EMD Uranium (Nuclear Minerals) Committee

2017 EMD Uranium (Nuclear Minerals and REE) Committee Annual Report

April 26, 2017

Table of Contents

Page

Vice-Chair Reports:

EMD Uranium (Nuclear & REE) Committee

2017 EMD Uranium (Nuclear and REE) Committee Annual Report

Michael D. Campbell, P.G., P.H., C.P.G., C.P.H., Chair
Executive Vice President and Chief Geologist (Mining) / Chief Hydrogeologist (Environmental)
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Founding Member of EMD in 1977, and Past President of EMD: 2010-2011
Fellow SEG; Fellow GSA; Fellow AIG; Fellow and Chartered Geologist GSL; EurGeol; and RM SME

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Vice-Chairs:

- **Henry M. Wise, P.G., C.P.G., (Vice-Chair: Industry),** SWS Environmental Services, La Porte, TX
  (Founding Member of EMD in 1977)
- **Steven S. Sibray, P.G., C.P.G., (Vice-Chair: University),** University of Nebraska, Lincoln, NE
- **Robert W. Gregory, P.G., (Vice-Chair: Government),** Wyoming State Geological Survey, Laramie, WY

Advisory Group:

- **Kevin T. Biddle, Ph.D.,** V.P., ExxonMobil Exploration (retired), Houston, TX (Founding Member of EMD in 1977)
- **James L. Conca, Ph.D., P.G.,** Senior Scientist, UFA Ventures, Inc., Richland, WA
- **Gerard Fries, Ph.D.,** Areva Mines, KATCO JV, LLP, Almaty, Kazakhstan
- **Michael A. Jacobs, P.G.,** Pioneer Natural Resources, (Founding Member of EMD in 1977), ex-Tenneco Uranium Inc., Midland, TX
- **Roger W. Lee, Ph.D., P.G.,** NewFields/I2M Associate, Austin, TX
- **Karl S. Osvald, P.G.,** U.S. BLM, Wyoming State Office Reservoir Management Group, Casper, WY
- **Mark S. Pelizza P.G.,** M. S. Pelizza & Associates, LLC, Plano, TX
- **Arthur R. Renfro, P.G.,** Sr. Geological Consultant, Cheyenne, WY (Founding Member of EMD in 1977)
- **Samuel B. Romberger, Ph.D.,** Sr. Geological Consultant, Golden, CO
- **David Rowlands, Ph.D., P.G.,** Rowlands Geosciences, Houston, TX

Special Consultants to the Uranium (Nuclear and Rare Earths) Committee:

- **Ruffin I. Rackley**, Senior Geological Consultant, Anacortes, WA, ex-Teton Exploration, Casper, WY
  (Founding Member of EMD in 1977, Secretary-Treasurer: 1977-1979, and Past President: 1982-1983)
- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD in 1977) , ex-Teton Exploration
- **M. David Campbell, P.G.**, CEO, Vice President and Senior Project Manager, I2M Associates, LLC, Houston, TX
- **Robert A. Arrington**, VP, Exploration, Texas Eastern Nuclear, Inc. (retired), College Station, TX
  (Founding Member of EMD in 1977)
- **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) monitors the uranium industry and the production of electricity within the nuclear power industry because that drives uranium exploration and development in the United States and overseas.

Input for this Annual Report has been provided by

Henry M. 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

Robert Gregory, P.G., Vice Chair (Government) on governmental (State and Federal) activities in uranium, thorium, and rare-earth research.

Special input and reviews are provided by members of the Advisory Group. Of the latter group, two new members of the Advisory Group have been appointed recently; they are: Roger W. Lee, Ph.D., P.G., Austin, Texas, and Mark S. Pelizza P.G., Plano, Texas.

In this report, we also provide summary information on current thorium and rare-earth exploration and mining, and associated geopolitical activities as part of the UCOM monitoring of "nuclear minerals," thorium and rare-earth elements (REE) activities (a function approved by the UCOM in 2011). Uranium and thorium include REE minerals in deposits in the U.S. and around the world (more).

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 Justin Drummond of Queens University, Kingston, Ontario, Canada was awarded the McMurray Memorial Grant in 2016 (more). Other recipients of the Grant since 2009 are presented in the following Table 1.

Table 1

Recipients of the Jay M. McMurray Memorial Grant from AAPG

2009	FORMATION OF PRECURSOR CALCIUM PHOSPHATE PHASES DURING CRYSTAL GROWTH OF APATITE AND THEIR ROLE ON THE UPTAKE OF HEAVY METALS AND RADIONUCLIDES	Olaf Borkiewicz	Miami University
2010	PRECIPITATION KINETICS OF AUTUNITE MINERALS: IMPLICATIONS FOR URANIUM IMMOBILIZATION	Denise Levitan	Virginia Tech University
2011	THE FORMATION MECHANISMS OF UNCONFORMITY-RELATED URANIUM DEPOSITS: INSIGHTS FROM NUMERICAL MODELING	Tao Cui	University of Windsor
2012	NOVEL NANOSEISMIC SURVEY TECHNIQUES IN TUNNELS AND MINES	Chiara Mazzoni	University of Strathclyde
2013	(U-TH)/HE AND U-PB DOUBLE DATING CONSTRAINTS ON THE INTERPLAY BETWEEN THRUST DEFORMATION AND BASIN DEVELOPMENT, SEVIER FORELAND BASIN, UTAH	Edgardo Pujols	University of Texas at Austin
2014	ANTHROPOGENICALLY ENHANCED MOBILIZATION OF NATURALLY OCCURRING URANIUM LEADING TO GROUNDWATER CONTAMINATION	Jason Nolan	University of Nebraska-Lincoln
2015	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES: IMPLICATIONS FOR CALCRETE-HOSTED URANIUM MINERALIZATION, WESTERN AUSTRALIA	Justin Drummond	Queen's University
2016	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES, WESTERN AUSTRALIA: IMPLICATIONS FOR CALCRETE-HOSTED URANIUM MINERALIZATION	Justin Drummond	Queen's University
2017	RECONSTRUCTION OF CRETACEOUS PROVENANCES OF ABEOKUTA GROUP OF THE EASTERN DAHOMEY BASIN SOUTHWESTERN NIGERIA BASED ON THE FIRST URANIUM-LEAD DETRITAL ZIRCON GEOCHRONOLOGY	Fadehan Tolulope Abosede	University of Lagos

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 (more). 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* (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).

In 2015, we modified the format of the UCOM report to provide greater coverage and more timely information in a more concise format. To accomplish this, the UCOM members examine certain topics as we have in the past, such as the driving forces behind the current uranium mining industry conditions and activities, and their driving forces, e.g., yellowcake prices, nuclear power plant construction, uranium reserves and world-wide exploration, especially new discoveries.

To support this coverage, we 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 and processing (more), and marketing, as well as on topics related to: c) uranium recovery technology (more); d) nuclear-power economics (more), reactor designs (more), 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). The latter have direct and indirect impact on the costs, mining, and utilization of uranium, thorium, and rare-earth fields.

Our coverage also includes reviews of the current developments in research on thorium (more), helium-3 (more), and fusion research (more), and environmental and societal issues related to nuclear waste storage and handling (more). Current research developments in the rare-earth commodities are also summarized (more). We draw on the I2M Web Portal database, which currently contains approximately 5,000 abstracts and links to current technical reports and media articles from sources in the U.S. and around the world, (see the Index to all commodity fields covered in the I2M Web Portal (here)). The primary emphasis of the I2M Web Portal reflects those of UCOM (more).

The nature and impact of radiation, perceived and real, are receiving coverage from a variety of mining and nuclear power adversaries. In response, we have been addressing these important issues since the beginning of the recent era in reporting within the UCOM (2005) while continuing to address the issues surrounding human-health issues in greater detail over the past few years (more) and (more). We have added a section in our reports titled: *Ambient Radiation in the Atmosphere*, at the end of our reports.

This places radiation in context with our environment, on the ground, in the atmosphere, in the orbital reaches, and in space.

The AIPG Texas Section has invited UCOM members and members of EMD to join them in sponsoring and participating in a field trip to visit the in-situ uranium mining and processing projects located in the south Texas in the spring of 2018. For further information, see the AIPG announcements (more).

OBJECTIVES OF UCOM REPORTS

Based on our review of the various sources of information, one of the principal objectives of our Annual (Spring) and Mid-Year (Fall) reports is to provide a summary of the important developments in uranium exploration and production of yellowcake (U_3O_8) to the members of the Energy Minerals Division, AAPG, and to the general public.

These activities are driven by nuclear-plant demand for fuel for the 99 reactors (and for those under construction/planned for use in the future). Plants also must plan for the storage of their waste products in the U.S., especially since the U.S. federal government failed to provide the national storage facility mandated by law while still charging nuclear plants billions of dollars to build Yucca Mountain Facility (without success) and to manage the plants' radioactive waste, when alternative were available, e.g., the WIPP project in New Mexico..

We also include and assess the status of thorium and rare-earth exploration (and development) because both are often encountered in some types of hard-rock uranium deposits and the presence of both impact the economics of recovering uranium and rare earths, often with some credit for thorium concentrates. In this Annual report, we are providing a detailed assessment of rare-earth mining and processing projects in the U.S. and overseas.

EXECUTIVE SUMMARY

- The two primary objectives of this report are to alert the members of the Energy Minerals Division, AAPG and the general public on the current activities within the uranium, thorium, and rare-earth industries in terms of prices, exploration, and environmental issues involved.

- An associated objective is to report on the vagaries employed by local news media and news media in general around the country regarding the uranium exploration and mining, and on nuclear power in general, its expansion and opposition.

Factors Involved Uranium Prices

- As new uranium supplies have come on-line and demand has not, a condition of oversupply developed creating depressed prices until 2017, which now shows some increase as supplies have been limited by some large producers.

- One of the current impacts on the uranium price includes the U.S. government, which has just finished dumping some of their back-up yellowcake supply into the U.S. market.

- The U.S. government sales are more than double the expected uranium production this year in the U.S.

- Proceeds from the sale of federal uranium inventory were used to fund the cleanup of legacy federal government nuclear facilities, such as the Paducah and Portsmouth uranium enrichment plant sites.

- The current uranium production growth has already been built into the supply chain that has come on-line with ramping up production and this creates an increased amount uranium to be sold on the basis of the spot price into a weak market, which has been keeping prices low.

- The spot uranium price, as of late March, 2017, remains below $30.00 due to a long-term uranium oversupply, although with the Japanese reactor restarts, this will serve as a catalyst for a rising uranium spot price with increasing utility contract prices over the long term.

- Although uranium prices remain weak due to the oversupply and lower utility demand (Japan), many mining companies are moving forward with uranium project developments, hoping to capitalize on the eventual rebound in prices expected in later 2017 or 2018.

- Recent uranium spot-price increases involve the perception of supply consumption, which ultimately drives a uranium price bull market, but with early price volatility.

- Six percent of the 57 million pounds U_3O_8 delivered in 2015 was U.S.-origin uranium at a weighted-average contract price of $43.86 per pound (committed to individual utilities).

- Foreign-origin uranium accounted for the remaining 94% of U.S. deliveries at a weighted-average contract price of $44.14 per pound U_3O_8 . Uranium originating in Kazakhstan, Russia, and Uzbekistan accounted for 37% of the 57 million pounds.

U.S. Uranium Exploration and Development

- Known deposits and some new discoveries occur in 13 U.S. States, with Virginia most notable because of the potential large size of the known deposit.

- About 42% of U.S. uranium comes from conventional mines (open pit and underground) about 51% from in situ leach, and 7% is recovered as a by-product from other mineral extraction.

- U.S. production of uranium concentrate in the fourth quarter 2016 was 725,947 pounds U_3O_8, down 11% from the third quarter 2016 and up 16% from the fourth quarter 2015.
- During the fourth quarter 2016, U.S. uranium was produced at seven U.S. uranium facilities, the same number as in the third quarter 2016.

- The U.S. consumes a significant portion of the world's uranium for nuclear power, yet it produces only a few million pounds of it inside the U.S. As the country has tried to focus on energy independence, there will likely be a push to potentially subsidize production by U.S uranium companies (or production by a U.S. or Canadian companies operating outside the U.S.).

- A number of U.S. uranium mining companies continue to develop their promising deposits in the U.S., Peru, Turkey, and elsewhere in anticipation of increasing uranium prices in later 2017 or 2018.

- Australian-origin and Canadian-origin uranium together accounted for 47% of the uranium delivered to U.S. yearly requirement. The remaining 10% originated from Bulgaria, Czech Republic, Malawi, Namibia, Niger, and South Africa.

U.S. Nuclear Power Activity

- Ninety-nine nuclear reactors are currently licensed and operating in the U.S., and five are being closed or are in the process of being shuttered. Nuclear plants operate 24/7 and generate about 63% of the U.S. carbon-free electricity, but competitive electricity markets do not incorporate these attributes and some plants could be shuttered over the years to come on economic grounds in competition with the currently low-priced natural gas and coal-burning power plants.

- Estimated U.S. nuclear generation in December 2016 was 71.7 billion kWh, compared to 69.6 billion kWh in December 2015. Estimated U.S. nuclear generation for the full year 2016 was 804.9 billion kWh, compared to 797.2 billion kWh in 2015.

- Refueling outages in 2016 averaged 35 days, one day less than the 2015 average. Fifty-one reactors refueled in 2016, compared to 63 in 2015.

- The estimated full-year generation for Palo Verde 2, 11.7 billion kWh, was higher than any other unit's 2016 estimated total in the U.S.

- ❖ The U.S. fleet's average estimated capacity factor in December 2016 was 96.2%, compared to 94.8% in December 2015. Eighty-five reactors operated at 99 percent or higher capacity factor during December (the remaining 14 reactors are either down for re-fueling, repairs, or shuttered).

- ❖ The average estimated capacity factor for the full year 2016 was 91.5%, compared to 92.2% for 2015.

- ❖ In January 2017, Entergy Nuclear and the state of New York reached an agreement to retire the two nuclear reactors at the Indian Point Energy Center, located in Buchanan, New York, about 25 miles north of New York City.

- ❖ Indian Point is one of four nuclear power plants in New York state and accounts for about 12% of total electricity generated from all sources statewide. Under the agreement, Entergy will retire one reactor in April 2020 and the other in April 2021.

- ❖ In the U.S. and worldwide, new nuclear power plants coming on line are largely balanced by old plants being retired. Over 1996-2013, 66 reactors were retired as 71 started operation. There are no firm projections for retirements yet, but the WNA estimate that at least 60 of those now operating will close by 2030, most being small plants.

- ❖ The 2016 WNA Nuclear Fuel Report reference scenario shows 132 reactors closing by 2035, and 287 new ones coming on line, which include 28 Japanese reactors coming back on line by 2035. This does not include SMRs.

- ❖ X-energy, LLC announced that it has started the conceptual design phase for its Xe-100 high temperature gas-cooled (HTGR) pebble bed modular reactor. The Xe-100 is an innovative advanced nuclear power plant design, that uses its own made-in-the-U.S., proliferation-resistant spherical nuclear fuel elements, called pebbles.

- ❖ The Xe-100 is a 200 MWt (75MWe) reactor that takes less time to construct because of factory-produced components. It cannot meltdown and is walk-away safe under any accident scenario without the need for human intervention.

Small Modular Reactors (SMRs)

- ❖ Small Modular Reactors (SMRs) continue to receive increased attention in 2017, 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 at stations around a city.

- ❖ SMRs are ideally-suited to help integrate renewables onto the grid without increasing the carbon footprint. Oregon's NuScale power module was designed to integrate with renewable energy.

- SMRs can be grouped in a series of smaller reactor modules (aka nuclear batteries) that run independently, allowing the total power output in one or more modules to be varied in response to renewables intermittency in three ways: 1) SMR offline when renewables generate power, 2) SMR adjustment to compensate for intermittent power from renewables, and 3) SMR response to extremely rapid variations in renewables power generation.

- A U.S. Defense Science Board task force evaluated energy systems for remote or forward operating bases that could replace the diesel generators that serve as the standard electrical power sources at military bases. Alternate energy sources evaluated by the task force included very small modular nuclear reactors (VSMRS).

- VSMRs are designed to operate at less than 10 megawatts and to fit in a typical shipping container, in comparison to utility-scale reactors, which typically operate at 1,000 megawatts and are not mobile. The task force concluded that the U.S. military could become the beneficiary of reliable, abundant, and continuous energy through the deployment of such nuclear energy power systems.

- Jordan and Saudi Arabia have signed agreements on cooperation in uranium exploration and carrying out a feasibility study into the construction of two small modular reactors (SMRs) in Jordan covering the exploration and mining of uranium in central Jordan and basic and applied research related to nuclear energy and technologies, design, construction and operation of power plants and nuclear reactors in addition to cooperation in research and exploration for uranium exploration and mining, and radioactive waste management.

Nuclear Waste Storage

- Bipartisan support and Republican efforts to reinstate the Yucca Mountain facility are getting some support from a number of sources, including those in the new administration.

