EMD Uranium (Nuclear Minerals) Committee

2015 EMD Uranium (Nuclear Minerals and REE) Committee Mid-Year Report

December 29, 2015

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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 Earths) Committee (UCOM) has continued to monitor the nuclear power industry because it drives uranium exploration and development in the United States and overseas. Input for this Mid-Year Report has also been provided by Henry Wise, P.G., C.P.G. (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration and mining; Steven Sibray, P.G., C.P.G., 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.

Two new members have been added to the UCOM Advisory Group this year. They are Kevin T. Biddle, Ph.D., ex-ExxonMobil Exploration VP (retired), and Michael A. Jacobs, P.G., Pioneer Natural Resources USA, Inc., Midland, Texas, and ex-Tenneco Uranium Inc.'s West Cole Uranium Mine in Texas.

As "nuclear minerals," thorium and rare-earth elements (REE) activities have also been monitored during the period for this Mid- Year 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 with uranium, 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 of the UCOM reports 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).

We are pleased to announce that Jason Nolan of the Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, Nebraska was awarded the McMurray Memorial Grant in 2014 (more).

PUBLICATIONS AND NUCLEAR OUTREACH

The EMD co-sponsored Journal: *Natural Resources Research* has published the bi-annual *Unconventional Energy Resources: 2015 Review* in Volume 24, Issue 4, December, 2015 (more). The UCOM 2015 contribution begins on page 450 and is titled: *Energy Competition in the Uranium, Thorium, and Rare Earth Industries in the U.S. and the World: 2015*. Earlier versions include: the 2013 version (here); 2011 (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 the associated revisions of 2012 have been included in a revised PDF version of the chapter. The text of Chapter 9 follows the Memoir 101 book cover and Chapter 9's Table of Contents, which is then followed by the author biographies, the Memoir 101's Press Release, the book's Table of Contents, ordering information, and the book preface (more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (more).

James Conca, Ph.D., a member of the UCOM Advisory Group, 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 (here).

We have modified the format of the UCOM report this year to provide greater coverage and new information in a more concise format. To accomplish this, we will cover certain topics as we have in the past, such as the driving forces behind the current uranium industry conditions and activities, e.g., nuclear power plant construction, yellowcake prices, data on reserves and exploration, especially new discoveries.

For the rest of the coverage, we will draw on the I2M Web Portal, which provides references and reviews of technical reports and media articles with a focus on: a) uranium exploration (more); b) mining, processing, and marketing as well as on topics related to: c) uranium recovery technology; d) nuclear-power economics, reactor design, and operational aspects that drive uranium prices (more); and e) related environmental and societal issues involved in such current topics as energy resource selection and climate change (more). They all have direct or indirect impact on the uranium, thorium, and rare-earth fields and their costs, mining, and utilization. This report also includes reviews of the current developments in research on thorium (more), helium-3 (more), and fusion research, and related environmental and societal issues. Current research developments in the rare-earth commodities are also covered (more).

For the complete list of coverage of the various sources of energy and associated topics, in the form of almost 4,000 abstracts and links to current technical reports and media articles from sources in the U.S. and around the world, see the Directory to all fields covered in the I2M Web Portal (here).

The references have been cited in the form of reference links and full citations and are listed in the References section at the end of this report combined with a list for additional reading on the nature of radiation.

EXECUTIVE SUMMARY

- U.S. production of uranium concentrate in the third quarter 2015 was 774,541 pounds U_3O_8, down 2% from the second quarter 2015 and down 47% from the third quarter 2014.

- At the end of September 2015, U.S. uranium concentrate production totaled 2,718,929 pounds U_3O_8. As expected, this amount is 29% lower than the 3,805,798 pounds produced during the first nine months of 2014.

- 89% of the fuel requirements of U.S. nuclear power plants will come from Canada, Australia, and Kazakhstan, and other sources, amounting to some 377 million pounds U_3O_8 per year.

- The spot uranium price of US$36.52/lb U_3O_8 for Q3 2015 was lower than estimate of US$40.00/lb (-8.7%).

- The spot price was as low as $28.50/lb in May, 2014. Since then, it has increased to the current $35.65/lb (representing a gain of 25%), largely remaining within a trading range of between $35.00/lb - $40.00/lb since the Spring of 2015.

- Uranium prices will be moving higher as worldwide utilities look to cover the current 15 to 20% fuel shortfall … but not in the next few months to a year.

- Japan has restarted a few of their reactors recently, with others to be restarted in 2016 through 2020 for the purpose of offsetting high energy prices of natural gas and renewables.

- The price of natural gas currently compromises the long-term economics of nuclear-power related in terms of the cost of the produced electricity, which in turn impacts the market price of yellowcake as plants are shuttered, retired, or as new plant construction is postponed for economic reasons.

- Utilities are refraining from placing uranium contracts on the premise that they control ample supplies, especially in Japan, and as new production from Canada and Kazakhstan have been committed and stockpiled over the past few years.

- Nearly five years after 2011, even Germany, Sweden, and France are beginning to realize that it would be cheaper to keep their nuclear power plants operating than transitioning to a wholesale commitment to wind/solar construction for other than remote areas.

- Reliance on brown coal, and large-scale wind/solar systems have neither met the climate needs of Germany, nor provided reasonable and stable electricity costs in Japan.

- ❖ 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 environmental considerations.

- ❖ 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.

- ❖ China and Russia are both financing nuclear power plant construction in numerous developed nations and undeveloped countries.

- ❖ Small Modular Reactors (SMRs) continue to receive increased attention in 2015, 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.

- ❖ There are political indications that the Yucca Mountain facility may still be opened to meet 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.

- ❖ Recent investigations by the U.S. Geological Survey and NURE data from the 1970s show that uranium, associated radionuclides (radon and radium) as well as nitrate are present in the groundwater of many aquifers in the U.S.

- ❖ The Canadian provincial and federal governments vigorously support natural-resource exploration and development, especially in uranium, thorium, and rare-earth activities, and the uranium industry in Canada is poised to take advantage of the price rise to come.

- ❖ Industry, in cooperation with the Australian government, is producing new discoveries, some also of world-class grade and pounds (U_3O_8), e.g., in South Australia, Western Australia, and in the Northern Territory.

- ❖ Based on a model developed from reviewing deposits in Kazakhstan, it has been concluded that there is considerable potential in Australia for the discovery of additional large sandstone-hosted uranium mineralization, including little-explored regions underlain by basins with known or potential hydrocarbons.

- ❖ 13 U.S. states contain known deposits and some new discoveries, with Virginia most notable because of the potentially large, recently discovered deposit there.

- ❖ Local adversaries continue to obstruct the development of the Coles Hill deposit in Virginia.

- Although new discoveries of uranium are being made throughout the world, thorium continues to receive funding as a possible alternative to uranium to provide safe and abundant nuclear power at a reasonable cost, especially in India that has been interested in thorium-based nuclear energy for decades because of large thorium resources.

- Firms from the U.S., Australia, Czech Republic, India, China, and Russia have also been working on thorium reactor designs and other elements of fuel technology using the metal.

- China not only has the largest proportion of the total global rare-earth resources in production, but also has the most extensively developed total supply chain for rare earths. Perhaps most important of all, China hosts the overwhelming majority of rare-earth R&D on the planet implemented by the largest group of scientists and engineers devoted to rare-earths studies in the world.

- The 2015 estimated Chinese domestic demand for praseodymium and neodymium is 30-35,000 tons yet the production quota is officially capped at 20,000 tons. The driver to this difference has been identified as the continuing illegal production of rare earths that appears to be the result of the Chinese government itself or at least its inaction.

- Radiation (or cosmic ray) measurements are now being made on regular flights of space-weather balloons that are equipped with radiation sensors that detect cosmic rays, a form of space weather. Cosmic rays can seed clouds, trigger lightning, and data are being collected on high-altitude radiation during commercial airline flights.

INTRODUCTION

The emphasis for this EMD Mid-Year Report will be on the recent and forecasted uranium (yellowcake) prices and how the uranium industry is responding to the current economic conditions in exploration and mine development, and to the expectations for the future. Thorium also is an important component to many rare-earth/uranium deposits and although thorium is not currently used as fuel to produce electricity, it is being considered as a fuel component by numerous companies in the U.S. and overseas. In some cases, rare-earth deposits also contain uranium in recoverable amounts and so the rare-earth prices are also important considerations in developing some deposits into viable, economic ventures.

The uranium market is guided to a large extent by expectations displaced years ahead by today's nuclear power-plant operations, anticipated constructions, and plant shuttering and retirement. As discussed previously (EMD UCOM 2015 Annual Report (more)), energy competition between nuclear and coal, natural gas, as well as with renewable energy projects are based on the cost to produce electricity and on the impact on the environment, complicated by the federal government's subsidizing and marketing wind and solar energy projects, has produced a complex transitional energy framework within the U.S. Some of the other governments in the world have also been involved in similar ways.

Uranium Prices

Uranium prices depend on the available yellowcake that is in line to be processed into fuel pellets for loading into nuclear power plants. As new power plants are announced, the uranium market becomes aware of this potential requirement but the actual need will not be realized for months, if not for a few years. Plant management must estimate when the fuel (in pellet assemblies) will be required and consummate purchases to reserve supplies for loading at some point in the foreseeable future.

Each plant requires about 50,000 pounds of equivalent yellowcake in the form of refined pellets every few years. The fuel assembly lowered into water creates fission that heats the water, which is modulated by graphite control rods in most current reactors that operate 24 hours a day 7 days a week. The system is designed for continuous production on average of 500 MW of electricity, usually for 3 to 5 years until time for refueling with new assemblies of fuel pellets.

The used-fuel assemblies are then stored on-site for cooling in pools of water, well circulated to maintain temperature control. This system was the problem in the Fukushima incident. The circulation system was interrupted allowing the water to boil off exposing the control rods which then oxidized producing radioactive steam that had direct access to the atmosphere. The excess hydrogen created by the boiling water, collecting in the building, then ignited, blowing the roof off the building in a dramatic fashion (more). The incident was called a "mega-disaster" by the media, but this was refuted later by many reporters (more) because no one had died or had been exposed to dangerous levels of radioactivity.

After some time, the spent fuel would be sufficiently cooled for shipment to the national storage facility, but aside from military storage sites (at Yucca Flats) and low-level radioactive storage sites, such as the WIPP facility in New Mexico (more), the federal storage facility designed to store spent fuel at Yucca Mountain has yet to be opened, primarily as a result of political, rather than technical issues.

With some 400 nuclear power plants in current operation worldwide, they require some 20 million pounds of yellowcake to be available for processing to fuel pellets to meet the various 3-5 year cycles of the plants. As each new plant construction is announced, an additional 50,000 pounds would be needed 5-10 years in the future to fuel the new plant and then the same every 3 to 5 years hence. This would stimulate new mine production or an expansion of existing mines, should the mines have such capabilities. Some mines in Canada, Australia, and perhaps Kazakhstan, and other areas have been shown to have such expansion capabilities, e.g., Cigar Lake, McArthur River.

In October, 2015, Cantor Fitzgerald (CF) released its Quarterly Commodity Outlook (more). The firm concludes that uranium prices will be moving higher as worldwide utilities look to cover the current 15 to 20% fuel shortfall, but not in the next few months to a year. In fact, CF lowered its uranium price forecast for Q4 2015 by about 6%, but concludes that the increase will occur later on with a significant increase in the price of uranium within the next 6-18 months as utilities rush to cover their uranium needs or be forced to operate their reactors below capacity.

As of the date of this report, utilities are refraining from placing uranium contracts on the premise that they control ample supplies, especially in Japan, and as new production from Canada and Kazakhstan has been committed and stockpiled over the past few years.

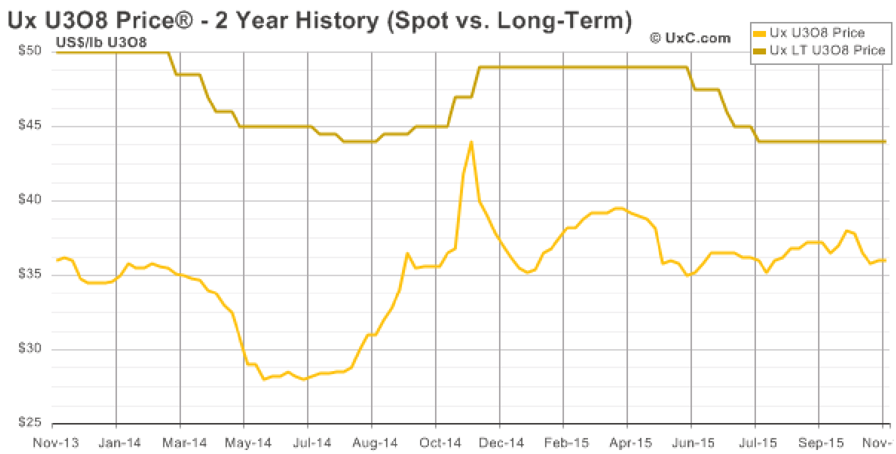


Figure 1 – Average U_3O_8 Spot Prices November, 2013, 2014 to November, 2015 (US$)
(from: http://www.uxc.com/)

The spot uranium price of US$36.52/lb U_3O_8 for Q3 2015 was lower than the CF estimate of US$40.00/lb (-8.7%). CF lowered their Q4/15 forecast by 5.9% to US$40.00/lb as utilities will not need to meet their uncovered requirements until the end of 2016. As illustrated in Figure 1, since May, 2014 when the spot price was at a low of $28.50/lb it has increased to the current $35.65/lb (representing a gain of 25%), largely remaining within a trading range of between $35.00/lb - $40.00/lb since the Spring of 2015.

