellowcake production has grown steadily over the past six years and may continue to grow, especially if the price continues to rise. Two uranium mills in Utah and Wyoming are in stand-by mode, and one in-situ leach plant in Wyoming was under construction in 2013 and has since begun operating. Demand for uranium concentrate is rising slowly, so increasing domestic production of uranium concentrate may reduce the market share of foreign-origin uranium in the future, as current inventories are used by the existing 100 nuclear power plants in U.S. and Canada and to fuel those plants currently under construction.

U.S. Uranium Reserves

Known uranium reserves in seven western states are estimated to total nearly 340 million pounds (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 (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 reserves, assuming certain prices and mining conditions. These issues have been evaluated further in the 2011 UCOM Annual Report (more).

The largest known undeveloped uranium property in the U.S., and 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 will be mined by underground methods and processed on-site to produce U_3O_8. Christopher (2007) prepared a rudimentary NI 43-101 report on the project (more). A more robust geological study of the deposit is provided by Dalhcamp (2010). It has yet to be confirmed that these reserves have been included in the 2008 EIA estimate of U.S. reserves.

U.S. Historical Uranium Reserves Estimates

At the end of 2008, 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 U.S. demand (more). At up to $50 per pound U_3O_8, however, uranium available through in-situ leaching (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.

Current Uranium Exploration and Development in the U.S.

Until prices rise to above $50/lb U_3O_8, uranium mining in the U.S. today is currently undertaken by only a few companies with efficient operations. In anticipation of rising uranium prices, uranium exploration is underway by many companies, often re-evaluating areas that were mined in the 1950s-80s.

WNA (2014) reports that conventional (non-ISL) uranium mining is resuming in the U.S. after some years. Cotter Corporation produced 38 tonnes U through its 400 t/day Cañon City mill, Colorado in 2005.

Of major importance to the U.S.-produced uranium supplies in the future is the Coles Hill uranium deposit in south-central Virginia. However, its development remains under local and state review. Concerns are being assessed regarding the potential threat to surface-water supplies downstream from the deposit (more), and as usual, those people who stand to gain from the development of the project (e.g., royalty owners, shareholders, merchants, services, local schools, jobs, State and local tax revenues, etc) are supporting the project, while those who have no vested or associated interest in the project are against its development for a variety of reasons (e.g. perceived water supply threat, anti-nuclear adversaries, political interests, etc).

Land access is partly controlled by the U.S. government, and in 2011 the Interior Secretary issued an order banning hardrock uranium mining (as opposed to in situ mining in sandstones) in about 4,000 square km of land in Arizona for 20 years, which blocked the development of 145,000 tU of known resources according to the World Nuclear Association (WNA) and also many acres of surrounding prospective ground. The industry contends that uranium exploration and mining here would not compromise the Grand Canyon watershed (more). The land is not within the Grand Canyon National Park or the buffer zone protecting the national park.

The industry contends that that the land withdrawal is not justified by information in the Interior Department's environmental assessment, and is an "arbitrary agency action" under the Administrative Procedure Act, and that it fails to comply with the National Environmental Policy Act by failing to take the "hard look" at the withdrawal's consequences that the U.S. Supreme Court required in a unanimous 1989 decision. In March 2013 a U.S. District Court judge declined to overturn the mining ban.

Spent-Fuel Storage

Spent nuclear fuel data is collected by the Energy Information Administration (EIA) for the Office of Civilian Radioactive Waste Management (OCRWM). The spent nuclear fuel (SNF) data includes detailed characteristics of SNF generated by commercial U.S. nuclear power plants. From 1983 through 1995 this data was collected annually. Since 1996 this data has 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 2002 (more), which raises the question regarding why these data have not be made available via the EIA website. Seems the I2M Web Portal is more up-to-date than the EIA is willing to make public on the nuclear waste storage issues (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.

The Chair's Perspective on Nuclear Power, Uranium Fuel, and the Post-Fukushima Revival *

*This is the original article that was just released in summary form in *The Explorer*, November issue, 2014 (more).