- Nuclear Regulatory Commission hearings could start before 2019 on licensing the project designed, built, and paid for to accept spent nuclear fuel for storage from plants around the U.S., as planned 25 years ago.

- Commercial nuclear waste is not actually a waste but a solid easily-handled material that can be reused in the future and is easily and safely stored in dry casks for over 160 years. Defense waste is actually waste, not useful at all, and is highly radioactive trash, sludge, cement and salt cake, and other radioactive waste types.

- An operating deep geologic nuclear waste repository, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, is fully permitted for defense nuclear waste, but WIPP was designed to take nuclear plant waste and could easily accommodate all.

International Uranium Exploration and Development

- Drilling is also very active in Africa, and South America, in China, and in Australia; although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states (Western Australia, Northern Territory, Queensland, and even South Australia).

- The African countries have identified sizable uranium resources, but security issues are involved in almost every project, impacting exploration and production, e.g., Zambia and Niger.

- Exploration in Canada has produced numerous uranium discoveries and continue development drilling, many of which are world-class deposits located around the periphery of the Athabasca Basin of Saskatchewan.

- Substantial investment money is coming into the new Canadian uranium discoveries in support of the development of these high-grade deposits, with Chinese and Russian funding.

- Greenland is planning to begin construction of the world's fifth-largest uranium mine and second-biggest rare-earths operation to help diversify its economy and reduce its financial dependence on Denmark, even though the near-term outlook for uranium demand is weak. The mine would have an annual processing capacity of 3 million pounds per year of yellowcake and rare-earth concentrate likely shipped to others for processing into individual rare-earth products.

- Russia's Vershinnoye deposit is one of the eight deposits of the Khiagda ore field (the total reserves are estimated at 45 thousand tons (about 90 million pounds of uranium (U_3O_8)), the development of which is being carried out by Atomredmetzoloto holding company of Rosatom. Its reserves amount to 4,577 tons (9.2 million pounds of uranium), the first production is planned in 2018.

- Kazakhstan state-owned Kazatomprom announced in January that it would cut production by 10%. The company supplies 40% of the world uranium. The company also announced the opening of a Swiss marketing arm suggesting that inventory management may become a policy tool. An inventory policy rather than direct supply would see it act as more of a swing producer or swing seller, using inventory and production levels to influence the uranium price in the future.

International Nuclear Power Activity

- There are currently 447 operating nuclear reactors in 31 countries, with a total installed generating capacity of more than 390,000 megawatts (MW).

- Construction of new power plants and continued operation of the 99 existing nuclear power plants in the U.S., with 4 under construction, 18 ordered (or planned), and 24 proposed new plants, and 447 plants in 30 countries around the world, all of which require large supplies of nuclear fuel every 3 to 4 years. The uranium price is related to demands of these plants and must be anticipated years ahead of actual sales, which in turn increases or decreases exploration as well as mining activities.

- Global nuclear generating capacity is expected to see 2.3% annual growth between 2012 and 2040, from 2.3 trillion kilowatt-hours to 4.5 trillion kWh. Its share of total primary energy over this period will increase from 4% to 6%, or more if the current expansion continues worldwide and in the U.S.

- 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 for importing natural gas and attempts to ramp up wind and solar energy on a large scale that failed has impacted Japan's economy severely.

- The economic stress created should be relieved over the next decade as the nuclear plants replace the need for imports and renewables.

- China had a three-year hiatus from allowing any nuclear reactor project to be developed, as it rewrote its regulations, but now (2017) China has 36 nuclear power reactors in operation, 21 under construction, and 40 others planned.

- In 2015, Russia and Jordan signed an intergovernmental agreement on cooperation in the construction and operation of two 1000 MWe VVER units at Az-Zarqa in central Jordan. Feasibility studies on the construction of those units are expected to be completed by mid-2017.

- In early 2017, China and Saudi Arabia signed a cooperation agreement for a joint study on the feasibility of constructing high-temperature gas-cooled reactors (HTGRs) in the Middle Eastern country.

- Sweden has changed its mind and now will construct nuclear reactors, and even Germany, after observing the impact of burning brown coal, having to buy natural gas from Russia, and after attempting to get renewables into operation, has demonstrated the value of nuclear power.

- Other countries have taken the Fukushima incident as a reason to change regulations, which stalled the development of additional reactors in Germany and other countries but this has all but melted away as the true impact of Fukushima becomes known, i.e., no deaths, no radiation impact.

Coal vs. Nuclear Power and Natural Gas

- 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 of using coal are always significant drivers.

- China, the U.S., and India will remain as the top three coal-consuming countries, together accounting for more than 70% of world coal use. Natural gas consumption will grow 1.9% annually over the same period.

- Although consumption of non-fossil fuels is expected to grow faster than consumption of fossil fuels, fossil fuels will still account for an incredible 78% of primary energy in use in 2040, whereas coal will be the world's slowest growing energy source, rising by 0.6% annually from 153 quadrillion Btu in 2012 to 180 quadrillion Btu in 2040.

- Republic of South Africa, a top ten producer of coal worldwide and is one of the leading coal export nations, is considering a move away from coal burned to produce electricity and towards low-carbon sources like nuclear and renewables. Currently, more than 90% of electricity is generated by coal, with only 3% from nuclear, 3% from natural gas and 2% combined from conventional and pumped hydroelectric.

- Asia is the world’s largest consumer of liquefied natural gas (LNG), accounting for three-quarters of global LNG trade and one-third of total global natural gas trade.

- After falling in six out of seven quarters from mid-2014 to mid-2016, coal production rose in the third and fourth quarters of 2016.

- Among the coal supply regions, the Powder River Basin in Montana and Wyoming saw the largest increases in the second half of 2016. The increases in coal production were driven by an increase in coal-fired electricity generation, which occurred as natural gas prices increased.

Renewable Energy vs. Nuclear Power

- Wind and solar energy projects are being funded and operated under large subsidies while their operation and maintenance costs remain underreported. 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. This is not to say that wind and solar 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 …. but they still must have a back-up power grid until battery systems are developed that can serve as back-up.

- ❖ Six years after the 2011 tsunami in Japan, even Germany, Sweden, and France are beginning to realize after serious economic evaluations that it would be less expensive to keep their nuclear power plants operating then transition to a wholesale commitment to wind/solar construction for other than remote areas not requiring grid-support. Reliance on brown coal and large-scale wind/solar systems have neither met climate needs of the former, nor have the latter provided reliable or stable electricity costs.

- ❖ One such 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 resurgence in the U.S. and elsewhere in the world, but not without some resistance from the usual opponents supporting protection of river ecosystems.

- ❖ Over the past year, a transitional period has become even more apparent from reductions in burning coal, oil, and to building renewables, such as solar and wind systems (in the hopes they prove to be cost effective) and nuclear power and natural gas (to provide the grid power).

- ❖ Although gaining popularity, wind in the UK is very intermittent and the electricity output of a wind turbine is proportional to the cube of the wind speed. A 20% drop in wind speed gives a fall in wind electricity supply of almost 50%. Because of wind intermittency the average output of the UK wind farm fleet is only about 30% of rated (installed) capacity, with peaks of up to about 80% and lows of less than 5% of rated capacity for about 7% of the time.

Thorium Resources and Thorium-Based Reactors

- ❖ 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.

- ❖ Several reactor concepts based on thorium fuel cycles are under consideration in the U.S. and elsewhere, but a considerable amount of development work remains before it can be commercialized in China, the U.S., India, etc.

- ❖ India has been developing a long-term three stage nuclear fuel cycle to utilize its abundant thorium resources. The construction of a 500 megawatt electric (MWe) prototype fast breeder reactor at Kalpakkam, near Madras, was about 94% complete in February 2013. It will have a blanket with thorium and uranium to breed fissile 233U and plutonium respectively.

Rare-Earth Resources

- 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.

- While in many cases the world major rare-earth producers hold large reserves, some countries have low rare-earth production and high reserves. The U.S. did not produce rare earths in 2016, but its reserves are the seventh-highest in the world. It is possible that the U.S. and others could become bigger players in the industry in the future.

- Rare-earths reserves by country, with a focus on the seven countries whose reserves are over 1 million MT, i.e., China: 44 MT; Brazil: 22 MT; Russia: 18 MT; India: 7 MT; Australia: 3.4 MT; Greenland: 1.5 MT; and U.S.: 1.4 MT, not including new mine in West Texas.

- Russian-born billionaire Vladimir Iorich has put in a bid to buy the shuttered Mountain Pass rare-earth mine in California, raising red flags for U.S. lawmakers concerned about the U.S. dependence on foreign countries for REEs and other metals necessary to maintain the U.S. military high-tech arsenal.

- To help promote domestic production of these strategic metals and block foreign firms from buying rare-earth mines on U.S. soil, Rep. Duncan Hunter, R-California, introduced the Materials Essential to American Leadership and Security, or Metals, Act to the House.

- The legislation could be advantageous for Ucore Rare Metals, which has a rare-earth element project in Southeast Alaska and is developing a system to recover strategic metals from other domestic sources, such as the new rare-earth mine in west Texas, operated by Texas Mineral Resources Corp, and others in the U.S.

- A large-scale uranium mine planned for Greenland would recover over 100 million tonnes of uranium and rare earths via an open pit mine in Kvanefjeld in southern Greenland, which is located about 8 km from the village of Narsaq.

Social Adversaries to Uranium Mining & Nuclear Power Development

- The adversaries of nuclear power (and of mining of uranium) continue to apply the same ill-founded and exaggerated claims throughout the world, mostly generated by competing energy interests and by paid commercial adversaries (wind, solar, and associated industries).

- ❖ The current technical media are filled with optimism for an expansion of nuclear power, which stands in stark contrast to the media of the 1970s, which stampeded the general public away from nuclear power by pandering to their unfounded fear of radiation leaks at Three-Mile Island, and a few years later at Chernobyl in the Ukraine.

- ❖ Industry and government need to inform and educate adversaries 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 low cost, 24/7 availability, and climate sensitivity.

- ❖ As a result of this transition, the Obama Administration’s concept of “informed consent of the public,” has fostered years of pandering to special interests, and has polarized energy selection by allowing political influences to replace rational selection based on economic and environmental factors in the U.S.

Radiation Perspectives

- ❖ Finally, on the basis that the impact of radiation is difficult for many people to understand and place into perspective, a new section has been included in the UCOM report for this Annual Report to provide information regarding ambient radiation and the exposure to humans.

- ❖ Since the large earthquake and tsunami causing the nuclear reactor meltdown in Japan on March 11, 2011, there have been no deaths directly caused by the radiation leak from the nuclear plant in Fukushima. The latest update (in April) by the World Nuclear Association on the Fukushima disaster states that there have been no deaths or cases of radiation sickness caused by that nuclear accident.

INTRODUCTION

The emphasis of this EMD Annual Report is on 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.

As indicated, 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 construction, and plant shuttering and retirement plans, as well as by the perceptions by government and industry leaders of the viability and safety of nuclear power used to generate electricity.

As discussed previously (EMD UCOM 2016 Annual Report (more) and EMD UCOM 2016 Mid-Year Report (more)), energy competition among nuclear energy, coal, natural gas, and various forms of renewable energy, has resulted in projects based more on the consumer price of electricity than on the impact to the environment.

The competition is complicated by the federal government's subsidizing and promoting wind and solar energy projects (at the expense of nuclear power), all within a complex transitional energy framework in force today in the U.S. that state and federal lawmakers in an under-regulated, regulated, free-market system are failing to keep long-term prices of electricity under control.

We are clearly in a transitional period from burning coal, oil, and natural gas, to using renewables, such as hydroelectric and nuclear (to provide the grid power) and solar and wind (should the latter two prove to be economic as subsidies expire) (more). It is clear that natural gas, hydroelectric power, and nuclear power will continue to provide the grid power in the U.S. for years to come (more), although the development of large-scale battery storage may provide some clarity in energy selection in the near future (more).

As a result of this transition, the Obama Administration's concept of "informed consent of the public," has fostered years of political pandering to special interests, and has polarized energy selection by allowing political influences to replace rational selection based on economic and environmental factors in the U.S. and other countries, notwithstanding the issues surrounding the long-standing sources of power that have driven the U.S. economy for more than 150 years, e.g., coal, and oil and gas.

These conflicts are at the root cause of the unnecessary delays (not-so-subtle road blocks) in the nuclear permitting process under the guise of opposing reviews introduced during public interaction, but ignoring informed scientific information and harboring NIMBY or generalized anti-nuclear intentions. These have even been encouraged by those within the government naïvely promoting solar and wind energy. This could all change if the new Administration fulfills its encouragement of nuclear power (more), and more recently in addressing current regulations (more).

ENERGY SUBSIDIES

Much of the confusion regarding subsidies involves the definition of a subsidy. There are direct, indirect, and so-call externalities (human health and environment) that are considered a type of subsidy (more). The latter is especially impacted by coal, which is expected to continue to decline for burning to produce electricity not only because of human health concerns (of humans working underground and carbon-lung issues, as well as underground methane leaks and associated explosions), but also because of the impact on climate change because of burning with CO_2 , mercury, and particulate emissions (more). The center issue with coal use now is in the deterioration of jobs in the coal industry, but other uses of coal are under study on a broad front (more).

States are beginning to address the issues surrounding energy competition by now attempting to level the market by including subsidies for nuclear power for parity with renewables (more), and to counter low gas prices, which are expected to rise in the future if not modulated by regulation with subsidies or other tax allowances (more). The few articles or reports that address subsidies were written to support a particular point of view, but these complicate matters even further with selective reasoning (more). An independent report is clearly needed on the subject of energy subsidies because the energy selection by utilities, states, and other entities making such decisions are impacted economically by subsidies.

It appears, however, that the oil and gas industries now receive far fewer state and federal subsidies than the renewable energy industries, the highest going to wind, solar, biomass, etc. The lowest subsidy going to nuclear energy (see Table 2).

Recognizing the benefits of some energy resources over others are beginning to emerge in providing ways to level the price competition to their essential elements, i.e., 1) environmental impact, 2) reliability, and 3) coverage. The first element is the basis for the denial of climate change since burning either coal or natural gas impacts the environment more than nuclear and renewables (more). Second, reliability favors nuclear and natural gas since wind and solar are not energy resources that provide electricity 24/7 and require a pre-existing 24-hr power grid. However, the new commercial batteries (storage units) could change the cost dynamics for renewables (more).

Finally, grid coverage favors the historical energy resources because the power grid has developed over the past 100 years with utility lines now powered by nuclear plants and natural gas plants supplied by pipelines (new and old) and ground transportation (trucks, trains, ships) (more).

Table 2

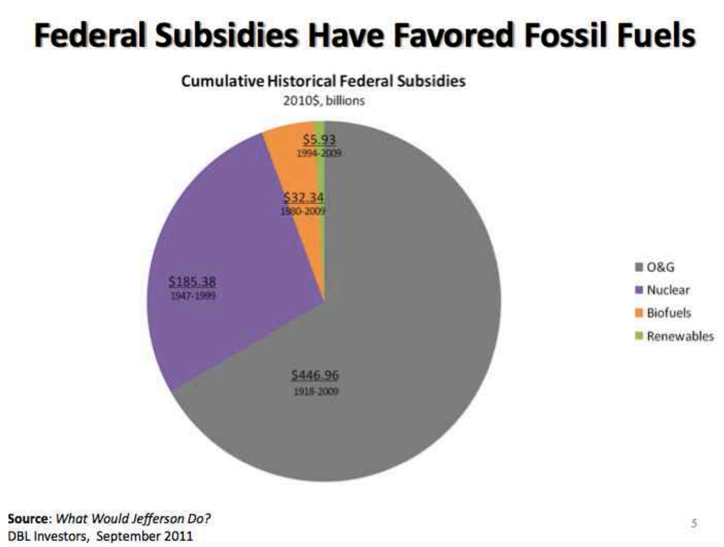
(Shepstone, (2015))

Direct Federal Energy Subsidies, 2010-2013 (Millions)					
Energy Type	**2010**	**2013**	**Change**	**% Chg.**	**% of Total**
Wind	$4,063	$4,274	$211	5.2%	33.2%
Low-Income Home Energy Assistance	$5,378	$3,116	-$2,262	-42.1%	24.2%
Solar	$461	$2,969	$2,508	544.0%	23.0%
Conservation	$3,091	$833	-$2,258	-73.1%	6.5%
Other	$623	$397	-$226	-36.3%	3.1%
Biomass	$178	$332	$154	86.5%	2.6%
Geothermal	$65	$312	$247	380.0%	2.4%
Other	$317	$209	-$108	-34.1%	1.6%
Hydropower	$60	$197	$137	228.3%	1.5%
Coal	$46	$74	$28	60.9%	0.6%
Biofuels	$348	$72	-$276	-79.3%	0.6%
Natural Gas and Petroleum	$80	$62	-$18	-22.5%	0.5%
Nuclear & Other	$70	$45	-$25	-35.7%	0.3%
Totals	**$14,780**	**$12,892**	**-$1,888**	**-12.8%**	**100.0%**

Historically, the global oil and gas and nuclear energy once received far greater subsidy support than now (more), and Figure 1. Note that the figure includes data prior to 2011, well before renewables surged in the past 5 years. For example, Table 2 covers the period from 2010 to 2013 and show solar, geothermal, hydropower (dams and pumped storage) and even coal with increasing subsidies. Although now data are available now for current levels, wind has certainly surged in recent years at the expense of solar and biomass, but the data remain to be seen.