Also, Uranium Participation Corp. (more), a Uranium Exchange Traded Fund (and other UETFs) invests assets in uranium oxide concentrates (U_3O_8) and uranium hexafluoride (UF_6) to form fuel pellets with the primary investment objective of achieving appreciation in the value of its uranium holdings through increases in the uranium price, registered an 8% gain during the same period, whereas every other uranium equity fund was down significantly, from Cameco (-12%) to Kivalliq (-60%). CF concludes that there is nevertheless tremendous value in the uranium industry due to the disconnect between the performance of the commodity price relative to uranium companies' activities, especially in light of the compelling supply-and-demand backdrop that is underpinned by the imminent uncovered requirements of the nuclear power utilities.

But, Moran reported that Salman Partners concluded that uranium spot prices will be rising significantly in the near future (more). Raymond Goldie, senior mining analyst at the firm, said spot prices are expected to rise from now until 2018 as a deficit in uranium consumes current inventories.

Goldie told the Investing News Network that over the next three years, long-term prices will move up to the $80-$85 range before easing to around $70/lb, as previously shuttered mines in the U.S. come back online. He expects that the demand will reach the critical point by early 2016, by which time he expects utilities to feel compelled to begin signing long-term contracts in order to ease concerns about the future security of supply, with those concerns, and spot prices peaking in the Q1 of 2018, as Goldie states in the report. He adds that they forecast prices to decline thereafter, from a 2018 peak of over US$70/lb U_3O_8, to a long-term level of around US$50/lb in real 2013 dollars. Prices thereafter should be sustained by supply management on the part of producers (mining companies), he emphasized.

As new energy demands are identified (in the form of either other electricity demands or new nuclear plant construction), the yellowcake market price would naturally increase but this also plays out in reverse when demand decreases leading to power plants going offline for whatever reason, albeit plant accident caused by a natural event such as occurred in Japan in 2011, or retired early due to some technical issues resulting from aging of the systems, or they may even be shuttered as a result of unnatural economic conditions where the price of natural gas drops to abnormal lows caused by an oversupply resulting from American geological/engineering advances. These were followed by American technological developments in producing new sources of oil, and especially natural gas, from known basins in the U.S., Canada, and as knowledge of the new developments spread into Europe, China, and the rest of the world (more).

The Impact of Natural Gas

The new discoveries in oil and gas are produced from previously unappreciated shale reservoirs in the U.S. and will be soon followed by similar developments in various parts of the world, now including China. But that technology requires gas and oil prices sufficient to cover the cost of the new technology to produce many such shale reservoirs. As the price declines, the supply of the new gas would eventually decline and the cost of natural gas would increase. This would vary in different parts of the U.S. of course, and such supplies could be converted to liquefied natural gas (LNG) and shipped around the world. A more complete assessment of the current shale gas and liquids distribution has been presented by Hammes, *et al.*, (2015) and Fishman, *et al*., (2014), and of the associated impact of current and future economics by Platt, *et al.*, (2015).

The price of natural gas currently compromises the long-term economics of nuclear-power related in terms of the cost of the produced electricity, and in turn impacts the market price of yellowcake as plants are shuttered, retired, or as new plant construction is postponed based on economic grounds. Notwithstanding climate-change mitigation, utilities can produce electricity at less cost by using coal or natural gas than current nuclear power plants. Anti-nuclear advocates compound the issues by supporting coal and natural gas on the basis of present cost alone while ignoring the impacts on the climate and current environment.

The gap between the decision to build and the time electricity comes on line from any completed nuclear plant can be up to 10 years, or more. This directly impacts the price stability of yellowcake, but it is offset some years into the future.

When nuclear power-plant construction begins to expand, this sets off a resumption of uranium exploration, mine planning, permitting, and other start-up activities on the assumption that the new plants will actually go into operation and require new fuel supplies. But sometimes, the uranium industry, if only a few suppliers remain, holds back from expansion and resists forward planning. This condition created a uranium cartel-like market in the 1980s by the companies operating in Canada and Australia on the basis of their large, high-grade deposits that were produced by low-cost operations. Under such conditions, the demand may increase, but may or may not be followed by spot uranium price increases, as occurred in 2007 but not in the 1980s (see Figure 1 and (more)).

The Impact of Uranium Deposit Characteristics

The uranium industry also has limitations to their mining activities as do natural-gas companies today. Each uranium deposit has certain inherent characteristics that impact their cost to mine. Each deposit that has been drilled and sampled has a calculated ore grade, an estimated in-situ horizontal and vertical extent of the economic sections of the uranium mineralization present. This can be for either in-situ mines or for those amenable to open-pit or underground development.

To these conditions must be added the cost to process the uranium feedstock into yellowcake from either uranium in solution produced by in-situ mining or from uranium ore mined from an open-pit operations. Other conditions include the cost to dispose of the processing or managing waste products (either by injection wells from in-situ mining operations or by waste or overburden dumps). An economic assessment of each mine renders a total cost to produce a pound of yellowcake, and this in turn reflects its potential economic return to investors relative to the prevailing uranium price at the time of sale, which reflects not only the demand from nuclear plant reactors that need fuel, but also the cumulative available production of yellowcake from the global uranium mining industry.

When the uranium price was low many years ago (in the range of \$10-\$12/lb U_3O_8) at a time when few, if any, nuclear plants were being built after the Three-Mile Island incident and the Chernobyl disaster, only the large mines in Canada and Australia with low operating costs combined with high ore grade, could survive in that market to supply the existing plants.

When the price began to rise as new power plants were being built overseas, new sources of uranium were mined by the new technology of in-situ mining and produced yellowcake at a competitive price. Mining companies expanded exploration and new uranium districts were discovered, some of which were placed into production, while other projects were put on the shelf until higher prices prevailed.

As in most mineral and fossil fuel commodities, new discoveries (or old properties) are brought into production or mined when prices go up. In response, new resources are discovered and become available (more, see pp.10-14).

The Impact of Japan

As Japan restarts their nuclear fleet, information is coming in on the economic damage that occurred to Japan not as a result of the devastation of the tsunamis of 2011, but as a result of the extra cost required to pay for imported natural gas. Attempts to employ wind and solar energy on a large scale failed economically and impacted Japan's economy as well, all occurring while their nuclear plants were shuttered. The plants have begun to be restarted, and the economic stress should be relieved over the next few years (more).

Just as the Japan tsunamis served to impact the worldwide nuclear power industry and associated uranium mining industry, Japan's recovery from the damage to their nuclear power plants has served to provide evidence to the world that no one died or were severely injured or irradiated as a result of the core meltdowns and associated release of radioactivity (more). The plant personnel performed well, although characteristically apologetic, though they were not the cause of the earthquakes and tsunamis.

As indicated earlier for 2016, Cantor Fitzgerald (Cantor) predicts that a major increase in the price of uranium will occur as utilities rush to cover their nuclear fuel needs or be forced to operate their reactors below capacity. In Japan, two reactors at Sendai have been restarted while adversary challenges are holding up the restarts of the Takaham 3 and 4 reactors. The Ikata 3 reactor recently received local government approval and it is expected to restart early in 2016. It should be noted that additional restarts of reactors in Japan will be a positive event from a market sentiment perspective, but it will have little impact on the actual supply and demand equation until additional reactors are restarted (more).

Cantor expects five more reactors in Japan will be restarted in 2016, and seven in 2017. Ultimately, 36 reactors are expected to be back online in Japan by 2020. Regardless of the developments in Japan, the rapid upward move in the price of uranium considered to be inevitable is considered by Cantor to be based on a looming, unavoidable supply deficit occurring before 2020 when uranium (yellowcake) supplies from all sources (mine level and stockpile) do not meet increased demand (particularly emanating in China).

Today in the areas of Japan damaged by the tsunamis, and aside from the on-going cleanup of the two damaged reactors, the lingering result is the psychological effects of a fear of radiation that still prevails in some nearby villages in Japan. As they learn to use scintillometers (aka personal Geiger counters) to demonstrate to themselves that the radiation levels are no more harmful than the sun at the beach and that food and water are safe to consume, this will ease their concerns for their environment around them (more).

Future Uranium Price Increases

Despite the fact that utilities have not been buying, nor have they been contracting at the appropriate levels that would cover their needs, many have deferred this decision under the premise that ample inventories remain and are readily available.

They have been correct in taking this stance over the past few years as Japanese utilities have deferred their deliveries and miners were forced to sell yellowcake earmarked for Japan to other buyers in the open spot market.

In addition, with new uranium deposits generally located in remote regions, deeper, or are in more rigorous permitting jurisdictions, are of lower grade, or have less existing infrastructure than the mines of today, Cantor concludes that the long term all-in sustaining costs for uranium will be around US$80/lb, which is about twice the current spot price. Moreover, the current spot price is barely above the cash costs of current producers. However, if too many new deposits are put into production, this may depress the spot and long-term market price.

When all-in sustaining costs are considered many current uranium producers are operating at a deficit at current spot prices. The only reason some miners are still in operation is because they are producing into long-term contracts at prices at or above US$50/lb. These are the same contracts that are expiring and creating the 15%-20% gap for utilities. Cantor does not assume that the same level of production (which is already below global demand) will continue at the current long-term price of US$44/lb, much less at the current US$36.50/lb spot price. Cantor personnel contend that these conditions will not last long and that both a price rise and production increase are anticipated by industry analysts within the foreseeable future as the new nuclear power plants come online.

Renewable Energy Systems

Nearly five years after 2011, even Germany, Sweden, and France are beginning to realize that it would be cheaper to keep their nuclear power plants operating then transition to a wholesale commitment to wind/solar construction for other than remote areas. Reliance on brown coal, and large-scale wind/solar systems have neither met climate needs of the former, or in the latter have provided reasonable and stable electricity costs (more).

Offshore wind systems do show significant cost advantages but their actual operating & maintenance (O&M) costs are unknown at present. The number of wind and solar pundits are flooding the Internet with optimistic outlooks but only recently does the subject of O&M costs enter the discussion (e.g., Solar O&M: more; and Wind O&M: more). Wind is getting mixed reviews (more). These renewables do not have established records in O&M within a scaled-up grid; the economics are only attractive with substantial state and federal subsidies (more).

However, one renewable energy source does appear to have favorable features that are similar to nuclear power. Hydroelectric power plants, involving both dams and pumped storage systems, may be about ready for a resurgence in the U.S. and elsewhere in the world (more), but not without some resistance from the usual opponents supporting river wildlife (more).

If climate change 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.

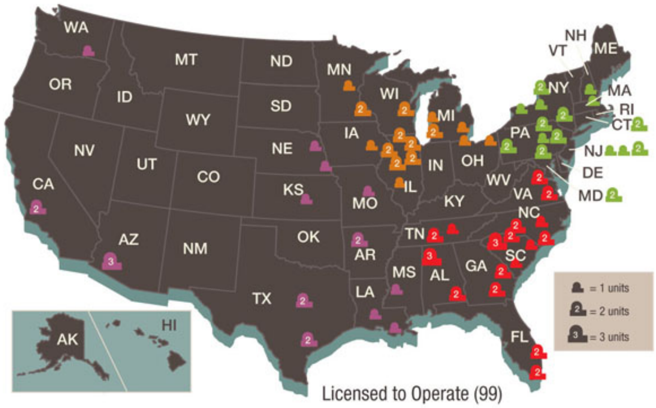
Coal is being tolerated because it is perceived by some that there are no other choices even in light of the significant damage to human health and the environment caused by burning coal (plus lignite in Texas and Louisiana, and brown coal in Germany), although lower derived electricity costs are significant drivers. (more).