Nuclear power, because of its use for both peaceful and military purposes, causes angst among some people, and produces fuel for those with other purposes, albeit competing energy sources, religion, or politically belligerent politics (1). Hence, as nuclear power was being developed in the 1970s in the U.S., the Three-Mile Island incident occurred (but no one was killed or irradiated outside the plant; two workers were burned with hot water). Accidents happen occasionally with any industrial activities, but the media panicked us all into retreating from nuclear power because of the fear of radioactivity (2).

Figure 4
The Sendai Plant, among others, is being re-started in Japan (22).

Then, the Chernobyl disaster (within a dual military-commercial reactor with serious design flaws) occurred a few years later, which caused us to retreat even further from using nuclear power to generate electricity. Heroic workers and fireman trying to control the fire lost their lives. And, nearly 4,000 children subsequently contracted thyroid cancer… but almost 99% of them have recovered after treatment (3).

After years of debate and re-evaluation of the impact of the event (4), the merits of nuclear power emerged again from the plethora of emotional adversaries to demonstrate its usefulness on the basis of its economic viability and on its actual safety record. After decades passed, and because of economic necessity, nuclear plant construction began again, this time to replace older reactor models and to begin installing improved nuclear power plants; but then again, an earthquake off Japan's coast this time created tsunamis that created havoc and caused the death of thousands of people, and which also flooded and damaged the backup power supply system that was designed to run the water pumps to keep the fuel rods cool at the plant in Fukushima. Absent the power to the pumps, the core of fuel rods over heated and was exposed while the water boiled away, and hydrogen gas collected in the building. The gas was ignited by an electrical spark creating the explosion that demolished the plant building, and which contributed to releasing radioactive material to the surrounding areas.

Not only has no one died from radiation releases at Fukushima, not a single person experienced radiation sickness. It was only the major physical destruction caused by the tsunami that cost thousands of lives, while the media focus for years afterward remained fixed to a large extent on the so-called "radiation disaster." Once again the media tried to panic the public, but after many months of sampling the region, the general conclusions have been reached by the scientific community that although radiation was released it was not widespread. More importantly, the level of radiation didn't reach dangerous levels except within the reactor area of the plant (5). It should be noted that technology can now measure extremely low levels of radioactivity, the context of which is often obscured by the media and exaggerated by nuclear advisories. During the past few years, the world revisited the safety features of the more than 435 reactors (especially those built along coastlines), and have redesigned the back-up power systems to avoid such failures in the future. One design even included a small nuclear reactor isolated underground onsite to provide emergency power, if needed (6).

Over the past year or so we have observed strong evidence that nuclear power is up and into a new expansion period (7). Japan has realized that they must re-start most of their 54 existing nuclear power plants because they need economic power supplies (wind, solar, and geothermal sources have not been shown to be economic or scalable). The existing plants are now being equipped with new systems to withstand earthquakes and any tsunami of the magnitude anticipated in the future. The U.S., U.K., Brazil, Bolivia, India, Vietnam, Poland, Jordan, Egypt, and the UAE have begun to build, and Saudi Arabia and other Middle Eastern countries are considering nuclear as the energy of choice.

Even Germany is re-considering their option for politically and environmentally safe and economically sensible sources of energy (8). Forty-four reactors are under construction in China (9). The plans for hundreds of coal-fired plant have been scraped; Russia and India are gearing up to begin new construction, and in the U. S., there are currently 62 commercially operating nuclear power plants with 100 nuclear reactors in 31 states, with five new plants under construction and 40 other sites are either under consideration or in design stages.

World-wide, the current 435 plants are expected to expand to over 600 within the next 30 years, but earlier if the new standard design reactors are adopted.

With the anticipated demand for uranium fuel, the uranium prices have begun to rise, which naturally sparks off uranium company exploration, mergers and acquisitions, and new mining and processing plants coming on-line in the U.S., Australia, Canada, Kazakhstan, and an increasing number of locations throughout the world, with early activities beginning to explore off world on the Moon and Mars by China, India, and just recently the U.S.

A re-purposed NASA encouraging commercial activities has changed their focus recently and have re-entered the 2nd Space Race to the Moon (10)(23), although the U.S. may be late again entering the race.