Figure 1

(Parkinson (2016)



The recent studies underway by the new administration to evaluate the role that regulations play in driving energy selection by environmental concerns about the impact of climate change will certainly reveal how the DOE establishment responds to strictly political influences now hovering over the government bureaucracy. The cited DOE memo (above) from the new administration implies that renewable energy subsidies own part of the blame in the current lack of a coherent and cost-effective energy-selection policy in the U.S. because previous analysts have documented the market-distorting effects of federal subsidies that boost one form of energy at the expense of the other forms of energy, especially as occurred during the previous administration via the EIA's overly favorable treatment of renewable energy reporting (more).

New ways are being developed to maintain the economic viability of nuclear power plants. These range for new subsides from the federal or state government to power utilities that deal with state governments (more). These cost-leveling approaches appear to be gaining favor by the general public on the basis that natural gas prices are currently, albeit artificially, low and will likely rise in the future, and on the basis that coal-produced electricity will be phased out sooner or later, assuming there are reasonable alternatives.

See further discussions on subsidies, pp. 50-53, this report.

THE URANIUM PRICES

The uranium price is obviously affected by the economic health of the nuclear power industry in the U.S., at least. The more plants, the higher the demand for fuel. As new uranium supplies from new mines have come on-line and demand has not, a condition of oversupply developed creating depressed prices until 2017, which now shows some increase as production have been limited by some large producers, i.e., Kazakhstan, to be discussed later. The principal impact on current prices is the overhang of uranium supplies remaining in the market (from a lack of consumption) resulting from the slow recovery of nuclear operations in Japan (more).

Other impacts on the uranium price include the U.S. government, which has just finished dumping some of their back-up yellowcake supply into the U.S. market (more). The U.S. government sales are more than double the expected uranium production this year in the U.S. However, proceeds from the sale of federal uranium inventory were used to fund the cleanup of legacy federal government nuclear facilities, such as the Paducah and Portsmouth uranium enrichment plant sites. This is an example of the government attempting to pay for its own activities albeit at the expense of the uranium industry (more).

The current uranium production growth has already been built into the supply chain that has come on-line with ramping up production and this creates an increased amount of uranium to be sold on the basis of the spot price into a weak market, which has been keeping prices low (more). As of late March, 2017, the price remains around \$25.00 to \$30.00 due to a long-term uranium oversupply, although with the Japanese re-starts, combined with Chinese and other new reactor start-ups, this will serve to diminish the oversupply and serve as a catalyst for rising uranium spot prices along with increasing utility contract prices over the long term. Figure 2 illustrates the "chart" view that suggests the bottom (and turnaround) of the uranium price has just begun.

Figure 2

Historical Spot Price of Uranium (U_3O_8)

However, even with the current low prices, many mining companies are moving forward with uranium exploration and mine-development projects hoping to capitalize on the eventual rebound in prices expected in later 2017 or 2018. The recent uranium spot-price increases involve the perception of supply consumption, which ultimately drives an eventual uranium price bull market, but with early price volatility (see Figure 3).

Even at the current low prices, only 6% of the 57 million pounds U_3O_8 delivered in 2015 was U.S.-origin uranium at a weighted-average contract price of \$43.86 per pound (committed to individual utilities). Foreign-origin uranium accounted for the remaining 94% of U.S.-contracted deliveries at a weighted-average contract price of \$44.14 per pound U_3O_8. Uranium originating in Kazakhstan, Russia, and Uzbekistan accounted for 37% of the 57 million pounds.

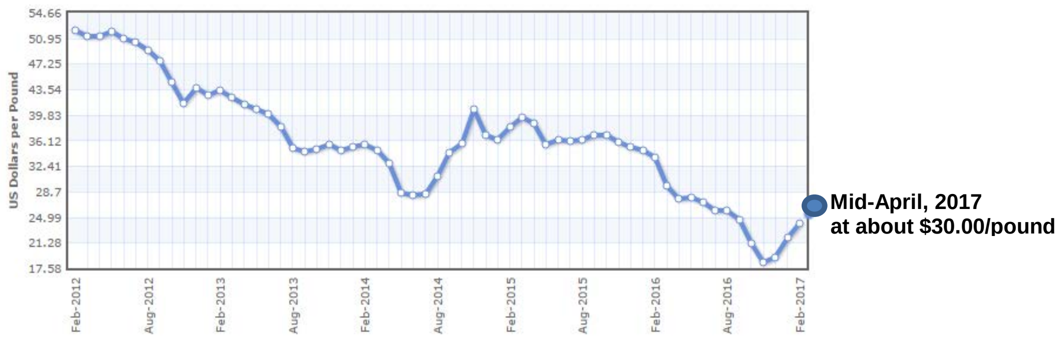


Figure 3

2012 - 2017 Spot Price of Uranium (U_3O_8)

Industry Response to Uranium Price Fluctuations

In the U.S., Energy Fuels and UEC are positioning themselves for the approaching price rise. Large overseas projects are also moving forward on expectations of future price increases (more).

The new Greenland projects has the added advantage of future production of uranium and rare-earths which supports the economic models from both uranium and rare-earth revenue streams. Only if prices collapse for both would such a project become untenable (more). Greenland is in the technical and media news for reasons relating to climate change research, astrogeology, and to the development of uranium, thorium, rare earths, and other metals, some of which may have had their origin in the large impact structures identified a few years ago (more).

This project will likely begin production soon if only because of its multi-product output and resulting supporting revenues received even when uranium prices are relatively low. But the Greenland project could stock-pile their uranium production now and wait until prices improve, just as the large Kazakhstan uranium mines have announcement earlier this year. Their rare-earth production alone could support the Greenland mine in the meantime. This process would aid in increasing the lifetime of the Greenland operations and serve to optimize profits (and increase and extend royalties for the Greenlanders).

Uranium Price Recovery

Regor (2016) indicated that there are two parts to why the spot uranium price has not recovered to any significant extent. First, the November-December, 2016, uranium spot market ($18.00 to $20.00 /pound U_3O_8) has been rather tight in terms of overall percentage of production, and there have been some nuclear-plant closures (which decreases demand), in addition to slow re-starts in Japan after Fukushima (which leaves uncommitted fuel available at lower prices).

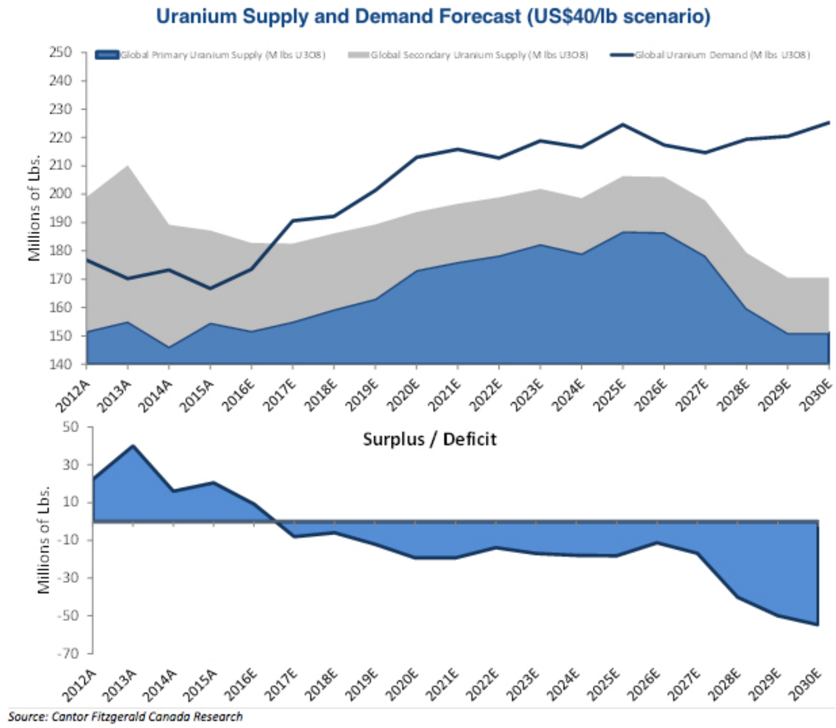
And with surplus production growth already been built into the supply chain that has come on-line and ramping up production at low cost from existing in-situ mines (Wyoming, Kazakhstan, etc), this has created a large amount of uranium to be sold into a weak spot market. Cameco Corp.'s Cigar Lake operations are an example of operating in a weak market, considering its high-grade deposits creating a low-cost operation in the range of $10 to $15/pound, which even provides a substantial margin of profit.

Fountain (2017) opines on the nature of the uranium market and provides an interesting summary, as follows:

- Despite negative sentiment from Fukushima, analysts say uranium fundamentals support rising prices.
- The World Nuclear Association says a 100% increase in international power stations is being either planned or proposed, 160 already being planned.
- The price of uranium got off to a good start in 2017, but has it fizzled out? The ETF chart for the stock URA suggests not, and it is just correcting the February high.
- According to several analysts the demand supply fundamentals for uranium should weigh on the demand side into 2020, with the world becoming increasingly more rather than less reliant on nuclear energy. Analysts are generally bullish, and uranium has made a solid advance from the price floor created in November 2016.
- David Talbot an analyst at Dundee Capital Markets, is forecasting a 6% annual growth in uranium demand through 2020, saying that up to 20% of demand is not covered from current production for the worlds existing 437 nuclear reactors.
- The historical and anticipated uranium supply, demand, and surplus/deficient are illustrated in Figure 4.
- *Morningstar* analyst David Wang predicts prices will rise to about $65 a pound by 2019.
- *MINING.com* suggests that the period from 2017-2020 will be a landmark period for the nuclear industry and uranium stocks, as the global operating nuclear reactor fleet expands, and
- The 2011 disaster at Fukushima created an irrational disconnect between sentiment and uranium fundamentals.

Figure 4

Fountain (2017)



Click to Expand Figure

- *Scientific American* opines that nuclear energy clean bonafides may be its saving grace in a wobbling global energy market that is trying to balance climate change ambitions, skittish economies and low prices for oil and natural gas.

- In all, over 160 power reactors with a total net capacity of some 182,000 MWe are planned and over 300 more are proposed. Energy security concerns and greenhouse constraints on coal burning have combined with basic economics to put nuclear power back into an expansion phase over the next 15 years, at least.

Mining companies are still making decisions based on the anticipated future contract price, not the current spot price. The breakeven-price for many in-situ mining operations that have passed capitalization by being in operation for some years is in the range of about $25-$35/pound, but new start-up mining operations usually require about $60/pound to cover initial capitalization and start-up costs in order to demonstrate financing approved funding.

The second reason is that a spot uranium price recovery has re-surfaced as Fukushima had a longer and more lasting impact on the overall market than many analysts thought was possible. This past year has seen major changes in the number of reactors constructed in China and elsewhere (more).

Mainland China has 35 nuclear power reactors in operation, 21 under construction, and more about to start construction, with the following considerations:

- The impetus for increasing nuclear power share in China is air pollution generated by coal-fired plants (although China must continue to burn coal to provide electricity to their citizens over the short-term,

- Additional reactors are planned, including some of the world's most advanced, which double their nuclear capacity to at least 58 GWe by 2020 to 21, then up to 150 GWe by 2030, and much more by 2050,

- China's policy is to have a closed nuclear fuel cycle, i.e, fast, breeder reactors that consume fuel leaving minimal waste,

- China has become largely self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle, but is making full use of western technology (Westinghouse and GE), while adapting and improving it, and

- China's policy is to 'go global' with exporting nuclear technology including heavy components in the supply chain and currently have at least five overseas projects in construction, and many more planned, with many such projects also financed by China to further government foreign policy.

On January 10, 2017 Kazatomprom Chairman, Askar Zhumagaliyev, announced that due to the prolonged recovery in the uranium market, the planned 2017 production from the Republic of Kazakhstan will be reduced by approximately 10% (more). This will amount to a volume greater than 2,000 Mt U (or more than 5 million lb U_3O_8) reduction in 2017 planned output, which is about 3% of total global uranium production.

Their management has had to make responsible decisions in light of the depressed market challenges because their mineral assets are far more valuable to their shareholders and stakeholders being left in the ground for the time being, rather than adding to the current oversupply situation.

A greater value for their resources will instead be realized when produced into improved markets in the coming years. This has set the stage for the recent increases in the spot price on the uranium world market by 10%, up to 24.25 US$/lb. Kazakhstan is the world's largest uranium producer; therefore, the production reduction in the country may facilitate further uranium price increases in the near future.

So, as the supply has become available (through mine production and from unused fuel in Japanese contracts coming available in 2011) and demand has not, a condition of oversupply has developed. As to the 2018–2019 period, analysts suggest that decline in production and expected significant rise in supply will create a shortage. Regor (2016) looked to that time frame as having the potential for a full recovery in uranium prices to a more sustainable long-term price of \$50–60/lb U_3O_8.

But the major issues of fuel availability always come down to the cost of fuel and then the location of the fuel. Aside from sources of fuel in the U.S., only Canada and Australia are favorite U.S. trading partners for producing yellowcake, among others such as Kazakhstan. Over 90% of uranium purchased by U.S. commercial nuclear reactors is from outside the U.S. Note that countries and values are from 2012 data, another example of EIA using out-of-date data and management (more).

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 for importing natural gas and attempts to ramp up wind and solar energy on a large scale that failed. These actions have impacted Japan's economy severely. This has occurred as their nuclear plants were shuttered, but, the plants have begun to restart, and the economic stress should be relieved over the next decade (more).

Freebairn (2015) reports that the Japanese fleet of 43 nuclear reactors, with a total installed capacity of about 42,000 MW, has been largely idled since September 2013, when the country adopted stricter nuclear safety requirements in the wake of the Fukushima tsunamis that damaged a few power plants along the coast of Japan.

The nuclear shutdown in Japan left a gap of around 30% in electricity supply. This gap was closed mostly at the time of expensive fossil fuels, primarily liquefied natural gas (LNG), but also by oil, and, from 2013 on, by coal.

Electricity savings and, since 2012, additional renewable electrical capacity also helped to close the gap. Yet by the end of 2013, import dependence had risen to 94% from 80% in 2010. Annual CO_2 emissions from power generation had grown by more than 110 million tonnes, or by 25%. Electricity prices had increased by 16% for households and 25% for industry, according to IEA data, and were set to continue to rise fast.

The situation was unsustainable for the long term. Thus, the government decided to fundamentally rethink its energy policy and move to restart most of the nuclear power in Japan (more).

Reactors have to receive a safety review approval from the Nuclear Regulation Authority, secure approvals from local towns and prefectures, and obtain final NRA approval of preoperational tests before it can load nuclear fuel and begin to generate electricity once again.

Twenty-four of the 43 reactors have applied to NRA for safety review; it is unclear how many of the remaining units will apply in the future. In addition, Japan Electric Power Development Co. has applied for NRA safety review of its new 4th Generation Ohma nuclear reactor, which is under construction and could come online by the end of 2021.

Additional restarts of reactors in Japan will be a positive event from a market perspective, but it will have little impact on the actual supply and demand equation until many more reactors are restarted (more). 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 with others under construction.

Current and ongoing updates on activities in Japan are available via the I2M Web Portal. The important role Japan is playing in the nuclear power expansion in the world, either directly or indirectly, is evident in the search results (more).

LONG-TERM CONTRACT PRICES

EIA (2016) recently reported that operators of U.S. civilian nuclear power reactors purchased a total of 57 million pounds U_3O_8 of deliveries from U.S. suppliers and foreign suppliers during 2015, at a weighted-average price of \$44.13 per pound U_3O_8. The 2015 total of 57 million pounds U_3O_8e increased 6% compared with the 2014 total of 53 million pounds U_3O_8. The 2015 weighted-average price of \$44.13 per pound U_3O_8 decreased slightly by 4% compared with the 2014 weighted-average price of \$46.16 per pound U_3O_8.

Sprott (2016) concludes that China certainly leads in long-term nuclear power plant construction. If all of China's planned, proposed, and under construction reactors are built, that country alone would boost the global reactor count by 51%. But China actually only represents 36% of the global pipeline. Other countries on the nuclear build list include India, South Korea, Russia, the UAE, and the U.S.

India just ratified a new nuclear liability law that addresses an issue that has been limiting deals for new reactors. The old law put liability in the event of an accident on reactor vendors, rather than operators, as is the norm, and that liability had deterred foreign vendors from signing up to sell reactors to India for decades. Now, with that rule changed, there should be a flood of new Indian reactor deals. That matters because India is right behind China in terms of planned reactors over the next decade, with plans to construct about 60 reactors.