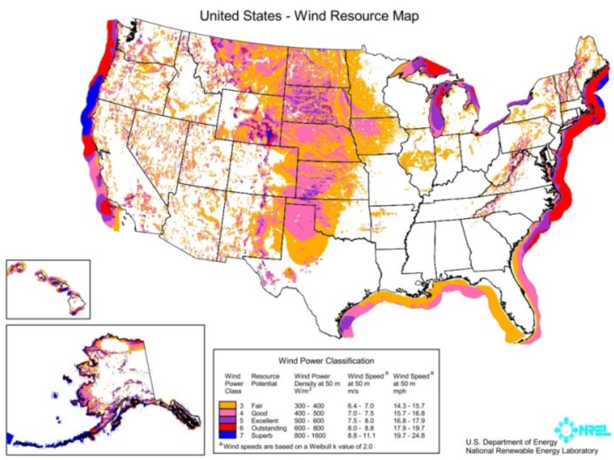
Further, wind and solar energy projects are still being funded and operated under large subsidies while their operation and maintenance costs remain underreported (more and more). Serious questions are being raised by independent reviewers on the economic viability of the two energy sources in terms of the generated cost of electricity (more). This is not to say that they do not have a role to play in energy selection.

They are particularly well suited for the small, isolated population centers scattered throughout the high plains and southwest U.S. as only an example. This complementary suitability is illustrated in Figures 2, 3, and 4 where the resources are available, notwithstanding the periods of little wind and no sunlight.

The distribution of the eastern power grid is illustrated in Figure 2 showing the locations of the currently operating U.S. nuclear power reactors, and areas suitable for wind and land-based solar development. Other legitimate considerations should also include further assessments of off-world development of solar energy transmitted from the Moon to receiving stations throughout the U.S. (more). Orbital solar arrays, however, are considered to be too vulnerable to damage by collision with space junk or by hostile intentions.

As illustrated in Figures 2 and 3, wind farms are useful in isolated areas away from the main eastern power grid. Harting (2010) estimated that power losses along transmission lines are significant so transmitting electricity long distances drives up the cost to isolated areas. Local generation of electricity eliminates such line losses.





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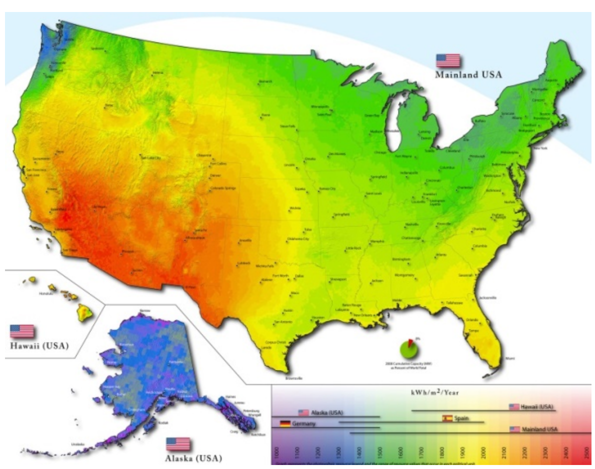


Figure 2 – Currently Operating U.S. Nuclear Power Reactors, and Areas Suitable for Wind and Solar Development

NRC (2015) and EIA (2015)

Figure 3 – Night Lights illustrating Eastern Power Grid and Isolated Western Areas of Large Population.

(Click to Enlarge)

Figure 4 – A Wind Farm Providing Power to an Isolated Town in Northwestern Texas
Photo taken by iPhone (MDC) from altitude of 35,000 Feet
(Click to Enlarge Photo)

Future Nuclear Build-Out and Uranium Supplies

Nuclear fuel prices represent a very small segment of the total cost to produce electricity 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 other competing energy sources, even if the latter coal or natural gas power plants have major impacts on the environment.

There is a general perception by some economists and the general public alike that the capital price of a plant is prohibitive (and the only significant parameter in selecting an energy source). When a nuclear plant is planned and constructed it is designed to last decades. Many U.S. plants are now demonstrating that their lifetimes may well be 50 to 75 years. Any unbiased economist would agree that such economy of scale and lifetime of investment, combined with even a 20-year pay-out, would be considered by many to be an outstanding investment. Like building a hydroelectric project, the dam, the turbines, and the ancillary systems are designed to last for many decades, with only minimal operation and maintenance costs relative to all other sources of energy. Qvist and Brook (2015) have concluded that a build-up of nuclear plant construction to replace coal and natural gas in generating electricity could be achieved over the next 25-30 years (more).

URANIUM DEMAND

Annual uranium consumption is about 179 million pounds globally and annual mine production is about 152 million pounds, with the shortfall currently covered by stockpiled uranium from the post-Fukushima reactor shutdown (more). Demand is expected to grow to 228 million pounds by 2020 (more). The growth will be led by a significant increase in consumption of uranium by China but many other countries will have needs, such as India and Russia, as well (more). Even the Middle East (Saudi Arabia), Southeast Asia (Indonesia, Vietnam, etc.), Korea, U.K., Australia (being debated currently), and Argentina and others are building reactors with both China and Russia playing major roles in construction or financing (more), or both (more).

For example, China has 30 operable nuclear reactors and 21 under construction, 43 new plants by 2020 and 136 proposed by 2030, according World Nuclear Association data (updates). Japan has 43 operable reactors, 3 new reactors under construction, 9 planned and 3 proposed (more). Globally, there are 324 reactors proposed, compared with 301 a year ago in 2014.

The anticipated rebound in demand will be driven in part by a scarcity of inexpensive fuel supply at the old prices because countries who idled their nuclear reactors and were beginning to consider alternative energy (wind and solar) sources following the 2011 earthquake and tsunamis that destroyed two of Japan's Fukushima reactors (without loss of life or exposure to harmful radiation (more)) are having second thoughts about alternative energy and their practical reliability and excessive costs associated with wind and solar systems.

Eighty-nine percent (89%) of the fuel requirements of the current global fleet of nuclear reactors were met in 2014 by the following top producers, in order of rank: 1) Kazakhstan, 2) Canada, 3) Australia, 4) Niger, 5) Namibia, 6) Russia, 7) Uzbekistan, 8) U.S., 9) China, and 10) Ukraine, totaling some 377 million pounds U_3O_8 per year (more). It should be noted that as the uranium price rises, more in-situ uranium mines in the U.S. will come online as Japan restarts their reactors and other countries bring new construction online, 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 online to compete in the world markets, as discussed in the 2011 UCOM Annual Report (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 what they currently have by 2020, to alleviate problems with air pollution (more) created by burning coal to generate electricity (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 (updates). 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.

The price of the commodity is also expected to increase in the next six to 12 months as China aggressively ramps up construction of nuclear reactors and utilities around the world. This may drive China to renegotiate contracts with uranium producers, according to Rob Chang, a metals and mining research analyst at Cantor (more).

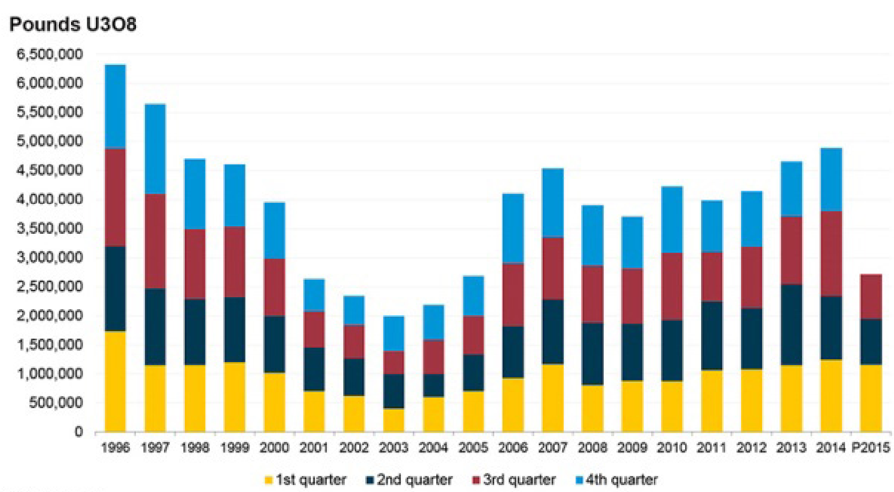
URANIUM PRODUCTION IN THE U.S.

3rd Quarter 2015

U.S. production of uranium concentrate in the third quarter 2015 was 774,541 pounds U_3O_8, down 2% from the second quarter 2015 and down 47% from the third quarter 2014. The 33% reduction in the third quarter production compared with the 1,154,408 pounds U_3O_8 produced in the first quarter 2015 may be attributed to the continued low market price of uranium for some U.S. uranium producers. Additionally, the third quarter 2015 production level was the lowest quarterly U.S. production since the fourth quarter 2005 (see Figure 5).

During the third quarter 2015 U.S. uranium was produced at seven U.S. uranium facilities, one more than in the second quarter 2015, when White Mesa Mill in Utah restarted production (EIA, 2015).

Figure 5 - Uranium concentrate production in the United States, 1996 - 3rd quarter 2015



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

U.S. Uranium Mill in Production (by state)

1. White Mesa Mill (Utah): Energy Fuels

U.S. Uranium In-Situ-Recovery Plants in Production (by state)

1. Crow Butte Operation (Nebraska): Cameco
2. Hobson ISR Plant/La Palangana (Texas): Uranium Energy Corp.
3. Lost Creek Project (Wyoming): UR Energy
4. Nichols Ranch ISR Project (Wyoming): Energy Fuels
5. Smith Ranch-Highland Operation (Wyoming): Cameco
6. Willow Creek Project (Wyoming): Uranium One

At the end of September 2015, U.S. uranium concentrate production totaled 2,718,929 pounds U_3O_8. As expected, this amount is 29% lower than the 3,805,798 pounds produced during the first nine months of 2014. A listing of the uranium in-situ-recovery plants by owner, location, capacity, and operating status is presented in Table 1. All were in operation, developing, on stand-by, or in remediation. The total operating capacity as of the Q3, 2015 in is 27 million pounds of yellowcake per year. For additional notes on potential production, see the Notes at the bottom of Table 1.

Table 1

U.S. URANIUM IN-SITU-RECOVERY PLANTS BY OWNER, LOCATION, CAPACITY, AND OPERATING STATUS
(EIA, 2015)

In-situ-leach plant owner	In-situ-leach plant name	County, state (existing and *planned* locations)	Production capacity (pounds U_3O_8 per year)	Operating status at end of 2014	1st quarter 2015	2nd quarter 2015	3rd quarter 2015
AUC LLC	Reno Creek	*Campbell, Wyoming*	2,000,000	Developing	Developing	Developing	Partially Permitted And Licensed
Azarga Uranium Corp.	Dewey Burdock Project	*Fall River and Custer, South Dakota*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Cameco	Crow Butte Operation	Dawes, Nebraska	1,000,000	Operating	Operating	Operating	Operating
Hydro Resources, Inc.	Church Rock	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Hydro Resources, Inc.	Crownpoint	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Lost Creek ISR LLC	Lost Creek Project	Sweetwater, Wyoming	2,000,000	Operating	Operating	Operating	Operating
Mestena Uranium LLC	Alta Mesa Project	Brooks, Texas	1,500,000	Producing	Producing	Standby	Standby
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	Converse, Wyoming	5,500,000	Operating	Operating	Operating	Operating
South Texas Mining Venture	Hobson ISR Plant	Karnes, Texas	1,000,000	Operating	Operating	Operating	Operating
South Texas Mining Venture	La Palangana	Duval, Texas	1,000,000	Operating	Operating	Operating	Operating
Strata Energy Inc	Ross CPP	Crook, Wyoming	375,000	Under Construction	Under Construction	Under Construction	Under Construction
URI, Inc.	Kingsville Dome	Kleberg, Texas	1,000,000	Restoration	Restoration	Restoration	Restoration
URI, Inc.	Rosita	Duval, Texas	1,000,000	Restoration	Restoration	Reclamation	Reclamation
URI, Inc.	Vasquez	Duval, Texas	800,000	Restoration	Restoration	Restoration	Restoration
Uranerz Energy Corporation	Nichols Ranch ISR Project	Johnson and Campbell Wyoming	2,000,000	Producing	Producing	Operating	Operating
Uranium Energy Corp	Goliad ISR Uranium Project	*Goliad, Texas*	1,000,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One Americas, Inc.	Jab and Antelope	*Sweetwater, Wyoming*	2,000,000	Developing	Developing	Developing	Developing
Uranium One Americas, Inc.	Moore Ranch	*Campbell, Wyoming*	500,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One USA, Inc.	Willow Creek Project (Christensen Ranch and Irigaray)	Campbell and Johnson, Wyoming	1,300,000	Operating	Operating	Operating	Operating
Total Production Capacity:			**26,975,000**				

Notes: Production capacity for 3rd Quarter 2015. An operating status of "Operating" indicates the in-situ-leach plant usually was producing uranium concentrate at the end of the period. Hobson ISR Plant processed uranium concentrate that came from La Palangana. Hobson and La Palangana are part of the same project. ISR stands for in-situ recovery. Christensen Ranch and Irigaray are part of the Willow Creek Project. Uranerz Energy has a tolling arrangement with Cameco Resources. Uranium is first processed at the Nichols Ranch plant and then transported to the Smith Ranch-Highland Operation plant for final processing into Uranerz's uranium concentrate. CPP stands for central processing plant.