Energy Speculations

In the UCOM's function to monitor the activities in the energy arena of the U.S. and overseas, we have concluded that natural gas and nuclear power and geothermal energy will dominate energy sources for decades to come, all three of which will likely replace coal, while wind and solar will continue to be tested to determine if they can have a significant place in the energy picture (after government subsidies are removed (24)), and whether they can be scaled up to meet the needs in other than remote areas away from national power grids and to meet the operation and maintenance demands of their moving parts (13).

Coal may even become useful in time other than for burning to produce electricity. A new Carbon Age is dawning using "clean coal" after all and is no longer just an oxymoron but many industrial and academic researchers have visions of coal becoming germane economically and environmentally sound (11). Products of carbon will become widespread in the foreseeable future, both on Earth and off world (12).

Climate-change issues will re-enforce the domination of the two energy sources (19); however, there is some recent evidence that with increasing temperatures come increasing methane releases from the deep sediments offshore, which may have an even more serious impact on the climate than CO_2 releases (14).

But, by moving away from burning coal, the transitioning to additional nuclear power systems in the form of either large-scale plants or in the form of small modular reactors that will soon be delivered on a trailer truck or rail-road car, will finally come into their own, driven by the merits of their economy and outstanding safety record (15 and 16). The transition from burning coal to other reliable, base-load energy sources (like natural gas and nuclear power) will likely be slow because industry cannot change quickly unless companies are placed on an emergency footing by government (17). However, a large number of coal-fired plants are still in the planning stage for construction in the U.S. (18).

So, such changes in our selection of energy sources may not become widespread in this decade, but they certainly will become apparent in the decades beyond. Competition between energy sources should be encouraged as long as the selection is based on economics and environmental factors. But media bias will continue to try to scare us, to stampede us, and to turn us politically toward one extreme or the other in making our decisions on energy sources and other current issues.

Another Perspective on the Use of Coal, but Not for Burning as Nuclear Power Ascends

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As industry has begun to pull carbon dioxide out of the atmosphere and store it in underground reservoirs, we also have the option to not burn the coal of fossilized dead forests. Alternative sources of energy to generate electricity are available. We also have the option to prevent the destruction of the living forests (and their associated eco-systems) that produce much of the oxygen that humans and other organisms need to exist. The carbon in coal can also be used to make other common "clean" products. Coal may then become "clean coal" after all and not just an oxymoron with visions of becoming germane economically.

Figure 5 - A Coal-Fired Power Plant

China, Australia, Russia, India, the Asia Pacific region, and the United States have large coal resources, but they are currently committed for burning to generate electricity, putting huge quantities of particulates, carbon dioxide, carbon monoxide, mercury and other contaminants into the atmosphere (see Figure 5).

The United Nations has formalized bold position to burning coal in a recent press release[10], but the Asia Pacific region is largely dependent at present on coal and geothermal energy, rather than wind and solar resources, and even the latter two have serious drawbacks[25].

Coal in its most common natural form is composed primarily of carbon consisting of decomposed and fossilized organic material from plants and animals that lived millions of years ago. This material has been metamorphosed into rock or densely packed sediment by heat and pressure from being buried thousands of feet below the surface. Coal forms in stages, starting with organic mud, progressing through metamorphism successively (given sufficient heat and over-lying pressure) to lignite, bituminous coals, and ultimately anthracite coal (the metamorphic version of carbon). Graphite forms as a result of organic material or limestone undergoing even greater heat and pressure at depth over an even longer period of time.

In discussions with an associate a few months ago (James L. Conca, Ph.D.), as we were finishing a report on our investigations of using nuclear systems to generate electricity to power the 2nd space race that has just begun [4, 5, page 182], we realized the importance of carbon-based materials that were on the verge of replacing many products made of less sturdy materials, especially those applications requiring materials that provide superior strength and protection from radiation. These materials have applications in products on Earth as well. [7]

A shift in the paradigm is afoot it seems. Carbon derived from coal is becoming more important than wood and petroleum products as feedstock to make common products that society uses every day. Carbon formulations can replace wood, some metals, and some plastics, the latter once considered to be "the future" by a family friend providing advice in the movie *The Graduate*. The new material of the future comes from coal and other carbon-rich materials such as graphite. One word, carbon, will carry many present graduates to a rewarding future but plastics will still be needed as well.