Operators of nuclear reactors do not risk running out of fuel, because that would cause serious system problems. In addition, they cannot load the rough yellowcake into their reactors; they need fuel rods, which are made from yellowcake in a process that requires between a year and a year and a half to complete. To provide a time buffer, operators cover their uranium fuel needs at least three years out, and often as much as a decade out.

A major uranium production shortfall is predicted to arrive 2019 (more). During the uranium price spike in 2007, mining companies signed supply deals out of concern that prices would stay very high, improving their economics. Shortly thereafter, prices declined. Nevertheless, those contracts were still binding, and many of those incorporated ten-year terms.

A number supply contracts will expire this year (2017). As a result, nuclear operators are uncomfortably uncovered three years out. They have been slow to sign new contracts to replace those about to expire because they have been able to pick up cheap uranium on the spot market over the past five years. Power -plant operators are, no doubt, evaluating the supply-and-demand data, contract timelines, and price predictions, and they have likely concluded that the market is setting up to tighten this year or next.

So, new contracts are imminent. And those new contracts will support higher prices because producers will demand it. Why? It is because mining companies need higher prices to develop new mines, i.e., in the $60.00/pound range. But again, the high-grade, low cost mines in Canada and Australia can be profitable at considerably lower prices than $60.00. This was apparent during the "Cartel" days of the 1970s and 1980s when they dominated the mining industry. Smaller, lower-grade mines could not operate at a profit then until prices rose substantially years later.

Historically, power plants purchase uranium of three material types for 2015 deliveries from 36 sellers, two more than in 2014. Uranium concentrate was 55% of the 57 million pounds U_3O_8 delivered in 2015. Natural UF_6 was 30% and enriched UF_6 was 15%. During 2015, 21% of the uranium was purchased under spot contracts at a weighted-average price of $36.80 per pound. The remaining 79% was purchased under long-term contracts at a weighted-average price of $46.04 per pound (more). Data for 2016 will be released by EIA in the next few months.

Spot contracts are contracts with a one-time uranium delivery (usually) for the entire contract and the delivery is to occur within one year of contract execution (as of signed date). Long-term contracts are contracts with one or more uranium deliveries to occur after a year following the contract execution (signed date) and as such may reflect some agreements of short and medium terms as well as longer term.

New and Future Uranium Contracts

In 2015, power plant operators signed 54 new purchase contracts with deliveries in 2015 of 12 million pounds U_3O_8 at a weighted-average price of approximately $38.00 per pound. Nine new contracts were long-term contracts with 24% of the 2015 deliveries and 45 new contracts were spot contracts with 76% of the deliveries in 2015.

Power plant operators report minimum and maximum quantities of future deliveries under contract, to allow for the option of either decreasing or increasing quantities. As of the end of 2015, the maximum uranium deliveries for 2016 through 2025 under existing purchase contracts totaled 183 million pounds U_3O_8. Also, as of the end of 2015, unfilled uranium market requirements for 2016 through 2025 totaled 259 million pounds U_3O_8. Data for 2016 are forthcoming from EIA. These contracted deliveries and unfilled market requirements combined represent the maximum anticipated market requirements of 442 million pounds U_3O_8 over the ten-year period for power plant managers.

Uranium Feed, Enrichment Services, Uranium Loaded

In 2015, plant operators delivered 41 million pounds U_3O_8 of natural uranium feed to U.S. and foreign enrichers. Forty three percent of the feed was delivered to U.S. enrichment suppliers and the remaining 57% was delivered to overseas enrichment suppliers (EIA, 2016). These suppliers then ship their product on to fuel fabricators to make pellets that are loaded into an assembly for loading into a reactor (see Figure 5 for the fuel cycle).

Since the beginning of 2016, Haywood (2016) reports that there has been a significant difference in how uranium stocks have reacted to the price movements so far this year. Their report states that the TSX Venture Exchange has made gains of 29% to date.

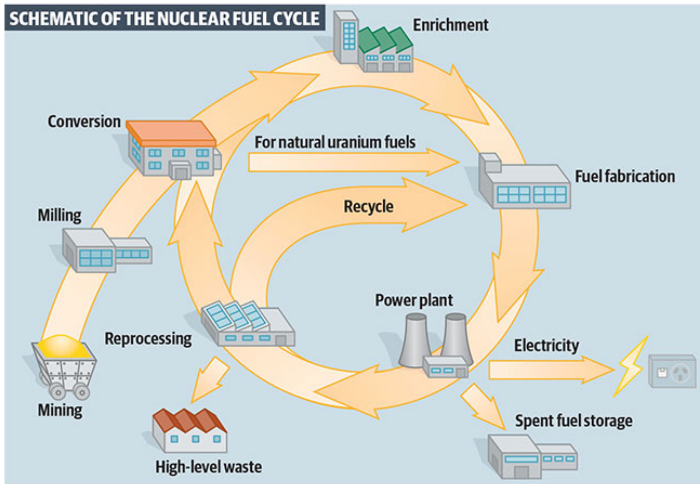


Figure 5

Nuclear Fuel Cycle

(EIA, 2016)

Haywood indicates that exploration and development companies will benefit from strong long-term fundamentals in the uranium industry, underpinned by a deep global reactor construction increase of more than 60 reactors that will require fuel over the next decade.

Many of the mining companies are counting on future price increases within the next year or two; hence the funding they are receiving is to be used to move their projects forward in anticipation of production within the next few years.

In summary, editors of the *The Focus Economics* (2016) blog states that prices have been under pressure since the nuclear incident in Fukushima in 2011, which led to the sharp decrease in demand for uranium and the shuttering of numerous nuclear reactors around the world. Moreover, the uranium market has remained oversupplied due to excess U_3O_8 inventories, thus putting downward pressure on prices. However, a depletion of stockpiles coupled with the construction of new reactors, particularly in countries such as China, India, Russia, as well as others in the Middle East, Argentina, etc., will boost prices going forward in 2017 and beyond.

Once shuttered nuclear plants are now in start-up mode, especially in Japan, Sweden, and even Germany may be re-thinking their policies about wholesale conversion to renewables and of burning brown coal, which combined, have driven up the price of electricity in Germany and increased CO_2 substantially.

URANIUM PRODUCTION IN THE U.S.

Through 4th Quarter 2016

U.S. production of uranium concentrate in the fourth quarter 2016 was 725,947 pounds U_3O_8, down 11% from the third quarter 2016 and up 16% from the fourth quarter 2015. During the fourth quarter 2016, U.S. uranium was produced at seven U.S. uranium facilities; the same number as in the third quarter 2016 (more).

U.S. Uranium Mill in Production (state)

1. White Mesa Mill (Utah)

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

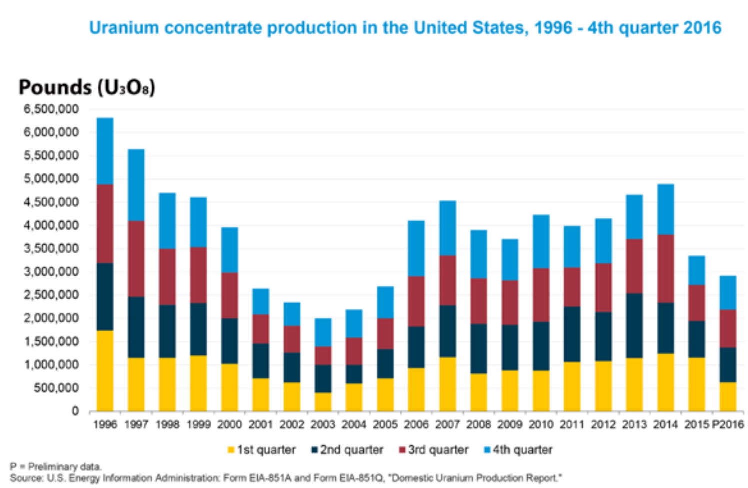
1. Crow Butte Operation (Nebraska)
2. Lost Creek Project (Wyoming)
3. Nichols Ranch ISR Project (Wyoming)
4. Ross CPP (Wyoming)
5. Smith Ranch-Highland Operation (Wyoming)
6. Willow Creek Project (Wyoming)

2016 Total - 4th Quarter

U.S. uranium concentrate production totaled 2,916,558 pounds U_3O_8 in 2016. This amount was 13% lower than the 3,343,207 pounds produced in 2015 and the lowest annual U.S. production since 2,689,178 pounds produced in 2005 (see Figure 6).

Figure 6 (EIA-2017)

(Click to Enlarge)



The status of the in-situ recovery plants in the U.S. are presented in Table 3. Notice that there are 19 such facilities in various states of readiness.

Table 3
(EIA-2017)

Domestic Uranium Production Report 4th Quarter 2016
Release Date: February 10, 2017
Next Release Date: May 2017

Table 4. U.S. uranium in-situ-leach plants by owner, location, capacity, and operating status

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 2015	1st quarter 2016	2nd quarter 2016	3rd quarter 2016	4th quarter 2016
AUC LLC	Reno Creek	*Campbell, Wyoming*	2,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	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	Partially Permitted And Licensed
Cameco	Crow Butte Operation	Dawes, Nebraska	1,000,000	Operating	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	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	Partially Permitted And Licensed
Lost Creek ISR LLC	Lost Creek Project	Sweetwater, Wyoming	2,000,000	Operating	Operating	Operating	Operating	Operating
Mestena Uranium LLC	Alta Mesa Project	Brooks, Texas	1,500,000	Standby	Standby	Standby	Standby	Standby
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	Converse, Wyoming	5,500,000	Operating	Operating	Operating	Operating	Operating
South Texas Mining Venture	Hobson ISR Plant	Karnes, Texas	1,000,000	Operating	Standby	Standby	Standby	Standby
South Texas Mining Venture	La Palangana	Duval, Texas	1,000,000	Operating	Standby	Standby	Standby	Standby
Strata Energy Inc	Ross CPP	Crook, Wyoming	375,000	Changing License to Operational	Operating	Operating	Operating	Operating
URI, Inc.	Kingsville Dome	Kleberg, Texas	1,000,000	Restoration	Restoration	Restoration	Restoration	Restoration
URI, Inc.	Rosita	Duval, Texas	1,000,000	Reclamation	Reclamation	Reclamation	Reclamation	Reclamation
URI, Inc.	Vasquez	Duval, Texas	800,000	Restoration	Restoration	Restoration	Restoration	Restoration
Uranerz Energy Corporation (An Energy Fuels company)	Nichols Ranch ISR Project	Johnson and Campbell, Wyoming	2,000,000	Operating	Operating	Operating	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	Permitted And Licensed
Uranium One Americas, Inc.	Jab and Antelope	*Sweetwater, Wyoming*	2,000,000	Developing	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	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	Operating
Total Production Capacity:			**26,975,000**					

Notes: Production capacity for 4th Quarter 2016. 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."

Ctrl+ Left Click to Enlarge Table.

URANIUM EXPLORATION IN THE U.S.

Known deposits and some new discoveries occur in 13 U.S. States, with Virginia most notable because of the potentially large size of the known deposit. A number of U.S. uranium mining companies continue to develop their promising deposits in the U.S., Peru, Turkey, and elsewhere in anticipation of increasing uranium prices in later 2017 or 2018.

Total uranium drilling data will not be available until May, 2017. See previous UCOM 2016 Annual Report (more). Drilling will increase substantially if the predicted price increases finally occur. If the number of mergers and acquisitions currently underway within the uranium industry is any indication, the industry is preparing to expand production within 2017 or soon thereafter (more), so exploration should be on the upswing already.

Recent exploration can be monitored online via the I2M Web Portal (updates), and by using more generalized search terms (here), which will reveal exploration and associated activities for uranium and other commodities as well. Google search results (current) continue to show a multitude of mergers, acquisitions and consolidations within the uranium industry.

Known deposits and some new discoveries occur in 13 U.S. States, with Virginia as the most notable because of the potentially 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 exploration in the U.S. has been conducted in Wyoming, Nebraska, Utah, South Dakota, Texas, Colorado, Alaska, Washington, Arizona, and New Mexico, and Virginia, with numerous other states having some "Frontier" potential (more). Campbell and Biddle (1977) explored the frontier uranium potential in the south-central U.S.

SIGNIFICANT FIELD ACTIVITIES IN EXPLORATION AND MINING

Other countries have set forth regulations and laws that if the letter of the law is followed, permits would be readily available to continue development drilling and resource assessment, to design mining approach, and to operate mines, for wastewater disposal, etc. So the potential time horizon for companies to reach production becomes more predictable.

But this has certainly not been the case in the U.S., where slow responses by state and federal agencies and anti-uranium mining activists and their attorneys have introduced misinformation, exaggerations, and downright falsehoods to slow or complicate the otherwise natural development of permitting in-situ uranium projects in Texas, Colorado, and South Dakota.

Wyoming does not have similar opposition because of strong state support and because Wyoming has been a major uranium producer since the 1960s without any issues of groundwater contamination from mining. Of particular note here is that natural groundwater "contamination" would be expected in and around undeveloped and undrilled roll-front uranium deposits anywhere they occur. This would involve high selenium, molybdenum, radium, radon, and other known geochemical indicators.

There are efforts being made to expose those adversarial activities attempting to sow the seeds of misinformation about the above natural “contamination”, creating unnecessary controversy and mistrust around some rural areas in the U.S. (more).

The subject areas are where uranium has formed in economic quantities and grade, such the Gulf Coast of Texas, Wyoming, and other areas, especially in southern Virginia, where a world-class deposit was discovered a few years ago and to date goes undeveloped because of NIMBY concerns by local residents, while ignoring the economic benefits to the local and surrounding areas (more).

The development of the Virginia deposit has been blocked by local and state anti-uranium mining sentiments, even though Virginia has two nuclear power plants, with two reactors at a plant in Surry County (Surry 1 and Surry 2, with start-up in 1972 and 1973) capable of generating a total of 1,638 megawatts, and two nuclear reactors in Louisa County (North Anna 1 and North Anna 2, with start-up in 1978 and 1980) capable of generating a total of 1,863 megawatts.

Having a local uranium fuel supply produced in Virginia, would provide Virginians with a sense of self-reliance as well as a major economic benefit to schools and local businesses. Electricity prices should then be stable for decades in Virginia and surrounding states. Also, once underway, the mine would generate local support, and diminish anti-nuclear opposition, and might even improve the energy markets in the area by minimizing electricity prices.

The opposition to the Virginia uranium project includes the dissemination of clearly biased articles, and reports, all designed specifically to inhibit uranium exploration and mining in Virginia (more, and more). Texas has similar opposition, but this is driven by local litigation against a uranium mining company and the State for the purposes of involving the EPA (more , see page 4, Review #28).

Energy Fuels, with projects in Texas and other western states has announced as of 2016 their combined uranium portfolio (see Figure 7). This illustrates reserves through inferred resources, much of which will likely become reserves as drilling increases in density and as the economic conditions improve in the coming years. EF is developing resources in anticipation of a protracted bull market (more).

UEC is a principal in the uranium mining industry today, their operations of which provide insight to anticipating a uranium bull market. UEC has produced and stockpiled yellowcake (uranium) during the five-year bear market with the intent to start selling its stockpile as uranium prices rise to considerably higher levels (more). That is a very smart management decision to say the least.

This assumes that funding is in place to maintain operations without revenue, for the time being. Another way to gauge how price levels impact industry is to monitor groups such as Global X Uranium. As the price exceeds the market's defined bottom, this is interpreted as a signal the bull market has begun and the uranium spot and contract prices may be rising soon (more).

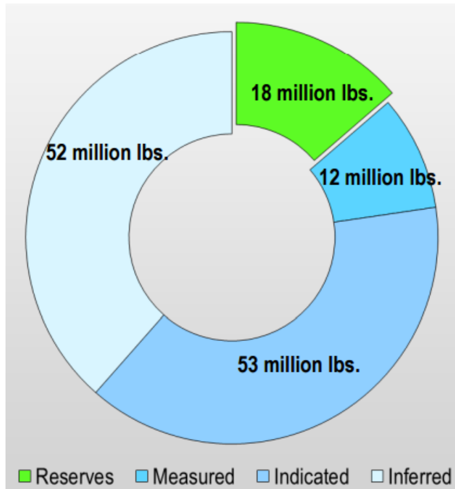


Figure 7

Energy Fuels Current Uranium Portfolio
(2017)

Plants purchased uranium of three material types for 2015 deliveries from 36 sellers, two more than in 2014. Uranium concentrate was 55% of the 57 million pounds U_3O_8 delivered in 2015. Natural UF_6 was 30% and enriched UF_6 was 15%. During 2015, 21% of the uranium was purchased under spot contracts at a weighted-average price of $36.80 per pound. The remaining 79% was purchased under long-term contracts at a weighted-average price of $46.04 per pound.