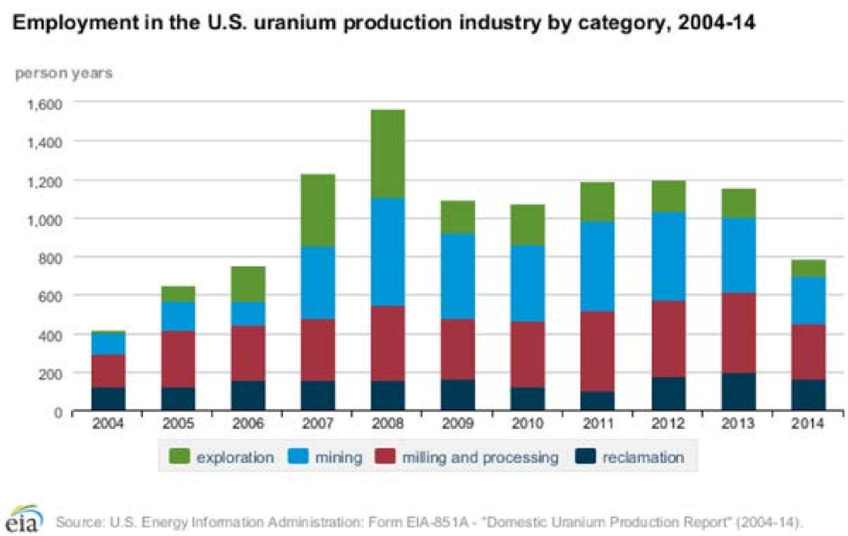
Source: U.S. Energy Information Administration: Form EIA-851A and Form EIA-851Q, "Domestic Uranium Production Report."

Employment in the Uranium Industry

The U.S. Department of Energy's Energy Information Administration (EIA) (2015) reports that the 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 6). Exploration employment was 86 person-years, a 42% decrease compared with 2013, as expected. Also, 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. The uranium industry employment for 2014 occurred in 9 States: Arizona, Colorado, Nebraska, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming. With the low prices of uranium, this decrease was expected, while an increase in 2016 in the price should stimulate increased activity.

Figure 6

(EIA – 2015)



NUCLEAR POWER PLANT OPERATIONS IN THE U.S.

Ninety-nine nuclear reactors are currently licensed in the U.S., and five have been recently closed or are in the process of being shuttered. Nuclear plants operate 24/7 and generate about 63 percent of America's carbon-free electricity, but competitive electricity markets do not value these attributes and some plants may be shuttered on economic grounds in competition with the currently low-priced natural gas and coal-burning power plants.

The current technical media are filled with optimism for an expansion of nuclear power (more), both in standard nuclear reactors and in the new small modular reactors (SMRs), which will be discussed later in this report. Both are known to provide safe, reliable 24/7 electrical production.

In the large capacity versions of 500 MW and up, financing is now designed for a facility to operate with upgrading over a period of at least 50 years.

Notwithstanding current un-natural economic restraints created by regulatory circumstances in the U.S. at least, nuclear power generates electricity that is still "too cheap to meter," and natural gas was once cheap enough to flare (more). The role of nuclear power in the U.S. provides safe and reliable grid-based electricity. The renewables of wind and solar also have their roles to play as well in the domestic applications and in remote regions of the U.S., see Figure 2.

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

Given the advantages of nuclear power, economic factors involving low-price natural gas have shuttered some nuclear plants and left others at risk of being closed. In the last year, some U.S. utilities have canceled nuclear development plans, according to the *Morningstar Utilities Observer* report for November, 2014. McMahon (more) has monitored the speculations by Morningstar analysts and others 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-price natural-gas environment, McMahon suggested that this 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/MW-hr for nuclear, compared to $24 for the most efficient gas plants) heavily favors nuclear on strictly economic grounds as well as being a climate-friendly source of energy (more).

With little significant emissions, combined with coal plant closures, likely gas price increases, and improving electricity prices, these 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 (more).

Voosen (2009) reported 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 they are retired or updated - 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 long-term financing and these same factors can be applied to hydroelectric power plants, building of which involves high construction costs and long-term financing. This also results in very low electricity costs and 24/7 reliability for 50 to 75 years, if not longer (here). For recent economic assessments on the subjects, see the search results for reports on "economics" in the I2M Web Portal (more).

But a few of the older nuclear power plants will be dismantled and the property decontaminated by replacing soil and transporting contaminated soil, and debris, which will need to be transported to a regulated landfill or storage facility designed for such material, such as the Waste Isolation Pilot Plant (WIPP) and Yucca Mountain facilities, when the latter is finally opened (more).

NUCLEAR POWER PLANT CONSTRUCTION OVERSEAS

Construction overseas continues to increase, aided by Chinese and Russian offers to finance the building of and operation of nuclear power plants in India, Bangladesh, the U.K., and other locations, see: (China: more) and (Russia: more). Recent announcements of such construction are reported in the I2M Web Portal (more).

SMALL MODULAR REACTORS

Small Modular Reactors (SMRs) continue to receive increased attention in 2015, 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 (more).

Numerous research and development programs are underway on SMRs by many companies in the U.S. and overseas (more). For additional, updated information and media items on SMRs to date, see (media: more). For technical information on the development and current status of SMRs, see (technical: more). NuScale Power is committing major funding to developing commercial applications of SMRs (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 database by the EIA. But this information is all that is available as of 2004, which raises the question regarding why these data have not be made available via the EIA website (more).

There are political indications that the Yucca Mountain facility may still be opened to meet 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 (here). Billions of dollars have been collected by the federal government to manage the nuclear waste.

Bipartisan support and Republican efforts to reinstate the Yucca Mountain are getting some support from a number of sources, now that the principal opposition will soon depart. 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 (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 (more).

URANIUM EXPLORATION IN THE U.S.

Uranium exploration data and associated expenditures for 2015 have not been released yet by the U.S. EIA. Such will be released in May, 2016 (EIA, 2015). In the meantime, Google search results (current) continue to show a multitude of mergers, acquisitions and consolidations. Recent exploration can be monitored online via the I2M Web Portal (updates), and by using more generalized search terms (here), which reveal exploration and associated activities for uranium and other commodities as well.

Known deposits and some new discoveries occur in 13 U.S. States, with Virginia most notable because of the potential large size of the deposit. Local adversaries continue to obstruct the development of the Coles Hill deposit in Virginia (more). Updates on the Coles Hill project are available via the I2M Web Portal (more). Uranium mining in the U.S. has been conducted in Wyoming, Nebraska, Utah, South Dakota, Texas, Colorado and New Mexico, with numerous other states having some potential. See Table 2 (more).

Table 2

U.S. WISE Project Reviews of Uranium Exploration, Mining & Associated Adversarial Issues

(Wise, 2015)

United States	
ARIZONA Anderson, AZ Arizona 1, AZ Canyon, AZ Grand Canyon Issues, AZ Pinenut, AZ	**TEXAS** Burke Hollow, TX Goliad, TX Palangana, TX Pawnee, TX
COLORADO Centennial, CO Hansen, CO Tenderfoot Mesa, CO Piñon Ridge mill, CO Prince Albert, CO Slick Rock (UEC), CO Taylor Ranch, CO Whirlwind, CO	**UTAH** Energy Queen, UT Green River #9, UT Green River (Mancos), UT La Sal (Laramide), UT La Sal #2 (Laramide), UT Sage Plain, UT Daneros, UT **VIRGINIA** Coles Hill, VA
IDAHO Idaho, ID	**WYOMING** Allemand-Ross, WY Antelope, WY Bison Basin, WY

NEBRASKA Crow Butte North Trend Expansion, NE **NEVADA** Apex-Lowboy, NV **NEW MEXICO** Cebolleta, NM Churchrock (STM), NM Crownpoint, NM Grants (Rio Gr.) mill, NM Grants Ridge (UEC), NM Juan Tafoya mill, NM La Jara Mesa, NM Roca Honda, NM **NORTH DAKOTA** Sentinel, ND **OREGON** Aurora, OR **SOUTH DAKOTA** Dewey/Burdock, SD South Dakota Issues	Bootheel, WY Collins Draw, WY Gas Hills (PRI), WY Lower Gas Hills (STM), WY JAB, WY Jane Dough, WY Juniper Ridge, WY Lost Soldier, WY Lost Creek, WY Ludeman, WY Nichols Ranch, WY North Butte, WY Reno Creek, WY Reynolds Ranch, WY Ross, WY Sheep Mountain, WY Shirley Basin (Pathfinder), WY Sky, WY West Alkali Creek, WY

Recent investigations by the U.S. Geological Survey and NURE data from the 1970s show that uranium, associated radionuclides (radon and radium) as well as nitrate are present in the groundwater of many aquifers in the U.S. Figure 7 illustrates where heavy agriculture uses fertilizer for a variety of purposes. Uranium also seems to be widespread in the numerous aquifers of the U.S., based on a study funded in part by the AAPG Jay M. McMurray Memorial Research Grant (more). Uranium is present in the Ogllala Aquifer in the High Plains of west Texas (more) and in the Evangeline Aquifer of east Texas and western Louisiana, which has been evaluated in some detail in the Houston area (2015, pp.22-28). In the late 1970s, south Texas and adjacent areas were also assessed (more).

Sites of known anomalous uranium (>30 ug/l) in groundwater of south Texas have been added to Figure 7. Such anomalous uranium is related to known uranium mineralization of potential economic interest in south and east Texas that occur within the Evangeline Aquifer and its lateral equivalent in southeast Texas and perhaps into Louisiana. Recent activity by the U.S.G.S. suggests that substantial undiscovered uranium resources may exist in south Texas (more).

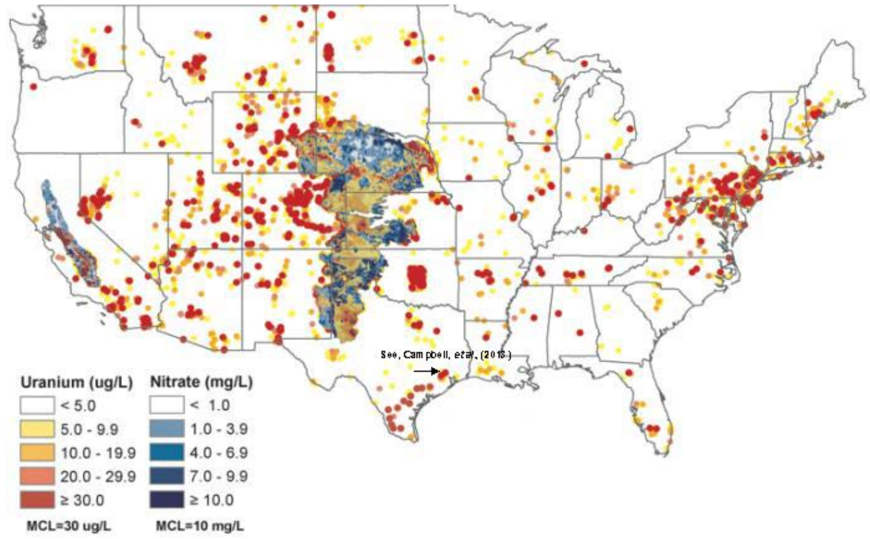


Figure 7 – Distribution of Uranium and Nitrate in Aquifers of the U.S. (After Goard (2015))

(Click to Enlarge Figure)

SIGNIFICANT FIELD ACTIVITIES IN EXPLORATION AND MINING

World-Class Deposits in Canada

Exploration and mining activities in the uranium have continued over the past few years despite the anticipated rise in the uranium price. Although the price rise has not occurred to date (see Figure 1), uranium companies see a bright future in the near future. The Canadian provinces and federal government vigorously support natural resource exploration and development, especially in uranium, thorium, and rare-earth elements (more), and the uranium industry in Canada is poised to take advantage of the price rise to come.

Ten to 15 uranium companies continue to be active around the Athabasca Basin in anticipation of rising prices, and some mergers and acquisitions have occurred, most notably Dennison Mines acquiring Fission Uranium (more). The Fission deposits are located in the vicinity of Patterson Lake and have been reported as multiple mineralized shear intercepts in shear zones resulting in the project's highest assays yet, 9.72% over 35.5 meters starting at 494.5 meters, with a Russian doll set of sub-intervals: 80.5% over 0.5 meters, within 72.02% over 3 meters, within 30.61% over 11 meters. Fission's high-grade deposit would produce around 100.8 million pounds of U_3O_8 with 95% metallurgical recovery, bringing 77.5 million pounds in the operation's first six years and another 24 million pounds over the following eight years. Annual production would average 7.2 million pounds over 14 years (more).