We re-discovered the merit of using carbon products to replace the need to harvest trees and produce petroleum that are used currently to manufacture wood-based and plastic-based products, such as furniture, utility poles, building construction materials, and a host of other products. Carbon-rich natural resources no longer need to be burned for the purpose of generating electricity but can be used as a feedstock to formulate carbon fiber and carbon nano-tubes and cages (microscopic structures of *graphene* that we'll define later) that are already used in reinforced plastics, heat-resistant carbon composites, many cell-phone components, batteries, fishing rods, golf club shafts, bicycle frames, sports car bodies, the fuselage of the Boeing 787 *Dreamliner*, and pool cue sticks. Carbon is also used to reinforce concrete and gray cast iron and many other products, such as carbon rods used as a neutron moderator in nuclear reactors to control the rate of fission.

Carbon is also used in components for heating nuclear fuel and in the cool-down process, and can absorb heat up to 3,000 degrees Celsius (that's about 5,432 degrees Fahrenheit) without any significant signs of deterioration.[22] Refractory crucibles for high-temperature are also made of graphite as well as in the manufacture of electrodes for many industrial applications, e.g., the aluminum and steel smelting industries.

Chairs and other furniture could be made from reformulated coal that could seat an elephant, last a hundred years, and be of any form and shape conceived of by the designer, even the cushions that go with them. Using high-carbon materials formulated for building materials would also minimize building fires and damage by high winds, and even replace gypsum wallboard to improve energy conservation within homes and interior strength of materials.

Even as we move off-world in the coming decades, carbon products of high density and strength will likely become more useful in exploration activities to protect human habitation and electronics from radiation and from various types of inherent stresses in orbit or encountered in building structures on or under the surface of the Moon, asteroids, and even Mars.[8] Some form of carbon material will also be needed to make the 28,000 miles of carbon-fiber belts required in building the first space elevator, see Figure 6. [5, page 201]

The production of carbon for use in consumer products would likely maintain or increase employment in the current coal and graphite industry and in the associated new carbon-based industries that formulate and manufacture new carbon products.

Underground mining of coal could be put off until it could be accomplished by robotic miners without the need for the continuous presence of humans underground in typically methane-rich and therefore potentially explosive and otherwise unhealthy environments.

Figure 6 - Artist's Conception of the Space Elevator
(Hoagland [15])

It is apparent that coal and associated carbon-rich natural resources such as lignite can be converted to high-grade carbon through industrial heat and pressure, producing material similar to the naturally occurring anthracite coal and graphite, and diamond [18, 24, and 33]

Graphite is a natural mineral that consists of carbon that forms only two bonds with other carbon atoms. This means it has free electrons, and for that reason it is a good conductor of electricity as well as a strong material. In addition, graphite exists in layers. This enables one layer to slip over another layer, making graphite an excellent lubricant. Also, since there are free electrons to absorb light, graphite is black. Blocks of formulated, fine-grained carbon (like *carbon black* used in copying machines) could also be used in new 3-D printing that has been developed recently to make all manner of large and small products out of carbon materials.

Graphite is composed of thousands of layers of graphene. It is used in pencil "leads" (the lead's hardness is adjusted by altering the associated clay content). One can split the microscopic layers of graphene in graphite by marking with a pencil on paper and applying *Scotch Tape* over the mark and then pulling off the tape. You will see a graphene layer showing on the tape and on the paper.[23] For scale, there are still thousands of layers of graphene below those one can see.