Spot contracts are contracts with a one-time uranium delivery (usually) for the entire contract and the delivery is to occur within one year of contract execution (signed date). Long-term contracts are contracts with one or more uranium deliveries to occur after a year following the contract execution (or signed date) and as such could reflect some agreements of short and medium terms as well as longer term (more). The EIA report containing 2016 data will be available in May, 2017.

Farther down the supply line, uranium prices depend on the yellowcake that is available for processing 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 unbiased reporters (more).

U.S. NUCLEAR POWER ACTIVITY

Ninety-nine nuclear reactors are currently licensed and operating in the U.S., and five are being closed or are in the process of being shuttered. Nuclear plants operate 24/7 and generate about 63% of the U.S. carbon-free electricity, but competitive electricity markets do not incorporate these attributes and some plants could be shuttered over the years to come on economic grounds in competition with the currently low-priced natural gas and coal-burning power plants (more).

Estimated U.S. nuclear generation in December 2016 was 71.7 billion kWh, compared to 69.6 billion kWh in December 2015. Estimated U.S. nuclear generation for the full year 2016 was 804.9 billion kWh, compared to 797.2 billion kWh in 2015 (more detail).

Refueling outages in 2016 averaged 35 days, one day less than the 2015 average. Fifty-one reactors refueled in 2016, compared to 63 in 2015 (more). The estimated full-year generation for Palo Verde 2, 11.7 billion kWh, was higher than any other unit's 2016 estimated total in the U.S. (more).

The U.S. fleet's average estimated capacity factor in December 2016 was 96.2%, compared to 94.8% in December 2015. Eighty-five reactors operated at 99 percent or higher capacity factor during December (the remaining 14 reactors are either down for re-fueling, repairs, or shuttered). The average estimated capacity factor for the full year 2016 was 91.5%, compared to 92.2% for 2015 (more).

Nuclear plants make up the four largest power plants in the U.S., and seven of the ten biggest power plants, based on annual production (not nameplate capacity) because capacity factors are high in nuclear plants:

1. Palo Verde Nuclear Station 32,846,202,000 kWhs
2. Browns Ferry Nuclear Station 26,738,300,000 kWhs
3. Oconee Nuclear Generating Station 21,193,381,000 kWhs
4. South Texas Project Nuclear Station 20,651,667,000 kWhs
5. Grand Coulee Hydroelectric Station 20,266,322,000 kWhs
6. Braidwood Nuclear Station 20,263,665,000 kWhs
7. West County Energy Center (NGCC) 19,764,922,000 kWhs
8. Byron Nuclear Generating Station 19,252,381,000 kWhs
9. Limerick Nuclear Generating Station 19,077,244,000 kWhs
10. Scherer Coal-fired Power Plant 18,894,546,000 kWhs

Conca (2015) notes that the Grand Coulee Dam operations have decreased from first in nameplate capacity to fifth place in actual production. Only three of the top ten are *not* nuclear power plants – one hydroelectric, one natural gas and one coal. And most of the following ten are nuclear as well. These large power plants, and the next few dozen, are critical to the lives and livelihoods of 100 million Americans. Out of almost 5,000 power plants in the U.S., these few large facilities provide a significant amount of power to U.S., and are located in critical areas that support the largest population centers in the U.S. (more).

In January 2017, Entergy Nuclear and the state of New York reached an agreement to retire the two nuclear reactors at the Indian Point Energy Center, located in Buchanan, New York, about 25 miles north of New York City. Indian Point is one of four nuclear power plants in New York state and accounts for about 12% of total electricity generated from all sources statewide. Under the agreement, Entergy will retire one reactor in April 2020 and the other in April 2021 (more).

In the U.S. and worldwide, new nuclear power plants coming on line are largely balanced by old plants being retired. Over 1996-2013, 66 reactors were retired as 71 started operation. There are no firm projections for retirements yet, but the WNA estimate that at least 60 of those now operating will close by 2030, most being small plants. The 2016 WNA Nuclear Fuel Report reference scenario shows 132 reactors closing by 2035, and 287 new ones coming on line, which include 28 Japanese reactors coming back on line by 2035. This does not include SMRs.

X-energy, LLC announced that it has started the conceptual design phase for its Xe-100 high temperature gas-cooled (HTGR) pebble bed modular reactor. The Xe-100 is an innovative advanced nuclear power plant design, that uses its own made-in-the-U.S., proliferation-resistant spherical nuclear fuel elements, called pebbles (more). The Xe-100 is a 200 MWt (75MWe) reactor that takes less time to construct because of factory-produced components. It cannot meltdown and is walk-away safe under any accident scenario without the need for human intervention.

Ninety-nine nuclear reactors are currently licensed and operating in the U.S., and five are being closed or are in the process of being shuttered. Nuclear plants operate 24/7 and generate about 63 percent of the U.S. carbon-free electricity, but competitive electricity markets do not incorporate these attributes and some plants could be shuttered on economic grounds that are in competition with the currently low-priced natural gas and coal-burning power plants (more).

The recent technical media are filled with optimism for an expansion of nuclear power (more), which stands in stark contrast to the media of the 1970s, which stampeded the general public away from nuclear power by pandering to their unfounded fear of radiation leaks at Three-Mile Island and the Chernobyl plant in the Ukraine. The media now has turned to reality in assessing the value of the standard nuclear reactors and of the potential of the new, small modular reactors (SMRs), which will be discussed later in this report.

Both types 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 the current un-natural economic restraints created by regulatory circumstances in the U.S., nuclear power continues to generate electricity that is still almost "too cheap to meter," and natural gas was once cheap enough to flare (more). However, coal still is the chief source of energy in the U.S., but its use for burning is finally on the decline. Alternative uses of the vast carbon (graphene) within coal resources are being explored (more) and (more).

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 none the less shuttered some nuclear plants and left others at risk of being closed (more). The Indian Point plant has just announced plans to close by 2021 (more). This condition will not likely change until a) the natural gas prices rise substantially, or b) the old gas pipelines within cities create notable additional media events that would tend to drive the general public and regulators away from natural gas and toward nuclear power, even more so than now (more 1) and (more 2, including coal plants).

SMALL MODULAR REACTORS (SMRS)

Small Modular Reactors (SMRs) continue to receive increased attention in 2017, 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 at stations around a city (more).

SMRs are ideally-suited to help integrate renewables onto the grid without increasing the carbon footprint. Oregon's NuScale power module was designed to integrate with renewable energy. SMRs can be grouped in a series of smaller reactor modules (aka nuclear batteries) that run independently, allowing the total power output in one or more modules to be varied in response to renewables intermittency in three ways: 1) SMR offline when renewables generate power, 2) SMR adjustment to compensate for intermittent power from renewables, and 3) SMR response to extremely rapid variations in renewables power generation.

A U.S. Defense Science Board task force evaluated energy systems for remote or forward operating bases that could replace the diesel generators that serve as the standard electrical power sources at military bases. Alternate energy sources evaluated by the task force included very small modular nuclear reactors (vSMRS) (more).

VSMRs are designed to operate at less than 10 megawatts and to fit in a typical shipping container, in comparison to utility-scale reactors, which typically operate at 1,000 megawatts and are not mobile. The task force concluded that the U.S. military could become the beneficiary of reliable, abundant, and continuous energy through the deployment of such nuclear energy power systems.

Jordan and Saudi Arabia have signed agreements on cooperation in uranium exploration and carrying out a feasibility study into the construction of two small modular reactors (SMRs).

The new programs include: exploration and mining of uranium in central Jordan; basic and applied research related to nuclear energy and technologies; design, construction and operation of power plants and nuclear reactors; and cooperation in research and exploration and mining, and radioactive waste management (more).

SMRs continued to receive increased attention in 2016, with 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). The TVA is leading efforts toward a rational energy mix (more); see further discussions below (in section on Renewable Energy Systems).

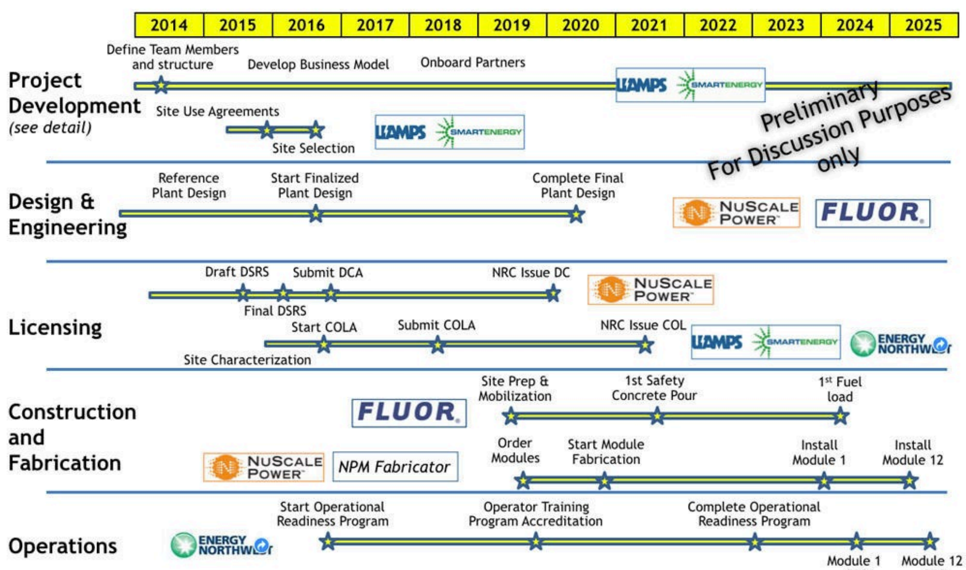
At least 100 research and development programs are underway on SMRs by many companies in the U.S. and overseas (more). For additional, updated information and media items on SMRs to date, see (media: more). For technical information on the development and current status of SMRs, see (technical: more). NuScale Power is committing major funding to developing commercial applications of SMRs (more). Bill Gates and others continue to support SMRs searching for the optimum design (more).

The plans for SMR from design development through commercial viability are shown for a number leading companies between now and 2025 (see Figure 8). Based on the current pace of the research, many of these goals will likely be realized well before 2025 (more).

The central focus of much of the current research and development seems to be on integrating SMRs with renewable energy systems (wind and solar systems) (more).

SMR Industry Research Planning

Figure 8 - (2017)



SPENT-NUCLEAR FUEL STORAGE

Spent fuel would be sufficiently cooled prior to shipment to a national storage facility at Yucca Mountain. However, the federal storage facility designed to store spent fuel at Yucca Mountain in Nevada has yet to be opened, primarily as a result of political rather than technical issues (more).

However, a low-level radioactive storage site, such as the WIPP facility located in New Mexico has been in operation for some years (more). See Figure 9 for general layout.

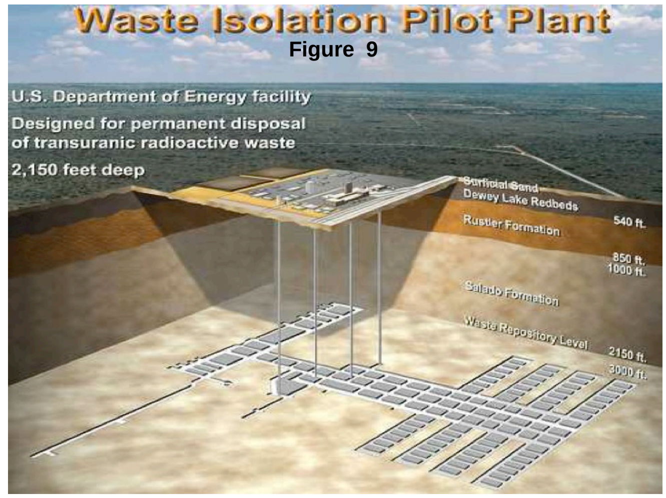


Figure 9

Commercial nuclear waste is not actually a waste but a solid easily-handled material that can be reused in the future and is easily and safely stored in dry casks for over 160 years. Defense waste is actually waste, not useful at all, and is highly radioactive trash, sludge, cement and salt cake, and other radioactive waste types.

An operating deep geologic nuclear waste repository, the Waste Isolation Pilot Plant (WIPP) located near Carlsbad, NM, is fully permitted for defense nuclear waste, but WIPP was designed to take nuclear plant waste and could easily accommodate all of it (more).

Bipartisan support and Republican efforts to reinstate the Yucca Mountain facility, however, are getting some support from a number of sources, including those in the new administration. Nuclear Regulatory Commission hearings could start before 2019 on licensing the project designed, built, and paid for to accept spent nuclear fuel for storage from plants around the U.S., as planned 25 years ago. See Figure 10 showing entrance to facility.

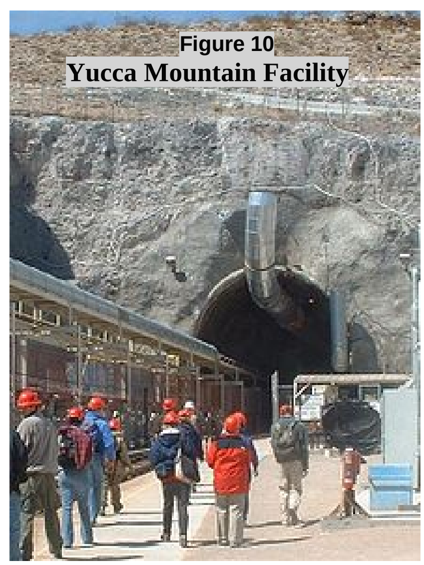


Figure 10
Yucca Mountain Facility

There are political indications that the Yucca Mountain facility can 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 eliminated. But Conca (2017) suggests that the WIPP site is capable of storing the waste instead of the Yucca Mountain facility (more).

Even though the ‘store in place” plan is viable, the nuclear power plants are not getting what they have been paying decades and mandated by law, that is, a secure place to store (not dispose) the U.S. nuclear waste (more). This distinction has been made on the basis that the material could be useful at some point in the future for reprocessing.

The activities of the growing support and the opposition against opening the Yucca Mountain facility is being continuously monitored by the I2M Web Portal (more). In all, billions of dollars have been collected by the federal government to manage the nuclear waste, but the completion of the Yucca Mountain Facility has been blocked by anti-nuclear opponents, including a few senators (more), so other sites are now being considered (more).

INTERNATIONAL URANIUM EXPLORATION AND DEVELOPMENT

Beyond the exploration and mining projects in the U.S., drilling in Canada is likely to be at record levels, primarily because of the world-class discoveries that are being developed in the Athabasca Basin over the past few years. UCOM reports over the past few years have discussed these in some depth. Drilling is also very active in Kazakhstan, in Africa, and South America, China, and Australia. Although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states (Western Australia, Northern Territory, Queensland, and even South Australia).

In response to the expansion in plant construction throughout the world, new discoveries of uranium deposits in Canada and elsewhere have increased in number over the past decade even under conditions of low market prices for U_3O_8. This continuing activity has occurred no doubt as a result of increasing confidence that nuclear power will continue to expand worldwide (and U.S.) to support the future demand for uranium.

As indicated above, exploration in Canada has produced numerous discoveries, many of which are of world class deposits located around the periphery of the Athabasca Basin of Saskatchewan (more). Specifically, NexGen is drilling up huge reserves with high uranium grades at depth (more), while Fission has made another major discovery in the Patterson Lake area (more), and UEX continues to expand its reserve base at Christie Lake with a wide zone averaging 20% uranium mineralization (more). The top 10 mines are located in: Canada (more than 1 mine), Kazakhstan (5 mines), Australia (1 mine and more), Niger (1 mine and more), Russia (1 mine and more), and Nambia (1 mine and more).

INTERNATIONAL URANIUM PRODUCTION

Regor (2016) indicates that the U.S. consumes a significant portion of the world's uranium for nuclear power, yet it produces only a few million pounds of it inside the U.S. As the U.S. makes an effort to focus on energy independence, there will likely be a push to potentially subsidize production of uranium by U.S uranium companies (or production by a U.S. or Canadian companies operating outside the U.S., e.g., the URI Temrezli Uranium Project in Turkey, the UEC Oviedo Uranium Project in Paraguay, Macusani in Peru, etc.) in order to avoid reliance on importing uranium to supply power plants by unreliable foreign-owned uranium mining companies. If that situation were to occur, a number of projects in the U.S. that are currently not economically viable would be brought on-line for immediate evaluation and preparation for mining.

Specifically, 6% of the 57 million pounds of U_3O_8 delivered in 2015 was of U.S.-origin at a weighted-average price of $43.86 per pound. Foreign-origin uranium accounted for the remaining 94% of deliveries at a weighted-average price of $44.14 per pound. Uranium originating in Kazakhstan, Russia, and Uzbekistan accounted for 37% of the 57 million pounds. Australian-origin and Canadian-origin uranium together accounted for 47%. The remaining 10% originated from Bulgaria, Czech Republic, Malawi, Namibia, Niger, and South Africa (more).