Fission's Triple R's earlier resource estimates do not include the recently expanded R600W zone to the west. The resource used a 0.1% cutoff based on US$50 uranium, showing:

- *indicated:* 2.29 million tonnes averaging 1.58% for 79.6 million pounds U_3O_8
- *inferred:* 901,000 tonnes averaging 1.30% for 25.9 million pounds U_3O_8

Also, the recent announcement does not mention that Fission's Triple R's mineralized zones contain gold as well as uranium, some 38,000 ounces (Indicated) and 16,000 ounces (Inferred), as well as significant rare earths in some zones.

Triple R takes in two zones, the land-based R00E and the much larger R780E, which lies some 225 meters east under about six meters of lake water. The recent Preliminary Economic Assessment (PEA) attributes its low operation expense partly to an open pit/underground design taking advantage of the large and relatively shallow, high-grade, basement-hosted deposit. The hybrid mine would feature surrounding dykes and slurry walls for water control. High-grade mineralization (above 4% U_3O_8) is captured within the open pit, eliminating the need for expensive, specialized underground mining methods (more).

The structure of the Athabasca Basin is shown in Figure 8 as well as the location of the major uranium deposits, such as the Cigar Lake deposit, the MacArthur River deposit, and Rabbit Lake around the eastern portion of the structure. The Patterson Lake deposits, mentioned above and below occur around the southwestern trends of the large oblate structure outlining the Athabasca Basin, which is a historical shallow tropical sea basin filled with sediments from the Hudsonian Mountains.

The Athabasca Basin was formed during the Statherian or Paleohelikian 1.7 to 1.6 billion years ago when coarse fluvial and marine clastic sediments were laid down containing gold, copper, lead, zinc, rare earth oxides, and uranium oxides (more). As indicated above and below, the highest grade uranium deposits in the world are found at and near the unconformity between these clastic layers and the Precambrian bedrock. They occur along preferred shear zones (see Figure 9).

Of particular note is the small, circular structure shown in Figure 8. Duhamel, *et al.*, (2005) suggest that the Carswell structure is older than the deposition of the Athabasca Basin and that the actual circular structure is quite probably a central rebound peak, a local expression of a larger multi-ring meteor impact structure hidden beneath the sediments in a crater in the basement some 118 to 125 km wide.

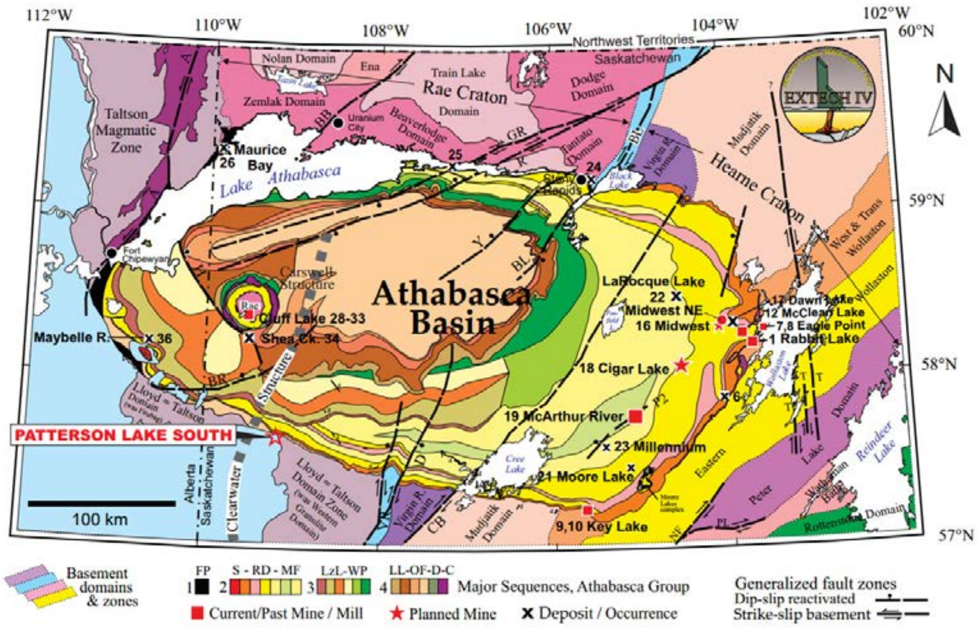


Figure 8 – Distribution of Uranium Projects around the Athabasca Bain (Ref)

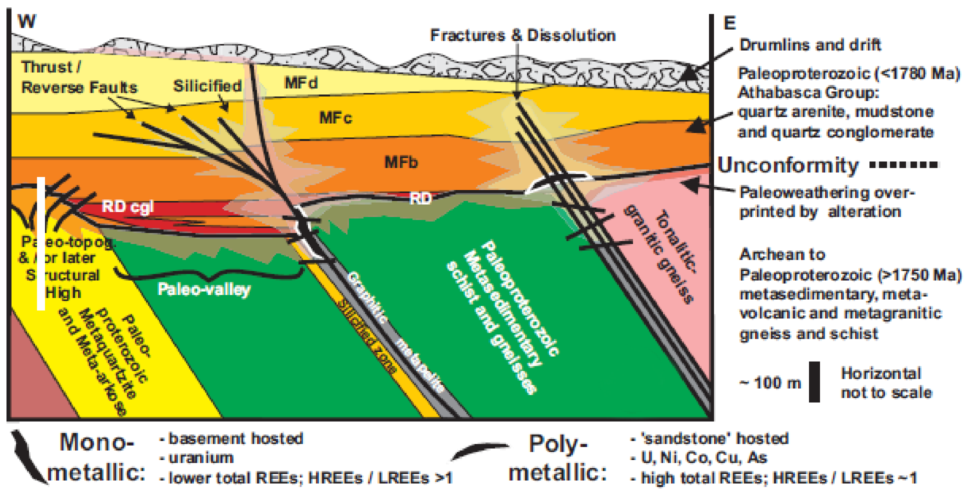


Figure 9 – Cross-Section of Distribution of Uranium Deposits Carrying Multiple Metals around the Athabasca Bain (Ref)

Drilling at the Patterson Lake property deserves special mention because it has produced very high grades of uranium in core holes. A few of these are illustrated in Figure 10. Note that drilling is conducted during winter months on the ice covering Patterson Lake through about 50 meters of lake sediments to reach bedrock, and the otherwise shallow zones of mineralization that occur along shear zones. Some of the core intersects contain mineralization with grades in excess of 20% U_3O_8.

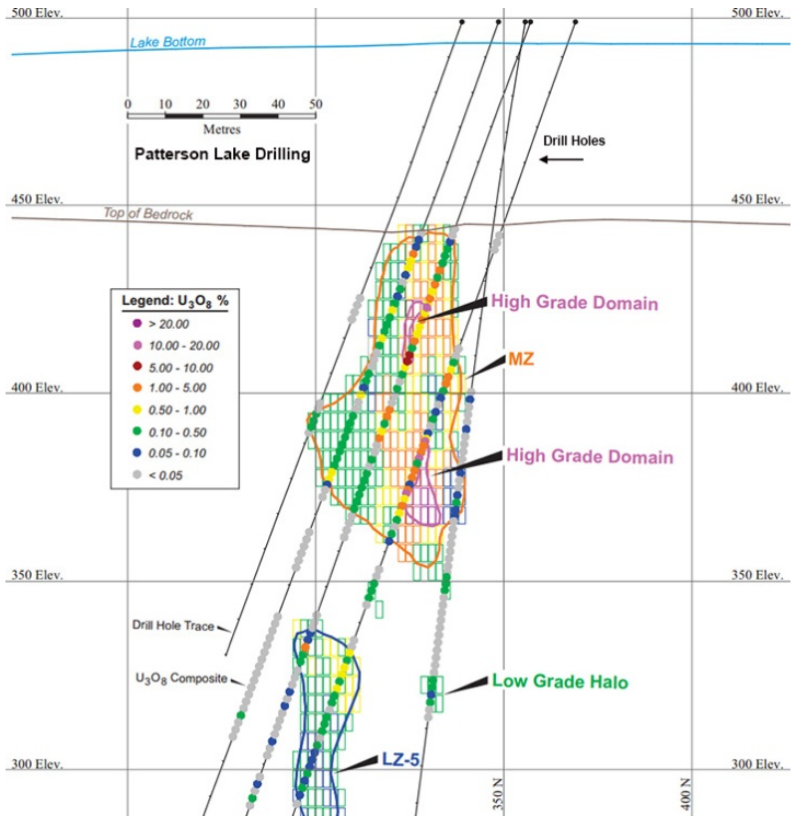


Figure 10 – Cross-Section of Drillholes Intersecting Major Mineralized Zones in the Fission - Paterson Lake Project in the SW of the Athabasca Bain, see Figure 7 (Ref)

The tonnage and grade of the Patterson Lake deposit are shown in Table 3 and includes an indicated 81 million pounds of U_3O_8 plus about 38,000 ounces of gold for combined open pit and underground mining. This does not include the Inferred Resources that may in the future be converted to Indicated Reserves by additional drilling (more).

The pit design for mining the Patterson Lake deposit is shown Figure 11. The ore to be mined by open pit is shown in gold color in the figure. The ore occurring at depths below the pit limit is to be mined by underground methods, as shown in blue. Figure 12 illustrates the mine plan in section view and shows the workings of the mine (more).

Table 3

TONNAGE AND GRADE BY ZONE AND SUB-ZONE – JULY 28, 2015
Fission Uranium Corp. - Patterson Lake South Property

	Tonnage	U_3O_8 grade (%)	Au grade (g/t)	U_3O_8 pounds	Au ounces
Indicated Open Pit					
R780E HG	107,000	17.98	2.75	42,565,000	10,000
R780E MZ	952,000	0.82	0.42	17,130,000	13,000
R00E	89,000	1.23	0.13	2,409,000	380
Total	**1,149,000**	**2.45**	**0.62**	**62,104,000**	**23,000**
Indicated Underground					
R780E HG	5,000	23.27	3.34	2,514,000	1,000
R780E MZ	645,000	0.85	0.54	12,082,000	11,000
R00E	16,000	2.07	0.17	712,000	90
R780E OTHER	197,000	0.85	0.58	3,699,000	4,000
Total	**863,000**	**1.00**	**0.56**	**19,007,000**	**15,000**
Indicated Open Pit and Underground					
R780E HG	112,000	18.22	2.78	45,079,000	10,000
R780E MZ	1,597,000	0.83	0.47	29,211,000	24,000
R00E	105,000	1.35	0.14	3,121,000	470
R780E OTHER	197,000	0.85	0.58	3,699,000	4,000
Total	**2,011,000**	**1.83**	**0.59**	**81,111,000**	**38,000**
Inferred Open Pit					
R780E HG	23,000	25.27	3.85	12,845,000	3,000
R780E MZ	23,000	1.62	1.18	802,000	1,000
R00E	3,000	2.04	0.03	133,000	0
HALO	21,000	0.54	0.24	248,000	160
R780E OTHER	5,000	0.31	0.20	31,000	0
Total	**74,000**	**8.61**	**1.64**	**14,060,000**	**4,000**

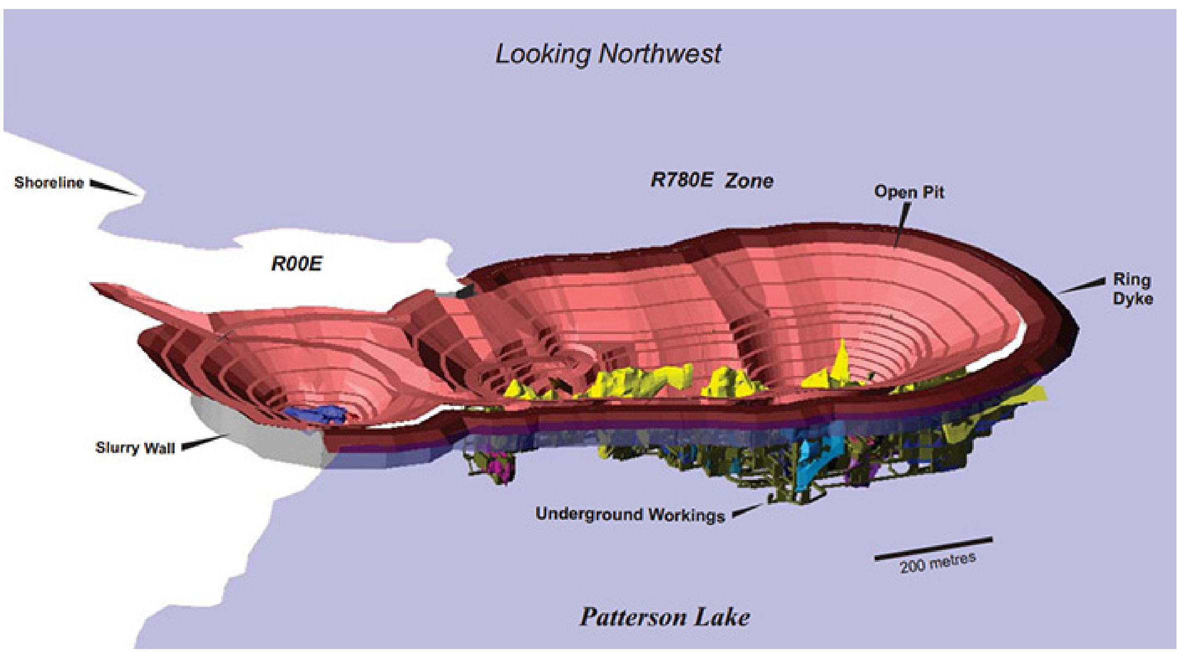


Figure 11 – Pit Design of the Patterson Lake Mine (Note that it is to be constructed into a shallow Lake: Ref)