There are other forms of carbon, but these are not commonly available on Earth. These forms include *Buckminster fullerene* and several cage and tubular varieties that can be made artificially and offer promise for future applications.[9] Meteorites also contain graphene in the form of "buckyballs", and lunar soils consisting of meteorite impact dust will likely also contain large amounts of graphene (and *carbyne* to be discussed later), in addition to helium-3. [5, page 182]. It is clear that these carbon materials are becoming increasingly important natural resources and are useful resources driving the expansion of a new carbon-based industry, not only in the nuclear industry but in many other industries as well.[26]

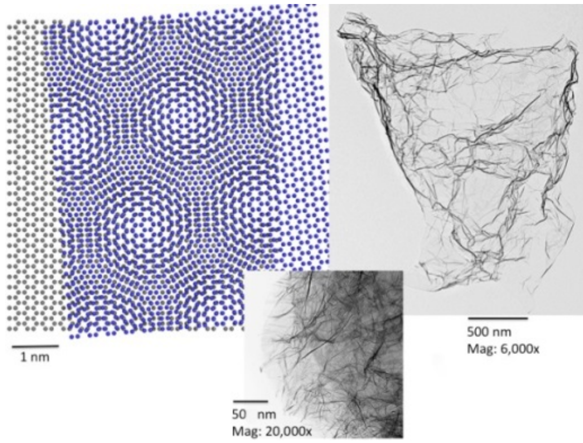

Figure 7 - The regular framework structure of carbon atoms in graphene sheets. (TEM images).
(Image credits - NIST (National Institute of Standards and Technology) and Cabot Corporation [3]**)**

Graphene appears at the atomic-scale like chicken wire made of carbon atoms and their covalent bonds (see Figure 7). Most importantly, graphene is the strongest material widely available in nature. [1] The regular structure of stacked graphene sheets show patterns within larger periodic Moiré patterns (see Figure 7). Discontinuities and defects in the stacked sheets can produce subtle strains, bulges or wrinkles as seen in transmission electron micrographs of graphene nanoplatelets consisting of only a few layered graphene sheets. These structures impart different properties to materials that can enhance performance in composites, batteries, electronics, and many other products (see Figure 8).

Graphene is an interesting submicroscopic material, and is now known to be:

- the strongest material in nature (200 times stronger than steel by weight),
- able to be mixed with other materials like plastics and cements,
- highly flexible,
- the thinnest useable material in the world (100,000,000 stacked sheets is less than an inch),
- a better heat and electricity conductor than copper,
- a material that can replace silicon in semi-conductors,
- a material that revolutionizes solar-power collection, and
- a material that dramatically improves the performance of lithium-ion batteries.

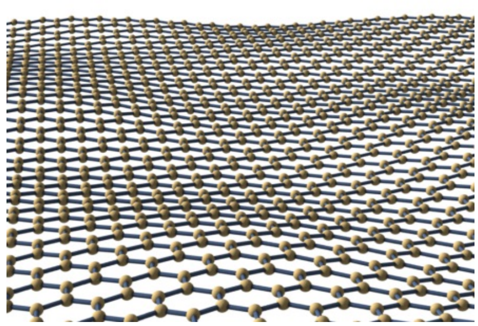

Figure 8 - Chicken Wire Pattern with Variations in the Grid.

The race is now on to commercialize graphene as an integral part of the nano-technology industry. China is leading the race at present. American companies have entered the race as well, especially since there are substantial security implications and increasingly important applications of graphene.[11] Its ultra-thin structure allows for sheets of the material to be stacked to increase energy storage and possibly double the current capacity of the new ultracapacitors.[12] A graphene-based core additive has been developed for various types of high-energy density lithium-ion battery applications. This is a new technology platform that helps lithium-ion battery manufacturers achieve superior performance.[3]

Graphene-based products are in development and are actively being studied in Europe, but Asia and the U.S. are currently leading when it comes to patent publications - even though it was pioneered in Britain.[9] Universities, corporations (IBM and others) and governments in Asia, Europe and North America are leading the effort. Industry and Wall Street are beginning to gear up for a new materials future (Example: Cabot Corporation,[2] and others [1 and 21]).

In another university-Industrial effort, a successful demonstration of a new direct carbon fuel cell design was carried out recently at the University of Queensland and by Direct Energy in Australia.[31] The demonstration indicated the apparent commercial integrity and viability of the unit, together with its scalability. The carbon fuel cells operate through a simple electrochemical reaction without excessive fumes and without combustion.