The African countries have identified sizable uranium resources (more) and likely will be providing substantial volumes of low-cost yellowcake to European and U.S. markets in the future, but security issues are involved in almost every project, impacting exploration and production, e.g., Namibia, and Niger, as well as South Africa, Tanzania, Malawi and Mozambique, Kenya, Burundi, Zambia (more).

With more than 450 nuclear power plants in current operation worldwide, they require some 23 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 will 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 Canada. But new, large deposits (some very high grade) have been discovered nearby around the rim of the Athabasca Basin of Saskatchewan and Manitoba, Canada, breccia pipe deposits in Arizona (more), and roll-front deposits elsewhere in the world (i.e., Peru, Uruguay and Paraguay, India, Iran, and Tanzania).

So, there will be no shortage of producing mines over the next few decades at least (more). But, this might even create market conditions that will keep the price below $75.00 per pound ($U_3O_8$). All told to date, 35 countries account for about 5 million tonnes of U_3O_8 in the ground (equivalent to about 10 billion pounds U_3O_8), which would provide utilities with fuel for some 80 years based on a worldwide consumption rate of 50 million pounds U_3O_8/year over a 3-year fuel cycle for 450 reactors (more). Based on recent discoveries in Canada, its percent of acknowledged world reserves will increase considerably.

One condition that could develop is a long-term over supply of uranium from a plethora of high- and low-grade deposits that would keep prices even below $50.00/ pound. The second condition created by the production of very high grade, large reserves of uranium that are likely present around the periphery of the Athabasca Basin of Canada (where new discoveries have been made in the past few years) could be produced at prices lower than most other uranium mining projects. Some grades are so high that the beginning of robotics mining may well be in the offing. This may raise the cost to mine and transport in the beginning but decrease as the technology settles in (more).

Substantial investment money is coming into the new Canadian discoveries to support the development of these high-grade deposits (more), including Chinese (more) and Russian funding (more). But what will the demand be in the foreseeable future to fuel the expanding fleet of nuclear power plants in the U.S. and worldwide?

Timing is all important in mining and in providing uranium for processing into fuel. It is also important for management to estimate when prices will be high enough for their projects to make reasonable profits. They have to set operations into motion well before reality arrives, which often results in some companies making the right moves in exploration and permitting, while others having been too aggressive but then have to wait, or have been too slow and have to catch up with the market losing premium dollars from higher prices.

Drilling within uranium prospects is very active in Africa, and South America, in China, and in Australia and Asia; although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states (Western Australia, Northern Territory, Queensland, and even South Australia).

Exploration in Canada has produced numerous uranium discoveries and continue development drilling, many of which are world-class deposits located around the periphery of the Athabasca Basin of Saskatchewan (more). Substantial investment money is coming into the new Canadian uranium discoveries in support of the development of these high-grade deposits, with Chinese and Russian funding.

Greenland is planning to begin construction of the world fifth-largest uranium mine and second-biggest rare-earths operation to help diversify its economy and reduce its financial dependence on Denmark, even though the near-term outlook for uranium demand is weak. The mine would have an annual processing capacity of 3 million pounds per year of yellowcake and rare-earth concentrate likely shipped to others for processing into individual rare-earth products (more).

Russia's Vershinnoye deposit is one of the eight deposits of the Khiagda ore field (the total reserves are estimated at 45 thousand tons (about 90 million pounds of uranium (U_3O_8)), the development of which is being carried out by Atomredmetzoloto, a holding company of Rosatom. Its reserves amount to 4,577 tons (9.2 million pounds of uranium), the first production is planned in 2018.

Kazakhstan state-owned Kazatomprom announced in January that it would cut production by 10%. The company supplies 40% of the world uranium. The company also announced the opening of a Swiss marketing arm suggesting that inventory management may become a policy tool. An inventory policy rather than direct supply would allow the project to serve as a swing producer or swing seller, using inventory and production levels to influence the uranium price in the future (more).

INTERNATIONAL NUCLEAR POWER ACTIVITY

Global nuclear electricity generation is expected to almost double by 2040, according to the latest projection by the U.S. Department of Energy's Energy Information Administration (EIA). Most of this growth will be in the developing world, it said. Total world energy consumption will increase by almost 50%, from 549 quadrillion British thermal units in 2012 to 815 quadrillion Btu in 2040.

This growth will be driven by industrialization in non-OECD countries, especially in Asia (EIA) The Organization for Economic Cooperation and Development (OECD) is a unique forum where the governments of 34 democracies with market economies work with each other, as well as with more than 70 non-member economies to promote economic growth, prosperity, and sustainable development. However, EIA (2016) has oddly expressed concerns about energy security and greenhouse gas emissions supporting the development of new nuclear generating capacity. China alone, which plans to add 139 GWe of nuclear capacity by 2040, accounts for 61% of world nuclear capacity growth over the period.

But in the U.S., EIA indicates that between 2013 and 2040, nuclear power's share of total generation could fall from 19% to 15% in its High Oil and Gas Resource case and to 18% in its High Oil Price case, where higher natural gas prices lead to additional growth in nuclear capacity (WNN-2015). But EIA (2016) also reports that, in general, the projected growth of electricity demand in OECD countries, where electricity markets are well established and electricity consumption patterns are mature, is slower than in the non-OECD countries. OECD GDP increases by 2.0%/year, less than half the 4.2%/year GDP growth projected for non-OECD countries. OECD net electricity generation increases by 38%, from 10.2 trillion kWh in 2012 to 14.2 trillion kWh in 2040.

Nuclear energy contributions will be the third fastest growth after natural gas and renewables (mostly wind energy). Global nuclear generating capacity is expected to see 2.3% annual growth between 2012 and 2040, from 2.3 trillion kilowatt-hours to 4.5 trillion kWh. Its share of total primary energy over this period will increase from 4% to 6%, or more if the current expansion continues worldwide and in the U.S. (WNN)

Among OECD countries, South Korea continues to increase its nuclear generating capacity (15 GWe), the EIA notes. At the same time, reactor shutdowns in Canada and Europe, together with the current reduced capacity in Japan, might see an overall drop of 6 GWe in nuclear capacity in OECD nations by 2040, but this is not likely to occur (more). All of these groups are showing renewed interest in maintaining or increasing their nuclear generating capacity if only on economic grounds and not only in consideration of climate needs.

Despite the move towards lower-carbon energy sources, energy-related CO_2 emissions are projected to increase from 32 billion tonnes in 2012 to 36 billion tonnes in 2020 and then to 43 billion tonnes in 2040, a 34% increase from 2012 to 2040. Much of the growth in emissions is attributed to developing non-OECD nations, many of which continue to rely heavily on fossil fuels (coal and natural gas) to meet the fast-paced growth of populations and associated energy demand, as per EIA at least (more, pg. 10). The latter reference further confirms EIA's anti-nuclear estimates by ignoring the impact of growing interest in nuclear power benefits and the development of SMR's and other new nuclear technology, while trumpeting oil and gas operations worldwide.

To meet the anticipated increase in demand for electricity, the U.S. now has five new reactors under construction and China has 20, Russia has 10 under construction, and together with others in construction elsewhere in the world, they will create the greatest demand in the history of nuclear power for U_3O_8 production over the next decade (more).

Other countries will be creating serious demands as well; for the rest of the list, see (more). But should the electricity demand increase even further as a result of improving economic conditions in the U.S., from regulation amendments favoring nuclear power in the market place, as natural gas prices increase (as predicted), and coal use continues to decline (as needed for climate change mitigation), then nuclear power could expand well beyond its current 19% of total energy generation in the U.S.

There are currently 449 operating nuclear reactors in 31 countries, with a total installed generating capacity of more than 390,000 megawatts (MW). Construction of new power plants and continued operation of the 99 existing nuclear power plants in the U.S., with 4 under construction, 18 ordered (or planned), and 24 proposed new plants, and 447 plants in 30 countries around the world, all of which require large supplies of nuclear fuel every 3 to 4 years. Worldwide top-10 countries with 15 or more operable nuclear power plants are shown in Table 4.

Table 4

Top-10 Countries with 15 or more Nuclear Power Plants

(WNN-2017)

Country	# Operable	# Under Construction	# Ordered/Planned
1. U.S.	99	4	18
2. France	58	1	0
3. Japan	42	2	9
4. China	36	21	40
5. Russia	35	7	25
6. S. Korea	25	3	8
7. India	22	5	20
8. Canada	19	0	2
9. Ukraine	15	0	2
10. U.K.	15	0	4

Note: 20 other countries have 9 or fewer currently operable nuclear power plants.

As discussed previously, the uranium price is related to demands of these plants and must be anticipated years ahead of actual sales, which in turn increases or decreases exploration as well as mining activities. Global nuclear generating capacity is expected to see 2.3% annual growth between 2012 and 2040, from 2.3 trillion kilowatt-hours to 4.5 trillion kWh. Its share of total primary energy over this period will increase from 4% to 6%, or more if the current expansion continues worldwide and in the U.S. (more).

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 for importing natural gas and attempts to ramp up wind and solar energy on a large scale that failed has impacted Japan's economy severely. The economic stress created should be relieved over the next decade as the nuclear plants replace the need for imports and renewables (more).

China declared a three-year hiatus from allowing any nuclear reactor projects to be developed. It rewrote its regulations, but now (2017) China has 36 nuclear power reactors in operation, 21 under construction, and 40 others planned (more).

2016 data confirm that construction elsewhere also continues to increase, aided by Chinese and Russian offers to finance the building and operation of nuclear power plants in India, Bangladesh, the U.K., and other countries, see: (China: more) and (Russia: more). Recent announcements of such construction are reported in the current I2M Web Portal (more).

OVERALL PERSPECTIVE

The adversaries of nuclear power (and of mining of uranium) continue to apply the same ill-founded and exaggerated claims throughout the world, mostly generated by competing energy interests and by paid commercial adversaries (wind, solar, and associated industries) who are encouraged to be against "climate change", and pass the misinformation meme on to well-meaning, but ignorant people in the U.S. and around the world (more1) and (more2).

A growing number of prominent professionals on the subject over the years have come to support particular nuclear power projects as the energy of choice for generating electricity throughout the world (more). This is based primarily on the issue that it minimizes damage to Earth's climate, and it has been a safe energy source operating over 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 adversaries 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 climate sensitivity (more).

Coal vs. Nuclear Power and Natural Gas

Although consumption of non-fossil fuels is expected to grow faster that the growth rate of fossil fuels, the latter still accounts for an incredible 78% of the primary energy in use in 2040, with coal still rising (albeit by only 0.6% annually from 153 quadrillion Btu in 2012 to a projected 180 quadrillion Btu in 2040. But China, the U.S., and India will remain as the top three coal-producing countries, together accounting for more than 70% of world coal use through 2040. Natural gas consumption is projected to grow by 1.9% over the same period (more).

According to the EIA, global electricity generation will likely increase by 69% between 2012 and 2040, from 21.6 trillion kWh in 2012 to 25.8 trillion kWh in 2020 and 36.5 trillion kWh in 2040. Additional information is available from EIA (more).

Coal continues to be burned to produce electricity 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 of using coal are always significant drivers (more).

Williams (2017) provides a summary of Chinese activities in coal and associated geopolitics:

- China continues to experiment with setting a price for coal by manipulating local production,
- China has banned coal imports from North Korea in 2017,
- Mongolia dramatically increased export of coking coal to China in 2016,
- International coal producers, Indonesia, Australia to benefit,
- Experts do not think this reflects a fundamental shift in coal industry decline,
- Paris climate agreement ratification continues, record global temperatures three years in a row reinforce the urgency of greenhouse gas emissions reduction, especially in China,
- Last year, China cut of 9.4% in local coal production from Australian and Indonesia. This led to expansion of coal exports from Mongolia, North Korea, Australia and Indonesia, and substantial price increase for exported coal, both thermal and coking. The effect was so dramatic that China partially reversed the cuts to allow local production boost for the 2016/2017 winter.

- China has increased pressure on North Korea by ceasing coal purchases. This began recently with a warning when a shipment 16,300 tons of coal from North Korea was rejected by China on the basis that the coal contained a higher than allowed level of mercury.

- China then announced a ban of all coal imports from North Korea for the remainder of 2017. This ban is a consequence of tensions due to recent North Korean missile tests and associated diatribe coming from the North Korean leader.

Note that the ban by China follows UN sanctions on North Korean coking coal exports (essentially all of which goes to China) for 2017 of 7.5 million tons. In 2016, China imported 22.5 million tons of coal from North Korea. The political significance is that the coal exports to China make up about a half of North Korean export income. Williams (above) assumes that this is China encouraging North Korea to stop being troublesome by developing nuclear weapons.

Although consumption of non-fossil fuels is expected to grow faster than consumption of fossil fuels, fossil fuels will still account for an incredible 78% of primary energy in use in 2040, whereas coal will be the world's slowest growing energy source, rising by 0.6% annually from 153 quadrillion Btu in 2012 to 180 quadrillion Btu in 2040 (more).

Republic of South Africa, a top ten producer of coal worldwide and is one of the leading coal export nations, is considering a move away from coal burned to produce electricity and towards low-carbon sources like nuclear and renewables. Currently, more than 90% of electricity is generated by coal, with only 3% from nuclear, 3% from natural gas and 2% combined from conventional and pumped hydroelectric (more).

Asia is the world's largest consumer of liquefied natural gas (LNG), accounting for three-quarters of global LNG trade and one-third of total global natural gas trade (more). After falling in six out of seven quarters from mid-2014 to mid-2016, coal production rose in the third and fourth quarters of 2016. But a number of Asian countries have been to evaluate nuclear power (more).

Among the coal supply regions, the Powder River Basin in Montana and Wyoming saw the largest increases in the second half of 2016. The increases in coal production were driven by an increase in coal-fired electrical generation, which occurred as natural gas prices increased (more). Kentucky is beginning to evaluate nuclear power in a state that has been culturally and economically dominated by coal. China as well is setting up a serious anti-coal policy for transition to nuclear over the next 20 years (more).

Renewable Energy vs. Nuclear Power

Wind and solar energy projects are being funded and operated under large subsidies while their operation and maintenance costs remain underreported (more). Serious questions are being raised by independent reviewers on the economic viability of the two energy sources in terms of the actual generated cost of electricity (more).

This is not to say that wind and solar 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 …. but they still must have a back-up power grid, until viable battery systems are developed (more).

Nearly six years after the 2011 tsunami in Japan, even Germany, Sweden, and France are beginning to realize after serious economic evaluations that it would be less expensive to keep their nuclear power plants operating then transition to a wholesale commitment to wind/solar construction for other than remote areas not requiring grid-support (more). Reliance on brown coal, and large-scale wind/solar systems has neither met climate needs of the former, nor have the latter provided reliable or stable electricity costs (more).

One such 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 resurgence in the U.S. and elsewhere in the world, but not without some resistance from the usual opponents supporting protection of river ecosystems (Conca, 2015).

Over the past year, the transitional period has become even more apparent from reductions in burning coal, oil, and to building renewables, such as solar and wind systems (in the hopes they prove to be cost effective) and nuclear power and natural gas (to provide the grid power). Dams also need to be recognized in the energy picture in the U.S. (more).

Although gaining popularity, as well as gaining detractors, wind in the UK is intermittent and the electricity output of a wind turbine is proportional to the cube of the wind speed (more). A 20% drop in wind speed decreases the wind electricity supply almost 50%. Because of wind intermittency, the average output of the UK wind farm fleet is only about 30% of rated (installed) capacity, with peaks of up to about 80% and lows of less than 5% of rated capacity for about 7% of the time. In the meantime, the UK is nevertheless moving forward on closing all coal-fired power plants over the next 10 years (more) and (more).

There is a noticeable increase in the chatter in the media about merging renewable energy systems with SMRs in order to provide the necessary back-up power required by wind and solar system. This appears to have merit, only because in such systems the actual costs will emerge as subsidies decrease (more).

RENEWABLE ENERGY SYSTEMS

While renewable energy sources (as promoted by the EIA) are projected to be the world's fastest growing energy source for electricity production between 2012 and 2040, growing an average 2.9% annually from a very small base (notice that the EIA does not list the kilowatt-hours produced).

Conca (2016) previously suggested that the TVA understands that the correct energy mix is more than just to lower carbon emissions. It is all about grid stability, making sure the power is available whenever it is needed without the use of costly back-up fossil fuel from plants on inefficient standby. Wind has larger and more erratic intermittency than solar and is, therefore, more difficult and costly to integrate, usually requiring natural gas plants to provide grid-backup.

SMRs are ideally-suited to help integrate renewables onto the grid without increasing the carbon footprint. While TVA's SMR siting application is not tied directly to a specific reactor, the leading SMR design is Oregon's NuScale power module was designed to integrate completely with renewable energy (more).