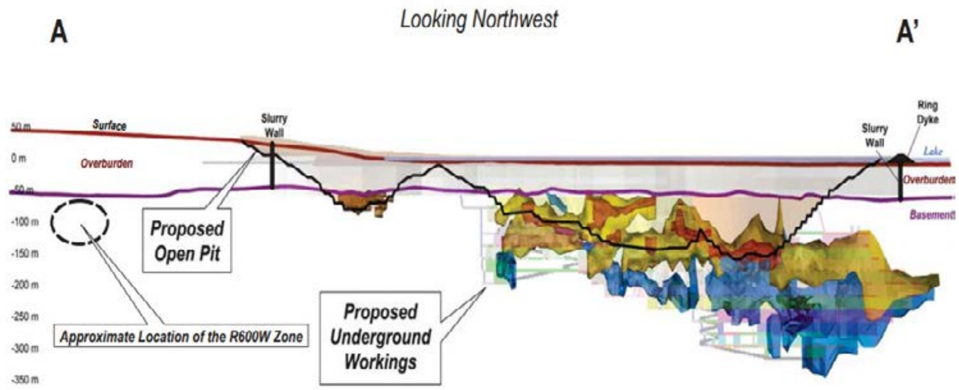


Figure 12 – A Cross-Section of the Pit Design for the Patterson Lake Mine (Note that that dewatering the pit will be followed by underground mining). (Ref)

The capital cost of construction of this mine will be in the high hundreds of millions of dollars, but the anticipated revenue will likely be about $4 billion from the uranium and about $46 million from the gold produced and sold, while royalty and local inhabitants will receive considerable benefit from mining operations.

Canada is geologically fortunate to have identified such uranium and other mineral resources. Figure 13 illustrates the depth to mine of a few of the known deposits in Canada by open-pit methods showing the average run-of-mine ore grade down to a depth of about 225 meters below the surface; deeper deposits (with even higher ore grade) that will have to be mined by underground methods are also shown. At McArthur River Mine (more), the ore grade is so high in sections of the mine that it will be mined by robotic miners to avoid extended proximity to human miners. The robotic mining equipment being developed for working in hostile conditions (either due to excessive radiation or temperature) will also be useful for off-world mining on asteroids in the decades ahead.

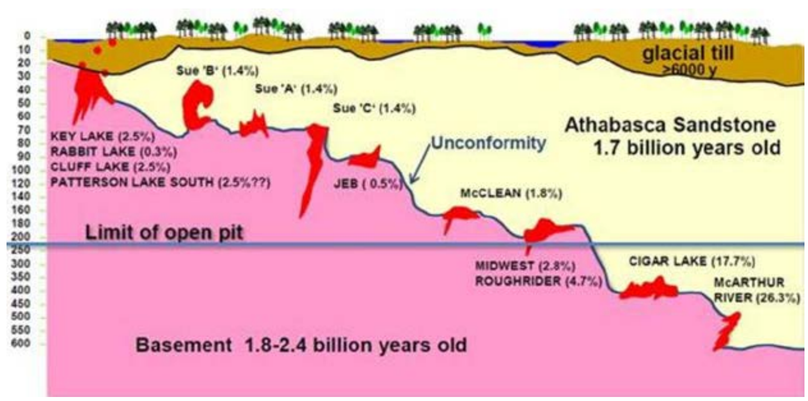


Figure 13 – A Cross-Section of the Various Depths of Canadian Uranium Deposits and Geological Associations in the Athabasca Basin (Ref)

Mining-friendly Canada continues to dominate the uranium news with additional discoveries by a number of companies. For example, just recently during a 33,000-meter summer program by NexGen Energy, they extended their previous discovery at the Rook 1's basement-hosted Arrow zone to greater depths, i.e., to about 645 meters below surface with 235 meters remaining open in all directions. The most recently reported drilling results include 10.1% U_3O_8 over 27.5 meters (not true width), starting at 492 meters in downhole depth. Included in that interval are three high-grade shears grading 20% U_3O_8 over 12 meters and an incredible 51.2% over 2.5 meters of core (more). This grade is similar to grades reported many years ago in the Africa.

The only other deposit showing higher grades of uranium was reported in the Shinkolobwe deposit located in what once was called the Belgian Congo (now the Democratic Republic of the Congo (DRC)) in central Africa. In 1937, 2,000 tons of 65% U_3O_8 were stockpiled to supply the world demand at the time (more, see page 7).

The Rook 1 property straddles the Athabasca Basin's southwestern rim, next door to Fission Uranium's Patterson Lake project discussed above, see Figure 8. CanAlaska Uranium Ltd.'s Patterson West property in the same area has a large, well-defined target in basement rocks, a similar geological environment that hosts the nearby Triple R and Arrow uranium discoveries. The southwest Athabasca Basin has the potential to host numerous major uranium deposits along a series of emerging exploration belts of shear zones (more).

Given the recent selloff in commodity markets, NexGen Energy is the only significant gainer at +124%, which is based on the discovery of an extensive mineralized zones in the Athabasca Basin carrying very high ore grades, e.g., 60 feet of core grading 21% U_3O_8 (more), and additional funding has been raised to pursue development (more). This multi-zone deposit adds to the already huge uranium resources that are available from the Athabasca Basin in northwest Saskatchewan and northeast Alberta (more), Canada. Other companies are being drawn to the area because of high grades (more), which provides major economic advantages in the market place.

World-Class Deposits in Australia

Industry, in cooperation with the Australian government, are producing new discoveries, some also of world-class grade and pounds (U_3O_8), e.g., in South Australia, Western Australia, and in the Northern Territory (more). Based on the model developed from reviewing deposits in Kazakhstan, Jaireth, *et al.* (2008) conclude that there is considerable potential in Australia for the discovery of additional large sandstone-hosted uranium mineralization, including little-explored regions underlain by basins with known or potential hydrocarbons, the latter of which serves to focus uranium mineralization in reducing zones within sandstones.

In addition to the existing mines in the area, UraniumSA's Samphire Project (Blackbush and Plumbush deposits) southwest of Whyalla, SA (more) and the Campbell prospect discovery of a light-green radium mineral and high radioactivity in the shallow dry-lake sediments of Pidinga

Lake located 120 miles north of Ceduna, SA (1969 - more) are but two of many more areas of interest likely to be discovered in Australia in the years ahead (more).

Figure 14 illustrates the existing sandstone uranium deposits, one prospect, and favorable basin areas in Australia. The underlying linked map (click on figure) shows the major uranium occurrences, other shows of uranium, felsic igneous rocks containing greater than 10 ppm U that would be favorable for the occurrence of uranium mineralization, and the geological province boundaries and outcropping felsic rocks.

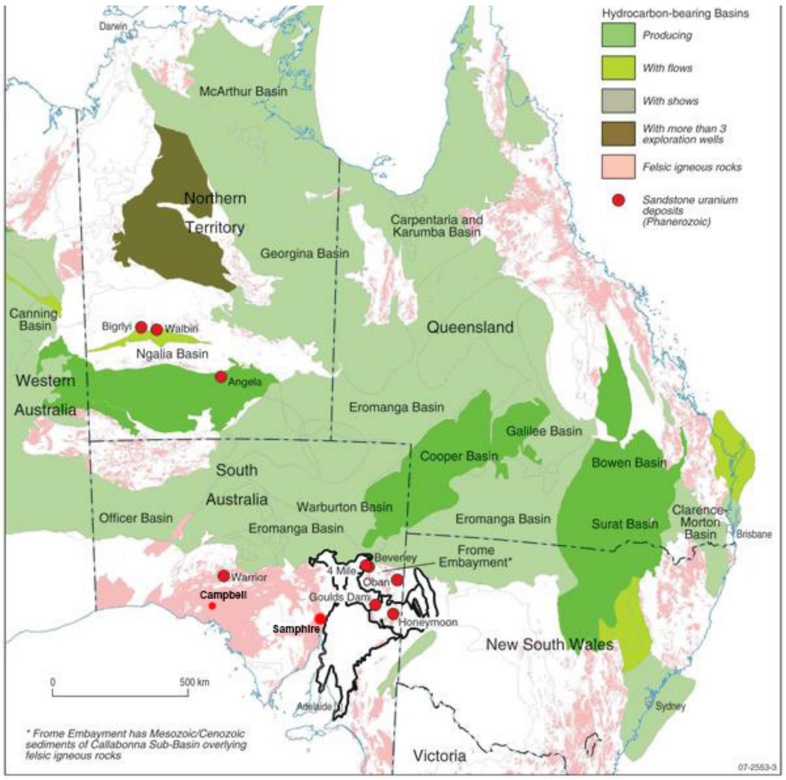


Figure 14 – Uranium Mines, Prospects, and Favorable Areas in Australia (Ref)
(For Expanded Map, Click on Figure)

Other Uranium Deposits in the World

The discovery of new uranium deposits in the world have increased in number over the past decade even with relatively low market prices. This continuing activity has occurred no doubt as a result of increasing confidence that nuclear power plants will continue to operate and will more than likely increase in in number in the years ahead.

In other parts of the world, uranium has been discovered in potentially economic grade and reserves in countries such Paraguay (more) and Uruguay (more) and 40 other countries around the world. These deposits are summarized in various country webpages published by the World

Nuclear Association (WNA), but even more detailed, preliminary information regarding the historical development of uranium exploration and mining in various countries can be obtained at the World Information Service on Energy (WISE) (more), Uranium Project website. It's primary purpose is to distribute information to adversaries of uranium mining and nuclear power throughout the world. The WISE source also serves to identify the location and issues surrounding the development of uranium and mining activities worldwide (See Table 4).

Table 4

Worldwide WISE Project Reviews of Uranium Exploration, Mining & Associated Adversarial Issues

(Wise, 2015)

Canada

British Columbia
Northwest Territories
Nunavut
Ontario
Québec
Saskatchewan
Yukon

South America

ARGENTINA
Cerro Solo (AR)
Don Otto (AR)
Laguna Salada (AR)

BRAZIL
Itataia (BR)

PERU
Colibri (PE)

Europe

CZECH REPUBLIC
Brzkov (CZ)
Jáchymov (CZ)

FINLAND
Talvivaara byproduct (FI)
Finland Issues

GREENLAND
Kvanefjeld (GL)

ITALY
Novazza (IT)

POLAND
Kopaniec (PO)

PORTUGAL
Nisa (PL)

SLOVAKIA
Jahodná-Kurišková

Spain
Mazarete (SP)

SWEDEN
Häggån (SE)
Jämtland (SE)
Närke (SE)
MMS Viken (SE)
Västergötland (SE)
Viken (SE)

United Kingdom
Ireland

Africa

BOTSWANA
Letlhakane (BW)

CENTRAL AFRICAN REPUBLIC
Bakouma (CF)

MALAWI
Kanyika (MW)

MALI
Faléa (ML)

MAURITANIA
Reguibat (MR)

NAMIBIA
Aussinanis (NA)
Etango (NA)
Husab (ex Rössing South) (NA)
Ida Dome (NA)
Langer Heinrich (NA)
Marenica (NA)
Norasa (NA)
Omahola (NA)
Ongolo (NA)
Rössing Z20 (NA)
Trekkopje (NA)
Tubas Sand (NA)
Tumas (NA)
Valencia (NA)
Zhonghe (NA)

NIGER
Azelik (NE)
Dasa (NE)
Imouraren (NE)
Madaouéla (NE)
Niger Issues

SOUTH AFRICA
Beisa Reef (SA)
Buffelsfontein tailings (SA)
De Bron-Merriespruit South (SA)
Ezulwini (SA)
Gold Fields' Witswatersrand tailings (SA)
Karoo (SA)
Mintails West Rand tailings (SA)
Mooifontein (SA)
Rand Uranium Co tailings (SA)

TANZANIA
Manyoni (TZ)
Mkuju River (TZ)

ZAMBIA
Mutanga (ZM)

ZIMBABWE
Kanyemba (ZW)

Asia

ARMENIA
Lernadzor (AM)

BANGLADESH
Sylhet and Moulvibazar

CHINA
NN (Guangdong prov., CN)
NN (Xinjiang Uygur AR, CN)

ESTONIA
Salamanca 1 (ES)

INDIA
Baghjanta (IN)
Balpakram (IN)
Gogi (IN)

Kanampalle (IN)
Kylleng-Pyndemsohiong-Mawthabah (IN)
Lambapur-Peddagattu (IN)
Mohuldih (IN)

KYRGYZSTAN
Kamushanovskoe (KG)

MONGOLIA
Dornod (MN)
Dulaan Uul, ISL (MN)
Gurvanbulag (MN)
Zoovch Ovoo, ISL (MN)

PAKISTAN
Shanawah (PK)

ROMANIA
Tulghes-Grinties (RO)
Uzina TG (RO)

RUSSIA
Berezovoe (RU)
Elkon (RU)
Gornoe (RU)

Tummalapalle (IN)

IRAN
Ardakan (IR)
Saghand (IR)

JORDAN
Siwaqa (JO)

KAZAKHSTAN
Zhalpak (KZ)

Karkhu (RU)
Khiagdinskoe (RU)
Olovskoye (RU)

SLOVAKIA
Kurišková (SK)

TURKEY
Temrezli, ISL (TR)

UKRAINE
Novokonstantinovskoye (UA)

Australia

NORTHERN TERRITORY
Angela / Pamela, NT
Koongarra, NT
Ranger 3 Deeps, NT

SOUTH AUSTRALIA
Beverley North Extension, SA
Crocker Well, SA
Four Mile, SA
Honeymoon, SA
Mt. McGee, SA
Oban, SA
Samphire, SA

WESTERN AUSTRALIA
Carley Bore, WA
Dawson-Hinkler, WA
Kintyre, WA
Lake Maitland, WA
Mulga Rock, WA
Wiluna, WA
Yeelirrie, WA

OVERALL PERSPECTIVE

A comprehensive assessment of opponents of nuclear power and associated mining of uranium (more) shows that they apply the same ill-founded and exaggerated claims throughout the world, mostly generated by the media pandering to local inhabitants, by competing energy interests, and by paid commercial adversaries (wind, solar, and associated industries). The claims are then passed on to well-meaning, but ignorant people in the U.S. and around the world (more).