The University researchers have refined the extrusion and manufacture of the fuel cell tubes to commercial grade quality. These tube extrusions contain the essential anode, electrolyte and cathode materials that are the key component in the conversion of gasified coal to power. A relatively small unit can replace large boilers, turbines and generators – noise free, no moving parts, minimal emissions and using half the amount of coal for the same output (which means double the electrical efficiency of a traditional coal-fired power plant).[32] This is another approach to using carbon but without combustion to generate electricity; the costs for such clean energy appear to be reasonable after all.

So it is now apparent that carbon can be used to generate power and manufacture everyday products including those utilizing microscopic electronics that will have a large impact on society in the years to come.[14 and 29] But that’s not the whole story. The strongest known material in the world may have recently been replaced with an even stronger material. Researchers from Rice University have calculated the properties of a little-studied form of carbon known as carbyne, and they've determined that it should have a specific strength surpassing that of any other known material. [1 and 16]

The new study shows that carbyne, made up of a chain of carbon atoms linked by alternate triple and single bonds or consecutive double bonds, is actually twice as strong as graphene, and exhibits unusual characteristics that make it appealing for a wide range of uses.[17 and 20] However, carbyne has also been detected in inter-stellar dust and meteorites, likely the result of the high temperatures and pressures experienced in those environments, and the Rice study indicates synthesizing it here on Earth has proven to be difficult. It may be in more abundance on the lunar surface and on passing asteroids. Sampling will tell us when we visit those sites sometime this decade.

New technology being developed using old resources (i.e. coal and graphite) is paving the way in some unexpected directions.[10] They will likely be important to industry for years to come in producing new building materials, developing new nanotechnology for the electronics industry, or in the field of medicine. The possible uses are vast. Flat screen TVs as thin as Saran Wrap... nanotechnology devices that would put the power of a supercomputers in the palm of your hand... and very small brain implants that may combat Alzheimer's[19], as well as a graphene-scale radio[28], to name just a few new applications under development to-day.

The carbon present in refined coal tar has been used for many years in the manufacture of industrial chemicals, such as creosote oil, naphthalene, phenol, and benzene. Ammonia gas recovered from coke ovens is used to manufacture ammonia salts, nitric acid and agricultural fertilizers. Thousands of different products have coal or coal by-products as common household constituents: soap, aspirins, solvents, dyes, plastics and various fibers, such as rayon and nylon.[27]

Coal is also an essential ingredient in the production of specialist products, such as:

- Activated carbon - used in filters for water and air purification, in kidney dialysis machines, and in gold and silver recovery operations associated with mining,
- Carbon fiber (Graphene Assemblies) - an extremely strong but light weight reinforcement material used in construction, mountain bikes and tennis rackets, etc.,[33]and
- Silicon metal – carbon is used to produce silicones and silanes, which are in turn used to make lubricants, water repellents, resins, cosmetics, hair shampoos and toothpastes, etc.

Not only are many products derived from reformulated coal useful in the world today, but by moving away from burning coal, the transitioning to additional nuclear power systems in the form of either large-scale plants or in the form of small modular reactors that will soon be coming down the road on a trailer truck or rail-road car, will finally come into their own, driven by the merits of their economy and outstanding safety record (see Figure 9).

The alternative energy sources of wind and solar will continue to be tested to determine if they can have a significant place in the energy picture (after government subsidies are removed), and whether they can be scaled up to meet the needs in other than remote areas away from national power grids and meet the operation and maintenance demands of their moving parts.

The transition from burning coal to other reliable energy sources (like natural gas and nuclear power) will likely be slow because industry cannot change quickly unless companies are placed on an emergency footing.

Figure 9 - A Nuclear Power Plant with Water-Cooling Towers and the Beginning of the Electrical Grid in the Area.

However, a large number of coal-fired plants are still in the planning stage for construction in the U.S.[30] Such changes in our energy usage may not become widespread in this decade, but they certainly will be apparent in the decades ahead.

So, in the big picture, coal has been used since the days of the cave man.[6] Coal (in making steam) drove the industrial revolution. It is useful today, and will be more so in the foreseeable future in driving a new, repurposed carbon industry, but just not for burning.

For the References in separate PDF (here).