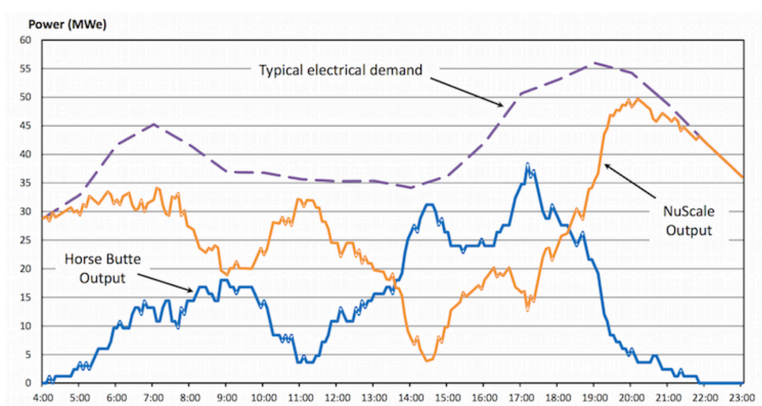


Figure 11 – Typical Grid Support of Renewables (Wind Farm and SMR) (NuScale – 2016)

An illustration of how a small modular reactor (SMR) would compensate for wind generation variations during load-following of, in this case, the Horse Butte wind farm in Idaho, in order to meet daily electricity demand is laid out in Figure 11.

SMRs are being considered for integrating TVA's growing renewable portfolio (driven by "popular" demand) without using natural gas or wasting of hydropower through losses from long-line extensions (more).

One of the strengths of SMRs is that they can be grouped in a series of smaller reactor modules (aka nuclear batteries) that run independently, allowing the total power output in one or more modules to be varied in response to renewables intermittency in three ways:

1. taking one or more SMR units offline for extended periods of sustained solar or wind output,

2. adjusting reactor power for one or more modules for intermediate periods to compensate for hourly changes in production by renewables (wind or solar), or

3. bypassing one or more SMR unit for immediate response to extremely rapid variations in electrical generation by renewables on the seconds-to-minutes scale.

If the renewable generation surpasses 15% of power output in the U.S. in the next decade, this type of load-following will be critical for maintaining a stable grid. Otherwise, excessive operation and maintenance costs inherent in wind and solar systems will likely become a factor in further expansion. Ramping up solar within a multi-energy system such as the TVA is also challenging, but for a different reason. Although Tennessee experiences plenty of sunshine, there is little state legislation promoting solar because coal is plentiful, provides jobs, and is relatively inexpensive in the region (more).

Tennessee has a solar rating of "good," meaning that with local and federal subsidies, a 3 kW home solar system costing around $15,000 would pay for itself within 10 years (more). Not only would the homeowner reportedly save over $800 a year on utility bills with such a system, but these generally increase property values by about $10,000 (more), assuming the subsidies are not eliminated.

But TVA also offers incentives, especially in their TVA Generation Partners Program (more), where a program involves a $1,000 plus $0.12/kWh above the base electricity rate, which will reduce years off of the 10-year payback period (more). The State of Washington also has a similar plan, but because of the vagaries of the weather, both solar and wind needed grid-support to the extent that without the subsidies extracting funds from state and federal budgets, the economics are challenging here as well.

When both hydropower and nuclear are marginalized, increasing electricity prices to the general public result (more). This common theme is becoming prevalent in the U.S. today where renewable energy is forced into the energy selection process by well-meaning political mandates ignorant of the impact on future energy prices and stability of power grids.

In addition, Conca (2016) reports that four Tennessee Valley Authority electricity distributors were recently picked to generate solar power, which the TVA will buy as part of a 2-year pilot program to encourage more solar-power production (more). Plans are underway to build a solar farm that will generate 1.35 MW of solar power that will be supported collectively by a number of individual customers. TVA currently has more than 400 MW of renewable solar power under contract, enough electricity to power more than 216,000 homes. But Google undertook a comprehensive conversion to renewables for their new operations complex in California and found the approach to be economically untenable (more).

More recently, Parkinson (2016) asks the question about why renewable energy cannot compete without a subsidy. You hear it all the time from the fossil fuel industry, he says. And the response from renewables? Take away fossil-fuel subsidies, and they would be able to compete on level terms, which of course is square-reasoning.

David Hochschild, a commissioner with the California Energy Commission, at the Energy Productivity Summer Study in Sydney, illustrates why the fossil fuel and nuclear industries do not want fossil fuel subsidies eliminated. Studies by the International Energy Agency point out that global subsidies for fossil fuels outstrip those for renewable energy nearly 10-fold. The International Monetary Fund said if climate and environmental costs were included, then the fossil fuel subsides increased another 10 times to nearly $5 trillion a year (more). This is the root of the discussion …. the definition of a subsidy.

The accumulated energy subsidies in the U.S. are under federal programs. Oil and gas dominate, followed by nuclear. The fossil fuel industry hates to talk about that, Hochschild claims that there is no such thing as an unsubsidized unit of energy …and of the definition is involved here as well. More square reasoning. Hochschild opines that the oil depletion allowance had been in place for the oil industry since 1926, and would be ongoing, despite the fact it was one of the most profitable industries in the world. He also claimed that if the insurance costs were paid by the nuclear plants, instead of paid by taxpayers as part of the electricity bills, there would be no nuclear plants because they could not compete with any form of energy used for producing electricity. Clearly there issues deserve further study and fact checked.

For natural gas, it was the drilling, or fracking, which had been made exempt from compliance with the safe drinking water act. That is a type of subsidy, Hochschild claims. And he pointed to taxpayer funded rail networks that have also subsidized coal over more than 10 decades. The large-scale wind and solar industries in the U.S. have had to content with repeated changes to their federal support subsidies. The tax credits have been changed seven times in a decade.

Renewables in Japan, Germany, Sweden, and France

Nearly five years after the 2011 tsunami in Japan, even Germany, Sweden, and France are beginning to realize after serious economic evaluations that it would be less expensive to keep their nuclear power plants operating than transition to a wholesale commitment to wind/solar construction for other than remote areas not requiring grid-support. Reliance on brown coal, and large-scale wind/solar systems have neither met climate needs of the former, nor in the latter have provided reliable and stable electricity costs (more).

Offshore wind systems do show significant cost advantages but their actual O&M costs are unknown at present. As indicated in previous UCOM reports (2015, pp.12-15), the number of wind and solar pundits continue to flood the Internet with unduly optimistic outlooks promising subsidies for those who can afford to pay the up-front costs involved in renewable conversion. Only recently does the subject of O&M costs enter the discussion regarding solar O&M: more; and wind O&M: more).

Wind is getting mixed reviews (more), even some environmental objections (more). But renewables still do not have established records in O&M within a scaled-up grid; the economics are only attractive with substantial state and federal subsidies. However, one such 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, are nearly ready for resurgence in the U.S. and elsewhere in the world (more), but not without some resistance from the usual opponents who believe river ecosystems are being threatened (more).

Current Positions on Renewables

If the climate is to be a consideration and if the cost of electricity, without local, state, and government subsidies, are 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 in many countries (including the U.S.) because there is a perception held 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 of using coal 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 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 suggest that wind and solar do not have a role to play in energy selection where they are useful (more, pp. 12-15). They are particularly well suited for the small, isolated population centers scattered throughout the high plains and southwest U.S., for example. However in such areas, existing power lines extending from a distant grid of a major population center are needed to support such renewables, which are neither a continuous nor reliable sources of power. All of which begs the question: do we really need such ancient, and certainly not free, sources of electricity when grid power is already present?

Independent economic assessments made over the coming years will provide the answer whether the renewable experiment underway today is successful or just a fade caught up in marketing. Byt if the connection to the power grid can be discontinued by the use of the new commercial batteries being developed (more), perhaps then renewables will be able to stand, or fall, on their own economics of generating electricity off the power grid.

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

THORIUM ACTIVITIES

Several reactor concepts based on thorium fuel cycles are under consideration in the U.S. and elsewhere, but a considerable amount of development work remains before it can be commercialized in China, the U.S., Canada, India, etc. India has been developing a long-term three stage nuclear fuel cycle to utilize its abundant thorium resources (more). The construction of a 500 megawatt electric (MWe) prototype fast breeder reactor at Kalpakkam, near Madras, was about

94% complete in February 2013. It will have a blanket with thorium and uranium to breed fissile 233U and plutonium respectively (more).

The U.S. is not the only country that contains thorium resources (more). 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 could 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 with adapting thorium as a nuclear fuel (more).

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

RARE-EARTH ACTIVITIES

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).

While in many cases the world major rare-earth producers hold large reserves, some countries have low rare-earth production and high reserves. The U.S. did not produce rare earths in 2016, but its reserves are the seventh-highest in the world. It is possible that the U.S. and others could become bigger players in the industry in the future.

Rare-earth reserves by country, with a focus on the seven countries whose reserves are over 1 million MT, i.e., China: 44 MT; Brazil: 22 MT; Russia: 18 MT; India: 7 MT; Australia: 3.4 MT; Greenland: 1.5 MT; and U.S.: 1.4 MT, not including a new mine in West Texas.

Russia-born billionaire Vladimir Iorich has put in a bid to buy the shuttered Mountain Pass rare-earth-element mine in California, raising red flags for U.S. lawmakers concerned about the U.S. dependence on foreign countries for REEs and other metals necessary to maintain the U.S. military high-tech arsenal (more).

To help promote domestic production of these strategic metals and block foreign firms from buying rare-earth mines on U.S. soil, Rep. Duncan Hunter, R-California, introduced the Materials Essential to American Leadership and Security, or Metals, Act to the House.

The legislation could be advantageous for Ucore Rare Metals, which has a rare-earth element project in Southeast Alaska and is developing a system to recover strategic metals from other domestic sources, such as the new rare-earth west Texas mine, operating by Texas Mineral Resources Corp, and others in the U.S.

A large-scale uranium mine planned in Greenland would recover over 100 million tonnes of uranium and rare earths via an open pit mine in Kvanefjeld in southern Greenland, which is located about 8 km from the village of Narsaq (more).

Roskill (2016) reports that the Baiyun Obo iron ore mine in Baotou, China, responsible for around a third of global rare-earth production, remained closed throughout 2016. China Northern Rare-earth Group marginally increased production from stocks to meet increasing demand, mainly from the neodymium-iron-boron (NdFeB) magnet and fluid catalytic cracking (FCC) catalyst sectors.

Illegal mining remains as one of the main issues for China, accounting for an estimated 44,000 tonnes to 46,000 tones REO, or approximately 33% of global production this year. China released plans to once again crack down on illegal mining; this time setting out a tracking plan in order to confirm the origin and path throughout the supply chain of materials (more).

China's exports increased by almost 50% in 2016, following the World Trade Organization ruling and withdrawal of 'illegal' export quotas and taxes the previous year. Most of this increase was for lanthanum, yttrium and other rare-earth compounds, excluding cerium.

Molycorp's exit from the rare-earth market in mid-2015 left only a small vacuum in the supply chain for light rare-earths outside of China. Silmet of Estonia previously processed material from the U.S. Mountain Pass operation and is thought to have replaced this with greater shipments from Russia in 2016 (more).

Meanwhile, Lynas is producing >10,000 tpy REO from its Malaysian plant. The company restructured its debt with its Japanese investors Sojitz and JOGMEC in October, meaning it no longer needs to make fixed repayments until 2020 and its interest costs have also been significantly reduced.

Rare-earth demand grew strongly in 2016 but with increased use of Nd-Fe-B magnets resulting from growing global wind turbine installations and hybrid/electric vehicle production capacity worldwide. The rapid increase in Chinese electric vehicle purchases, established in 2015, faltered in 2016 as recent incentives were withdrawn in the wake of widespread corruption (more).

The use of light rare earths, lanthanum and cerium in FCC catalysts, grew with increases to global refining capacity. The low oil prices and subsequent low costs to the consumer that prevailed through 2016 encouraged greater consumption of transportation fuels, especially in the USA. Use of rare earths was counteracted somewhat by the continuing shift to tight oil production in North America, which requires lower levels of refining (more).

Demand for europium and terbium in phosphors continued to nosedive in 2016 with the rapid uptake of LED lamps; prices for these previously-critical heavy rare earths have now fallen back to levels last seen a decade ago. Terbium oxide (99.9%, FOB China) prices were US$423.17/kg in late 2016, similar to prices in mid-2006, while europium oxide (99%, FOB China) prices were US$62.5/kg - compared to US$240/kg in June 2006.

Roskill (2016) concludes that overall, rare-earth prices in 2016 remained fairly quiet. The rare-earths industry is expected to see greater recovery in the coming years, however, as the NdFeB magnet market takes off. Industry focus will intensify on the rising deficit of neodymium and concomitant rise in neodymium prices over the next five years. Yet the long-term performance of this sector is threatened by potential substitution of NdFeB technologies in HEVs/EVs (with induction motors) and wind turbines (with induction/synchronous motors).

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 currently (more).

Mackowski (2017) provides a reasonably comprehensive list of rare-earth companies in the world and links to associated updates on company activities:

Alkane Resources Ltd. (ASX: ALK | OTCQX: ANLKY)

Date	Source	Title
3-Feb	InvestorIntel	Some gold sunshine after the rain
22-Feb	Mining Journal	Alkane set for defining year
5-Apr	InvestorIntel	Have you heard the Hafnium buzz?

Arafura Resources Limited (ASX: ARU)

Date	Source	Title
4 Jan	Proactive Investors Australia	Arafura gets cash boost for neodymium project
22 Feb	NT News	$1.19 billion rare-earths mine – step forward

Hastings Technology Metals Ltd. (ASX: HAS)

Date	Source	Title
17 Jan	Company Mailout	Major Resource Upgrade at Yangibana neodymium Project
2 Feb	Company Mailout	Exploration Drillhole BHW04 hits widest high grade intersection, provides new target at Yangibana
11 Mar	InvestorIntel	Great Thaw of the Rare Earth Ice Age
20 Mar	Company Mailout	Beneficiation Piloting successfully completed

30 Mar	Company Mailout	Hastings Technology Metals Ltd – Future supplier of rare earths to permanent magnet industry

Lynas Corporation (ASX: LYC | OTC: LYSDY)

Date	Source	Title
25-Jan	InvestorIntel	Lynas's Record Results – A Return to Rare-earth Confidence?
25-Jan	Industrial Minerals*	Lynas revenue rises as rare-earths prices edge up
25-Jan	Creamer Media	Lynas exceeds production guidance
16-Feb	Money Morning Australia	Why did Lynas Corporation's share price take off this morning?
28-Feb	The Australian	Lynas narrows first-half loss
1-Mar	Industrial Minerals*	Lynas optimistic on NdPr price outlook

Northern Minerals Limited (ASX: NTU)

Date	Source	Title
12 Jan	Business News	Chinese money starting to flow into Northern Minerals
3 Feb	Business News	Northern Minerals close to decision on heavy rare earths plant in WA
2 Mar	InvestorIntel	Northern Minerals ramping up to be the next heavy rare-earth supplier outside of China
21 Mar	Creamer Media's Mining Weekly	Northern Minerals to raise A$10m

Peak Resources Ltd. **(ASX: PEK)**

Date	Source	Title
11 Jan	InvestorIntel	Peak Resources – Prime rare-earth mover in 2017
18 Jan	Proactive Investors UK	In the News – Peak Resources, White Rock Minerals, Base Resources
21 Mar	Creamer Media's Mining Weekly	Ngualla gets environmental nod

Search Minerals Inc. **(TSXV: SMY)**

Date	Source	Title
10-Feb	InvestorIntel	The Search for North American rare earths
8-Mar	Company Mailout	Search Minerals produces high purity mixed rare earths oxide product from the pilot plant
22-Mar	InvestorIntel	Search Minerals – Survival of the Fittest in Rare Earths
25-Mar	InvestorIntel	Dr Dreisinger on extraction technologies for rare earths
5-Apr	InvestorIntel	North American rare-earths race heats up with patent advantage

Ucore Rare Metals Inc. **(TSXV: UCU | OTCQX: UURAF)**

Date	Source	Title
19-Jan	InvestorIntel	Comparing Capital and Operating Costs for MRT and Legacy Technologies in PGM Separations
1-Mar	InvestorIntel	The advantage of technology in the rare-earth universe

13-Mar	Company Mailout	Ucore announces option to purchase IBC Advanced Technologies Inc
29-Mar	Company Mailout	Ucore testifies before US Senate Committee on Energy & Natural Resources
5-Apr	InvestorIntel	Jack Lifton Discusses MRT and Tailings Monetization

Canada Rare Earth Corp. (TSXV: LL)

Date	Source	Title
23 Feb	Marketwired	Canada Rare Earth Corp: Significant progress in the permitting of the rare-earth refinery
24 Mar	Yahoo Finance	Canada Rare Earth enters into a second set of hedged purchase and sale agreements

Commerce Resources Corp. (TSXV: CCE)

Date	Source	Title
31 Jan	Resource Clips	The Ashram Advantage
18 Feb	Resource Clips	Province of Quebec invests in Commerce Resources' Ashram rare-earths project
23 Feb	Yahoo Finance	Edging China out of rare earth dominance via Quebec's Ashram rare-earth deposit

Greenland Minerals & Energy Ltd. (ASX: GGG)