A growing number of prominent professionals have come to support nuclear power as the energy of choice for generating electricity. This is primarily because it minimizes damage to Earth's climate relative to coal and natural gas; it is safe to operate, with more than 50 years without a death or significant radiation exposure to humans (except for Chernobyl (more)).

It is, therefore, incumbent upon industry and government to inform and educate the general public in the U.S. and throughout the world of the realities and need of uranium mining and on the superiority of nuclear power for generating electricity in terms of safety, long-term cost, 24/7 availability, and minimal impact on the climate (more).

THORIUM ACTIVITIES

Thorium continues to receive funding as a possible alternative to uranium to provide safe and abundant nuclear power at a reasonable cost. For example, India has been interested in thorium-based nuclear energy for decades. Still, extracting its latent energy value in a cost-effective way remains a challenge technologically; meaning much more research and development is required.

Nuclear giant Westinghouse, a unit of Toshiba, is part of an international consortium that Thor Energy established to fund and manage research on thorium applications. An established player in nuclear energy, Westinghouse provides viewpoints on thorium research in China as well.

Thor Energy is not the only company engaged in researching whether or not it is a viable alternative to uranium in nuclear energy. In fact, firms from the U.S., Australia, Czech Republic, India, China, and Russia have also been working on thorium reactor designs and other elements of fuel technology using the metal. However, Thor was the first to begin energy production using thorium.

The U.S. is not the only country that contains thorium resources. According to the USGS, in 2014 exploration and development of rare-earths projects associated with thorium were underway in Australia, Brazil, Canada, Greenland, India, Russia, South Africa, the U.S. and Vietnam (more).

Thorium may be useful not because uranium fuel is getting scarce (it is not) but because when thorium is used in reactors, it produces less waste than uranium. But there are still issues (more).

To review current reports, media items, and other information selected from the I2M Web Portal thorium database, see (more).

RARE-EARTH ACTIVITIES

At present, rare earth resources have been discovered in about 35 countries and regions around the world, with total reserves of 130 million tons, of which 42.3% are owned by China alone (more). In order to protect and rationally develop superior resources, China has adopted a cap-control policy for rare earth exploitation since 2006. Hence the rare-earth ore production in China suffered a continuous decline from 2010 to 2013. In 2014, the Chinese government raised the upper limit, a move that helped drive the rare earth output rise 14.5% year per year to 95,000 tons, amounting to about 86.4% of the global total.

China has not only the largest proportion of the total global rare-earth resources in production on Earth, but also the most extensively developed total supply chain for rare earths, and perhaps most important of all, the overwhelming majority of rare earths R&D implemented by the largest group of scientists and engineers devoted to rare earths studies and manufacturing on Earth.

Some evidence exists that 90-95% of all rare earth R&D today takes place in China (more). Thus, it would appear that the rare earths industry is much more important to China than it could ever be to any other nation.

Lifton (2015), cited Dr. Kingsnorth of Curtin University in Perth, Australia in his keynote speech at a recent conference, as stating that a large percentage of illegal mining and refining in China is primarily driven by the growing demand for praseodymium and neodymium for use in manufacturing rare-earth permanent magnets (more). He bases this conclusion on supply/demand data provided by the Chinese industry. For 2015, the estimated Chinese domestic demand for praseodymium and neodymium for magnets alone is 30-35,000 tons yet the production quota is capped at 20,000 tons. Kingsnorth suggests that the driver for continuing illegal production appears to be the Chinese government itself or at least its inaction.

Recently, the Wyoming Geological Survey received a substantial Department of Energy (DOE) grant to investigate rare earths in coal (more). In other developments, Australian rare-earths miner Lynas has emerged from the industry's boom and bust as the lone survivor in Australia (more).

In the U.S., Molycorp has ceased operations, for the time being (more). Texas Rare Earth Resources is preparing for production in the near future, along with U.S. government support to stimulate operations (more).

To review other current reports, media items, and other recent information selected for the I2M Web Portal rare-earth database, see (media: more) and U.S. Geological Survey research: (more).

URANIUM & RARE EARTH UNIVERSITY RESEARCH

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

Mr. Sibray will present his update on uranium and rare earth university research in the 2016 Annual UCOM report.

URANIUM & RARE EARTH STATE/FEDERAL GOVERNMENT RESEARCH

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

Mr. Gregory will present his update on uranium and rare earth government research in the 2016 Annual UCOM report.

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

Additional rare-earth research subjects investigated by the U. S. Geological Survey are available for review (more).

AMBIENT RADIATION IN THE ATMOSPHERE

On the basis that the impact of radiation is difficult to understand for many, we are adding a new section to the UCOM report for this Mid-Year Report to provide some clarity regarding the minimum safe radiation exposure to humans (more). This matter has also been treated in some detail earlier by this committee (more, pp. 171-177), and even (more).

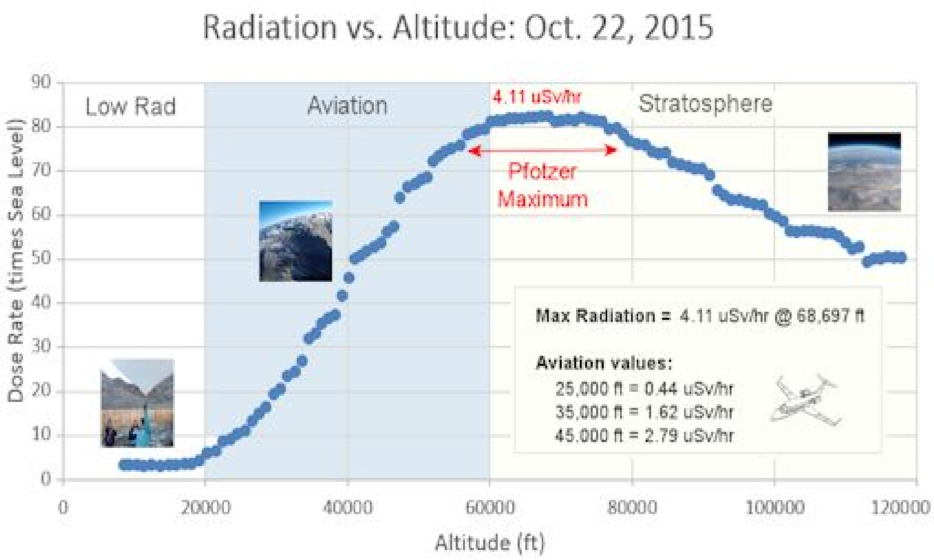
Radiation (or cosmic ray) measurements are being made on regular flights of space-weather balloons (more). Approximately once a week, *Spaceweather.com* and the students of *Earth to Sky Calculus* fly space weather balloons into the stratosphere over California and elsewhere (more). These balloons are equipped with radiation sensors that detect cosmic rays, a form of space weather. Cosmic rays can seed clouds (more), trigger lightning (more), and penetrate commercial airplanes (more). Their measurements show that a person flying back and forth across the continental U.S., just once, can absorb as much ionizing radiation as 2 to 5 dental X-rays.

As an example of the information available on *Spaceweather.com*, a situation report for October 30, 2015 is presented below:

Situation Report -- Oct. 30, 2015	**Stratospheric Radiation** (+37° N)
Cosmic ray levels are **elevated** (+6.1% above the Space Age median). The trend is **flat**. Cosmic ray levels have increased **+0%** in the past month.	Sept. 23: 4.12 uSv/hr (412 uRad/hr)
	Sept. 25: 4.16 uSv/hr (416 uRad/hr)
	Sept. 27: 4.13 uSv/hr (413 uRad/hr)
	Oct. 11: 4.02 uSv/hr (402 uRad/hr)
	Oct. 22: 4.11 uSv/hr (402 uRad/hr)

Figure 15 is the plot from the October 22, 2015 flight. The plot below shows the data recorded for increasing altitude vs. radiation dose rate during the balloon flight, which reach a maximum altitude of 120,000 feet above sea level. Figure 15 also shows the aviation range of radiation exposure.

Figure 15



Radiation levels peak at the entrance to the stratosphere in a broad region called the "Pfotzer Maximum." This peak is named after physicist George Pfotzer who discovered it using balloons and Geiger tubes in the 1930s. Radiation levels there are more than 80 times those at sea level and then decreases to 50 times. The reason for this decrease is likely related to the differing position of the Earth's geomagnetic field over California and New Hampshire (more), see Figures 16 and 17.

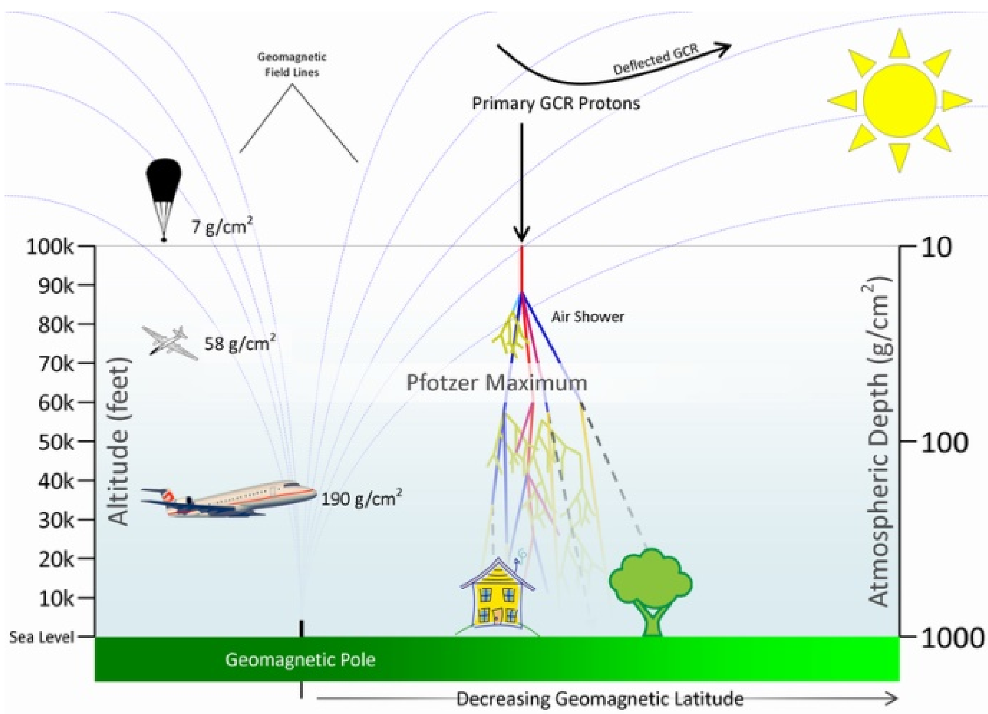


Figure 16 – Location of the Pfotzer Maximum Radiation (Ref)

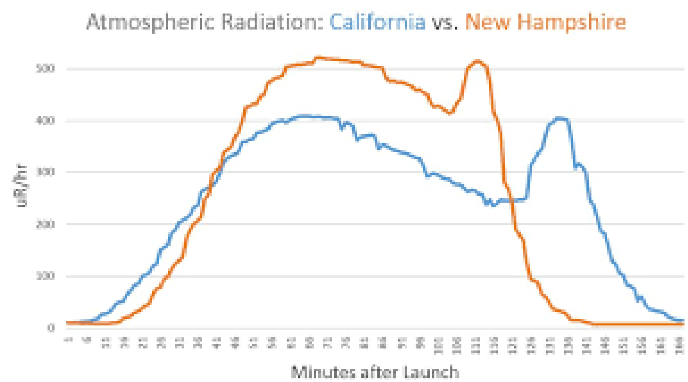


Figure 17 – Difference in Maximum Radiation (Ref)

At the entrance to the stratosphere, about 70,000 feet above Earth's surface, the broad layer of ionizing radiation called the Pfotzer Maximum extends from about 55,000 feet to 75,000 feet in altitude and is monitored to evaluate its response to solar storms. Most airplanes fly below it; satellites orbit high above it. Energy releases during large thunderstorms are known as Jets, Sprites and ELVE appear to be in the middle and above the Pfotzer Maximum zone but they also may contribute energy to the geomagnetic system in some way (see Figure 18).