About the Authors of the above article, (more)

STATUS OF THORIUM

Thorium holds significant promise as a replacement for uranium in the nuclear energy sector. As global energy consumption increases, thorium is being looked into as a possible alternative to uranium to provide safe and abundant nuclear power at a reasonable cost (more). For example, India has been interested in thorium-based nuclear energy for decades, according to the U.S. Geological Survey. The question of whether thorium works 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. 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 U.S., 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.

Today, there is a growing body of scientists and environmentalists seeking to resurrect this technology, believing that it is a viable solution to generate clean, safe, green energy (more).

The UCOM continues to monitor current thorium activities and will continue to provide input to the I2M Web Portal (more).

STATUS OF RARE EARTHS

The Chinese government has started to stockpile rare earths again and that there is a lot of pressure building for higher prices. The big six Chinese firms that have been designated to consolidate the industry there have reported pretty poor financial results and continue to face an escalating cost structure - their environmental costs are going up. Their labor costs are going up. They are mining lower grades. One industry watcher has suggested that that prices need to be 20 percent higher just so the Chinese can handle the new environmental rules alone (more).

Japan Oil, Gas and Metals National Corporation - JOGMEC - together with the Uzbek State Committee on Geology and Mineral Resources are conducting geological exploration for rare metals in the Chatkal-Kurama rare earth zone of Uzbekistan. Targets are tantalum, niobium, lithium, beryllium, rubidium, cesium and REEs in accordance with an agreement concluded between the committee and JOGMEC (more).

Canada may supply 20 per cent of the critical needs for REEs by 2018. That is the target set by the Canadian Rare Earth Elements Network, at the impetus of Canadian exploration companies. Canada has about a third of the non-Chinese world advanced rare earths projects, more than a third of the known critical rare earths resources and a greater degree of rare earths expertise than many people realize (more).

Although the major rare earth producers have been struggling of late because of depressed REO prices, some of the minor companies have made new announcements in their stock exchanges that have allowed expanded budget for detailed investigations of their deposits. For example, GéoMégA has gained 55 percent in stock value. The exploration and development company holds a 100-percent interest in the Montviel rare earths and niobium project in Quebec, and is also working with partners to develop a physical separation process for the production of rare earths.

At the beginning of the year, GéoMégA reported results from a phase 3 drilling program at Montviel, noting the intersection of a heavy rare earths zone containing dysprosium and neodymium oxide (more). The zone was defined over 350 meters by 20 meters by 230 meters and remains open at depth (more).

Namibia Rare Earths is focused on its wholly owned Lofdal rare earths project in Namibia. The permit area covers 573 square kilometers, and to date the company has completed over 14,000 meters of drilling within a 50-square-kilometer portion of the Lofdal carbonatite complex at the property.

Namibia Rare Earths reached a milestone for the project in 2014, initiating a preliminary economic assessment in May (here) and announcing the completion of the report in October (more). The report suggests that Lofdal has the potential to be developed as a 2,500-tonne-per-day heavy rare earths oxide mine with a seven-year mine life. Overall, the project would garner capital costs of U.S.$156 million for an after-tax net present value of U.S.$147 million at a 10-percent discount, and investors would see an after-tax internal rate of return of 43 percent with a 1.7-year payback period. To date, Namibia Rare Earths is up 52 percent.

Also located in Africa, Mkango Resources is developing its Songwe Hill rare earths project in Malawi. The exploration and development company's share price performance has been strong this year, with the stock up 42 percent year-to-date.

Mkango was fairly quiet at the start of the year, aside from some fairly successful financing activities (more), but in September the company reached a major milestone when it released results from a prefeasibility study for Songwe Hill (more). Mkango now has one of three African rare earths projects with a favorable prefeasibility or feasibility study in hand.

Based on a conventional open-pit design using contract mining, the study estimates a mine life of 18 years for Songwe Hill. The company believes there is significant potential to reduce the strip ratio and expand the production and mine life at the project. Initial capital expenditures are set at U.S.$ 217 million for an after-tax net present value of U.S.$ 293 million at a 10-percent discount, and a 36-percent after-tax internal rate of return. The mine is anticipated to begin production in 2017.

The UCOM continues to monitor current rare earth activities and will continue to provide input to the I2M Web Portal for monitoring by UCOM personnel (more).

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