Note in Figure 16 that the bottom of the Pfotzer Maximum is near 60,000 ft. This means that some high-flying aircraft are not far from the zone of maximum radiation. Indeed, according to the October 22nd measurements, a plane flying at 45,000 feet is exposed to 2.79 uSv/hr. At that rate, a passenger would absorb about one dental X-ray's worth of radiation in about 5 hours. For context of such radiation; see Radiation Dose Chart (here).

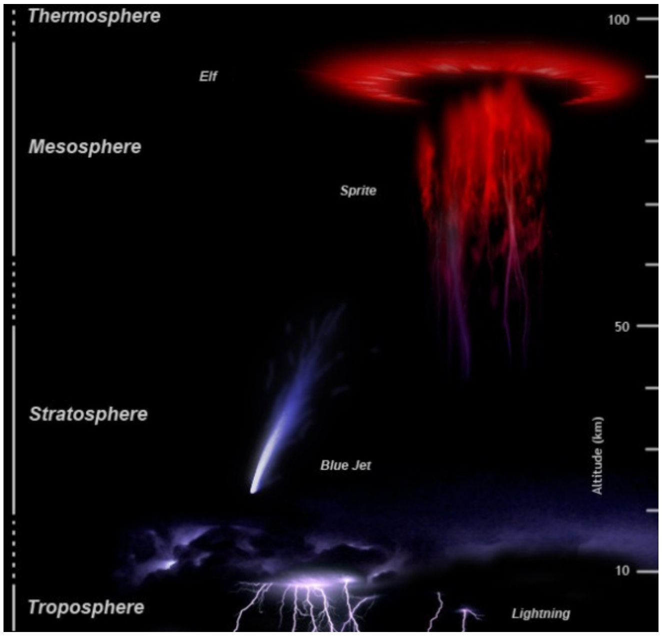


Figure 18 – **Sprites and Jet "Lightning" above Large Thunderstorms (Ref)**
(Click to Enlarge Graphic)

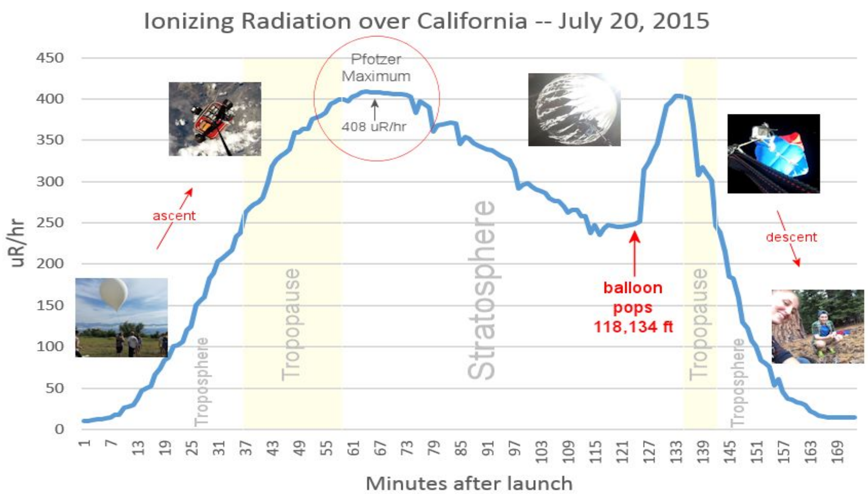


Figure 19 – Activities During a Balloon Launch (Ref)

The radiation sensors onboard the helium balloons detect X-rays and gamma-rays in the energy range 10 keV to 20 MeV. These energies span the range of medical X-ray machines and airport security scanners (more).

A list of references for additional reading on radiation is presented below:

REFERENCES AND READING LIST

Adams, R., 2015, "Some Science has Falsified the "No Safe Dose" Hypothesis about Radiation. Now what?" *Atomic Insights Blog*, January 21: http://atomicinsights.com/science-falsified-no-safe-dose hypothesis-radiation-now/

Angwin, M., 2015, **"**Me and Pico – Nuclear Power and Scare Stories," Northwest Clean Energy Blog, March 11: http://northwestcleanenergy.com/2015/03/11/me-and-pico-nuclear-power-and-scare-stories/

Boisvert, W., 2015, "Five Surprising Health Facts about Fukushima," *Energy for Humanity.org, March 13:* http://energyforhumanity.org/featured/five-surprising-health-facts-about-fukushima/

Brumfiel, G., 2013, Fukushima of Fear, *Nature*, **493,** *pp.* 290–293 (17 January 2013)doi:10.1038/493290a: http://www.nature.com/news/fukushima-fallout-of-fear-1.12194

Buja, A., *et al.*, 2006," Incidence among Female Flight Attendants: A Meta-Analysis of Published Data," *Journal of Woman's Health*, Volume 15, Number 1, pp. 98-105: http://www.biostat.jhsph.edu/~fdominic/papers/Buja.pdf

Cama, T., 2014, "Fukushima Radiation likely to Peak in U.S. Next Year," *The Hill*, December 29: http://thehill.com/policy/energy-environment/228215-fukushima-radiation-like-to-peak-in-us-next-year

Campbell, M. D., 1969, Uranium Exploration in South Australia: 1969 Summary Report: Australasian Mining Corporation – Uranium Exploration Project, Pidinga Lakes Area, Report No.1, for Minoil Services, Adelaide, 75 p. May: http://mdcampbell.com/SouthAustraliaUEX.htm

Campbell, M. D. and K. T. Biddle, 1977, "Frontier Areas and Exploration Techniques - Frontier Uranium Exploration in the South-Central United States," *in Geology of Alternate Energy Resources*, Chapter 1, Published by the Houston Geological Society, pp. 3-44; http://www.i2massociates.com/Downloads/CamBidd77A.pdf

Campbell, M. D., *et al.*, 2010, "EMD Uranium (Nuclear Minerals) Mid-Year Report," 32 p., http://i2massociates.com/Downloads/UraniumAAPG-EMD2010Midyear.pdf

Campbell, M. D., J. D. King, H. M. Wise, B. Handley, J. L. Conca, and M. David Campbell, 2013, "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," *in* Chapter 9, *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space*, (eds)

Ambrose, W. A., J. F. Reilly II, and D. C. Peters, AAPG-EMD Memoir 101, pp. 163 –213. http://i2massociates.com/downloads/Memoir101-CHAPTER09Rev.pdf

Campbell, M. D. and J. L. Conca, 2015, "Energy Competition in the Uranium, Thorium, and Rare Earth Industries in the U.S. and the World," Report of the EMD Uranium (Nuclear and Rare Earth Minerals) Committee, in *Natural Resources Research*, Vol. 4, pp. 8-16, December: http://www.i2massociates.com/Downloads/NRR2015Unconv_Review_online11.25.15.pdf

Criswell, D. R., 2013, "The Sun-Moon-Earth Solar-Electric Power System to Enable Unlimited Human Prosperity," *in* Chapter 8, *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space*, (eds) W. A. Ambrose, J. F. Reilly II, and D. C. Peters, AAPG-EMD Memoir 101, pp. 151 – 162, http://www.i2massociates.com/Downloads/CHAPTER08.pdf

Conca, J., 2013, "Absurd Radiation Limits are a Trillion Dollar Waste," Forbes.com, July 13: http://www.forbes.com/sites/jamesconca/2014/07/13/absurd-radiation-limits-are-a-trillion-dollar-waste/
Conca, J. 2012 to Present: Search Results on Nuclear Power and Associated Issues: from I2M Web Portal (here).

Fishman, N. S., 2014,"EMD Shale Gas and Liquids Committee Annual Report," 156 p., March 30: http://emd.aapg.org/members_only/annual2014/08e-gas-shales-EMD2014-annual.pdf

Hammes, U. *et al.*, 2015, "EMD Shales Gas and Liquids Committee Mid-Year Report," 136 p., November 16: http://i2massociates.com/Downloads/EMDShale-Gas-Liquids-Committee-Report-Nov_2015.pdf

Harting, C., 2010, "AC Transmission Line Losses," Submitted as coursework for Physics 240, Stanford University, PH240 - Introduction to the Physics of Energy, October 24: http://large.stanford.edu/courses/2010/ph240/harting1/

Jaireth, S., A. McKay, and I. Lambert, 2008, "Association of Large Sandstone Uranium Deposits with Hydrocarbons," in *AUSGEO News*, Issue No. 89, March: http://www.ga.gov.au/ausgeonews/ausgeonews200803/uranium.jsp

Lifton, J., 2015,"Rare Earths: Five Decades of Growth," in Lifton on Kingsnorth and the Global Rare Earth Market, InvestorIntel.com, November 30: http://investorintel.com/technology-metals-intel/lifton-on-kingsnorth-and-the-global-rare-earth-market/

Land, C. E., *et al.*, 2004 Draft, "Low-Dose Extrapolation of Radiation-Related Cancer Risk," Committee 1 Task Group Report of ICRP (the International Commission on Radiological Protection), December 10: http://www.icrp.org/docs/low-dose_tg_rept_for_web.pdf

McLeod, C., 2013, "Stolen Cobalt-60 Found; Thieves Likely to Die," Cobalt Investing News, December 5: http://investingnews.com/daily/resource-investing/critical-metals-investing/cobalt-investing/stolen-cobalt-60-found-thieves-likely-to-die/

Platt, J., 2015, "Energy Economics and Technology", Summary Report of the EMD Energy Economics and Technology Committee, pp.46-60, in *Natural Resources Research*, DOI: 10.1007/s11053-015-9288-6, Internet Access November 30, 2015 via: http://www.i2massociates.com/Downloads/NRR2015Unconv_Review_online11.25.15.pdf

PLOS One Search Results: Nuclear Power: Fukushima, Chernobyl, etc. http://journals.plos.org/plosone/search?filterSubjects=Nuclear+power&q=

Qvist, S. A., and B. W. Brook, 2015, "Potential for Worldwide Displacement of Fossil-Fuel Electricity by Nuclear Energy in Three Decades Based on Extrapolation of Regional Deployment Data," PLoS ONE 10(5): e0124074. doi:10.1371/journal.pone.0124074: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0124074

Radiation Dose Chart, 2012: http://www.ela-iet.com/EMD/radiation.jpg

Seaman, A. M., 2014,"Airline Crews may be more likely to get Skin Cancer," Reuters U.S. Edition: http://www.reuters.com/article/us-airplane-cancer-idUSKBN0GY2HO20140903

United Nations Scientific Committee on the Effects of Atomic Radiation, 2012, Biological Mechanisms of radiation Actions at Low Doses, A white paper to guide the Scientific Committee's future program of work: http://www.unscear.org/docs/reports/Biological_mechanisms_WP_12-57831.pdf

United Nations Scientific Committee on the Effects of Atomic Radiation, 2012, Report of 59th Session, May 21-25: http://www.un.org/ga/search/view_doc.asp?symbol=A/67/46
U.S. Energy Information Agency, 2015, "Domestic Uranium Production Report – Annual," April 30: http://www.eia.gov/uranium/production/annual/

Wicker, W., 2014, "Natural Radiation: Sources, Relevance and Uranium Levels Uranium Levels," Professor Emeritus Department of Environmental & Radiological Health Sciences Department of Environmental & Radiological Health Sciences Colorado State University Colorado State University: http://www.i2massociates.com/Downloads/WhickerNaturalRadiation.pdf

World Nuclear Association, 2015, "Nuclear Radiation and Health Effects," May 22: http://www.world-nuclear.org/info/Safety-and-Security/Radiation-and-Health/Nuclear-Radiation-and-Health-Effects/

World Nuclear News, 2015, "Canadian Accident Study Puts Risks into Perspective," August 25: http://www.world-nuclear-news.org/RS-Canadian-accident-study-puts-risks-into-perspective-2608157.html

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