Date	Source	Title
13 Jan	Herald Sun	GGG prices firm on back of investors

26 Feb	Mining Journal	Kvanefjeld on the cusp
14 Mar	Sputnik International	Rare-earth Monster Mine fuels world's largest Island's dreams of independence

Matamec Explorations Inc. (TSXV: MAT)

Date	Source	Title
24 Mar	Yahoo Finance	Matamec provides an update on the Kipawa rare earths project

Mkango Resources (TSXV: MKA | LSE: MKA)

Date	Source	Title
7 Jan	Mining Review	Mkango Resources gets green light to collaborate with Noble Resources
2 Mar	Proactive Investors UK	Mkango upbeat on Malawi rare-earth and uranium projects
21 Mar	Proactive Investors UK	Mkango signs 3-D magnets agreement with Metalysis

Mountain Pass (former Molycorp property)

Date	Source	Title
2 Feb	The Wall Street Journal*	California's Mountain Pass mine to be auctioned in bankruptcy
8 Feb	The Wall Street Journal*	Russian-born billionaire makes play for US rare-earths mine
3 Mar	InvestorIntel	Pala Investments eyes the US rare-earths market

Pele Mountain Resources Inc. (TSXV: GEM)

Date	Source	Title
1 Feb	Yahoo Finance	Pele Mountain provides update on Eco Ridge

7 Feb	Yahoo Finance	Pele Mountain provides update on rare-earth processing project in Elliot Lake

Rainbow Rare Earths (LON: RRE)

Date	Source	Title
16 Jan	Telegraph.co.uk	Rare Earth miner to list Burundi project on London Stock Exchange
25 Jan	Proactive Investors UK	Rainbow Rare Earths all set for standard list debut
28 Jan	Interactive Investor	Latest IPO is forgotten gem
31 Jan	Mining.com	New rare-earth miner lists in London, raises $10 million for Burundi project
9 Mar	MetalMiner	Africa vies to be a rare-earths player, create a rival for dominant China
23 Mar	Mining Review	Rainbow Rare-earths anticipates sales from Gakara rare-earth project by year end

Rare Earth Minerals PLC (LON: REM)

Date	Source	Title
7 Jan	Proactive Investors UK	Rare Earth Minerals shares to “re-test 2016 highs
18 Jan	Proactive Investors UK	REM highlights new mineral resource estimate at Yangibana

Rare Earth Salts

Date	Source	Title
27 Jan	Rareearthsalt.com	Rare-earth Salts eliminate technology risks
10 Feb	Rareearthsalt.com	Rare-earth Salts signs five-year commercial agreement
3 Feb	Yahoo Finance	Rare Earth Salts announces industry veteran joins as Director of Business Development

Spectrum Rare Earths Limited (ASX: SPX)

Date	Source	Title
9 Mar	Business Review	Spectrum Rare Earths pushes higher 16.67%

Stans Energy Corp. (TSXV: HRE)

Date	Source	Title
28 Jan	Mining.com	UN Court won't dismiss Stans Energy claims against Kyrgyz Republic

Texas Mineral Resources Corp. (OTCQX: TMRC)

Date	Source	Title
28 Mar	MarketWatch	Rare Metals Industry Veteran Jack Lifton joins Texas Mineral Resources advisory board

China

Date	Source	Title
3 Jan	Mining.com	China to become net importer of some Rare Earths
6 Jan	Industrial Minerals*	China rare-earth prices stable for January; exports increase
14 Jan	Global Times	China's largest rare-earth firm expects profit plunge
17 Jan	Industrial Minerals*	China's bid to replace toxic materials could be boon for rare earths
22 Mar	New Security Beat	As China begins adjusting for "True Cost" or Rare Earths, What does it mean for Decarbonisation?

Other Countries

Date	Source	Title
7 Jan	InvestorIntel	Russian government "unhappy" with rare-earth supply for defense sector

21 Feb	The Japan Times	As demand increases for rare-earth metals, deep sea mining gets second look
4 Mar	Korea Times	N. Korea stops rare-earth metal exports to China
8 Mar	Financial Times*	Africa holds promise of rare-earth riches
8 Mar	Africa Intelligence*	Rwanda: Government tends rare earths to attract Japanese companies
9 Mar	Industrial Minerals*	US bill seeks to re-establish local rare-earths production

Market Research and Commentary

Date	**Source**	**Title**
4 Jan	openPR*	Rare-earth Elements Market – Global Industry Analysis 2023
5 Jan	Patriarc*	Europe Rare-earths Market 2016 Growth, Trends and Competitive landscape Outlook to 2021
11 Jan	cHollywood News Portal*	Global Rare-earth Metals Market
11 Jan	Digital Journal*	Global Cerium Market to record an impressive growth rate by 2021
11 Jan	Argus Media*	Argus Rare Earths Annual 2016
13 Jan	Satellite PR News*	Global Rare Earth metals market is anticipated to reach US$8.19 billion by the end of 2024
18 Jan	Satellite PR News*	Global Rare Earth Elements (REE) Market Share, Trend, Segmentation and Forecast to 2020
3 Feb	InvestorIntel	The US rare-earth vulnerability and mammoth battery supply disconnect
4 Feb	Fox News	China’s secret Trump card: Could Beijing deprive our military of critical defense components?
7 Feb	openPR*	Global rare-earth metals market to record an impressive growth USD 9.0 billion in 2020

8 Feb	Industrial Minerals*	Chinese light rare-earths exports increase
9 Feb	Satellite PR News*	Good growth opportunities in rare-earth metal markets 2016-2026
14 Feb	openPR*	Permanent rare-earth magnets market – Offers valuable market forecasts & figures
15 Feb	Seeking Alpha	Four metals set to benefit from Trump vs China showdown
18 Feb	Industrial Minerals	A turning point for rare-earths?
19 Feb	Satellite PR News*	Rare-earth metals market to expand at 13.0% CAGR 2012-2018 driven by surging demand
25 Feb	InvestorIntel	The "real" impact of Trump on Technology Metals: Ecclestone vs Lifton
7 Mar	openPR*	Rare-earth Metals Market: Global Industry Key Manufacturers Analysis and Forecassts to 2021
March	Adamas Intelligence*	Rare-earth Market Outlook to 2025

*Requires registration

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).

See UCOM Vice-Chair reports below:

URANIUM & RARE EARTH UNIVERSITY RESEARCH

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

Interest in uranium research has decreased since the Japan tsunami and associated Fukushima Daiichi nuclear incident in 2011 with very few grants and new sources for funding. Interest in Rare-Earth Elements [REE] research has also decreased due weak market conditions. This contrasts sharply with Chinese policy, which is dominating research and development in all aspects of processing REE ores.

The Society of Economic Geologists Foundation (SEGF) and the SEG Canada Foundation (SEGCF) recently announced the Student Research Grant awards for 2016. Of the 50 grants awarded, two awards were for uranium related research and two awards were for research on REE or carbonatite deposits. One uranium research project will concentrate on the possible metal sources of the uranium rich Iron Oxide-Copper-Gold [IOCG] Olympic Dam deposit in Australia. The Olympic Dam copper gold deposit is also the largest uranium deposit in the world. The other uranium research project will study the formation of calcrete uranium deposits in Western Australia.

SEGF - SEGCF - 2016 Recipients

The SEGF-Hugh E. McKinstry Fund supports "study, research and teaching of the science of economic geology or for related projects," with preference given to field and related laboratory research by graduate students.

The SEGCF grant program is similar to the SEGF scholarship program. The Hugo T. Dummett Fund promotes applied economic geology research and the development of new exploration techniques. See awardees in the table below:

Name	Award Amount	University	Degree	Project Area
Alexander Cherry	US$2,600 SEGF	University of Tasmania (Australia)	Ph.D.	Sedimentary units within the Olympic Dam Cu-U-Au-Ag deposit: Provenance and implications to metal sources.
Ibiyemi Ogungbuyi	US$4,500 SEGF	University of Cape Town (South Africa)	Ph.D.	The Geochemistry and Source Characteristics of Carbonatites and Related Alkaline Rocks from Southern Namibia and Northern Cape, South Africa.
James Chapman	US$1,940 Hugo T. Dummett Fund	University of Arizona (USA)	Ph.D.	Empirical relationships between trace element concentration in detrital minerals and partition coefficients: estimation of whole rock REE concentrations.
Justin Drummond	CAN$1,020 SEGCF	Queen's University (Canada)	Ph.D.	Geochemistry and diagenesis of groundwater calcrete, Western Australia: implications for calcrete-hosted U mineralization.

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

Timothy Wyatt at the Colorado School of Mines is working on an industry supported uranium geology related Master of Science degree, “Residence of uranium in roll front deposits: A case study”

There are three Master of Science graduate students at the Colorado School of mines whose research involves the geology of REE. These students and their project are as follows:

> Michael Berger**,** "Characterization of alkaline igneous rocks and alteration at the Pajarito Mountain REE-Zr deposit, Mescalero Apache Indian Reservation, New Mexico".
>
> Emily Randall, "Exploring REE behavior under hydrothermal conditions as a function of temperature and fluid composition: Insights from integrated experimental and field studies".
>
> David R. Sutterfield , "Characterization of REE phosphate thermodynamics by calorimetry".

Dr. Thomas Monecke and his students at the Colorado School of Mines published the following two abstracts relating to their research on uranium deposits:

> Dedecker, J., Monecke, T., Reynolds, T.J., zAaluski, G., Kotzer, T. (2016) Pyrite enrichment in the P2 fault at the McArthur River uranium mine, Athabasca basin, Saskatchewan: Possible redox controls on mineralization. GSA Annual Meeting. Denver, Colorado, 25-28 September 2016, Geological Society of America Abstracts with Programs, v. 48, paper no 180-2. Talk
>
> Wyatt, T.O., Pfaff, K., Monecke, T., Zielinski, R.A., Gorman, B.P. (2016) Residence of uranium in roll-front deposits: A case study. GSA Annual Meeting. Denver, Colorado, 25-28 September 2016, Geological Society of America Abstracts with Programs, v. 48, paper no 148-1. Poster

In 2016, Dr. Virginia McLemore at New Mexico Institute of Mining and Technology published the following three reports relating to Thorium and REE resources in New Mexico:

> McLemore, V.T. and Robison, A., 2016, Exploration of Beach Placer Heavy Mineral Deposits in the San Juan Basin in New Mexico: Society for Mining, Metallurgy, and Exploration, 2016 Annual meeting preprint 16-136, 10 p., (more).
>
> McLemore, V.T., Asafo-Akowuah, J. and Robison, A., 2016, Assessment of Rare Earth Elements at Apache Mesa (Stinking Lake), Jicarilla Apache Reservation, Rio Arriba County, New Mexico: Final report to Jicarilla Indian Tribe, NMBG Open-file report 587, (more).
>
> McLemore, V.T., 2016, Episyenites in the Sevilleta National Wildlife Refuge, Socorro County, New Mexico - Preliminary Results; *in* Frey, B.A., Karlstrom, K.E. , Lucas, S.G., Williams, S., Ziegler, K., McLemore, V., and Ulmer-Scholle, D.S., eds., Geology of the Belen area: New Mexico Geological Society Guidebook 67, p. 255-262.

The 2017 *New Mexico Geology* published a special issue on uranium (more).

Campbell and Biddle (1977, pp. 6-10) conducted some early work on hydrochemical issues around the Morton Ranch mine in Wyoming. Modeling (reconstruction of) the paleohydrogeology of these formations could then be used to determine if the observed distribution of economic uranium deposits could be "recreated" using modern groundwater flow models. Understanding sources of uranium coupled with modern modeling techniques could lead to successful exploration of uranium deposits where no surface expressions or outcropping lithologic manifestations exist.

URANIUM & RARE EARTH STATE / FEDERAL GOVERNMENT RESEARCH

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

The Wyoming Legislature has funded several studies during the last three years conducted by the Wyoming State Geological Survey (WSGS) including rare earth elements (REE), lithium, iron, and zeolite resources. The WSGS released a report in June, 2013 which examined known and potential REE occurrences and deposits. Report of Investigations 65 (RI-65) covers reconnaissance surveys statewide and highlights areas of anomalous concentrations over five times the average crustal abundance. RI-65 was authored by W. M Sutherland, R. W. Gregory, J. D. Carnes, and B. N. Worman and is available at the WSGS website (more).

In June, 2016 the WSGS released a follow-up study to RI-65, A Comprehensive Report on Rare Earth Elements in Wyoming (RI-71), authored by W.M. Sutherland and E.C. Cola (more). RI-71 is focused on expanding the investigation of REE in areas not reached in the RI-65 timeframe and as a follow-up sampling in areas with anomalous REE concentrations, including an examination of select REE occurrences and their association with uranium deposits. Also released in 2016 were reports on the iron, lithium, and zeolite resources, all available on WSGS's sales website.

The WSGS also released in 2016 a public information circular (PIC 46) which is a general reference on the geology of uranium and its use. This publication is intended for the general reader and includes explanations of the nature and origination of uranium, physical and chemical properties, mining history in Wyoming, descriptions of the various steps of the nuclear fuel cycle. R.W. Gregory is the author of this resource and it is available for free download from the WSGS website (more).

Starting in the spring of 2017, the WSGS will be conducting a district-wide study of the Gas Hills uranium occurrences, stratigraphy, and structural and hydrological histories of the area. This project will include an extensive literature search to summarize what is known and also will be an attempt to further refine conditions of mineralization along with structural and hydrologic influences. The study is expected to be completed in late 2018. Coinciding with the Gas Hills district study is a USGS funded State Map mapping project of the Gas Hills 1:24,000 scale quadrangle. A digitized geologic map with cross sections and a technical report will be completed in April, 2018. R.W. Gregory is the lead investigator on both of these projects.

The U.S. Geological Survey (USGS) published via Hydrology Journal, an assessment of uranium concentrations in spring water near the Pigeon Mine in the Grand Canyon region. Geochemical analyses of water, sediment, and rock samples studied indicate a natural source for elevated uranium levels in nearby Pigeon Spring. Another recent study by USGS scientists released early in 2017 examines grade and tonnage models pertaining to roll front uranium deposits along the Texas coastal plain, with comparisons and contrasts between the geologic settings in the east and west portions of the Texas gulf coast. Links to these and other recent studies can be found (here).

The USGS also, in cooperation with the Texas Bureau of Economic Geology, released an assessment in 2015 that highlights an estimated 200 million pounds of estimated (eU_3O_8) resources in the south Texas gulf region. The study also reports an estimated 60 million pounds of identified uranium resources in the ground. They point out that that is roughly equal to 5 years' worth of uranium requirements for the U.S. (more).

The USGS also released in late 2015 their findings from a study conducted on core samples from an in-situ (ISR) recovery operation in the Powder River Basin, Wyoming. They examined the nature of distribution and concentration of uranium (in both +4 and +6 oxidation states) in the ground following mining operations. They noted links between higher concentrations of uranium and precursor minerals in layers of lower permeability, as well as slightly elevated uranium levels associated with organic matter and the clay/silica matrix. Examinations of microbial communities in the ore zone indicated a variety of co-existing microenvironments in the samples observed. Their findings could have important implications on groundwater restoration processes and methods (more).

For information on these and older research projects at the USGS visit their website (here).

Regarding rare earth elements (REE), the USGS is conducting a research project intended to develop mineral deposit models for future assessment work. In addition to REE deposits, they will also examine gold deposits types including epithermal, orogenic, Carlin-type, alkaline-related, iron oxide copper gold, and Precambrian paleoplacers. Rich Goldfarb heads that project.

Another REE project is headed by Philip Verplanck, which aims to gain insight into the role fluids play in the development of ore-grade REE enrichment. The main focus will be on carbonatites, a primary source of light REE. Summaries of these and other research projects at the USGS can be found (here) and (here).

Additional rare-earth research is available for review via the I2M Web Portal (more).

SOCIAL ADVERSARIES TO URANIUM MINING & NUCLEAR POWER DEVELOPMENT

The adversaries of nuclear power (and of mining of uranium) continue to apply the same ill-founded and exaggerated claims throughout the world, mostly generated by competing energy interests and by paid commercial adversaries (wind, solar, and associated industries).

The current technical media are filled with optimism for an expansion of nuclear power, which stands in stark contrast to the media of the 1970s, which stampeded the general public away from nuclear power by pandering to their unfounded fear of radiation leaks at Three-Mile Island, and a few years later at Chernobyl in the Ukraine.

Industry and government need to inform and educate adversaries 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 low cost, 24/7 availability, and climate sensitivity.

As a result of this transition, the Obama Administration's concept of "informed consent of the public," has fostered years of pandering to special interests, and has polarized energy selection by allowing political influences to replace rational selection based on economic and environmental factors in the U.S.

Further to our discussions in the 2015 Annual Report (more, p. 29), over the past few years, members of UCOM have been monitoring the national and local press and some members contribute to the publication "Confronting Media & Other Bias against Uranium Exploration &

Mining, Nuclear Power, and Associated Environmental Issues," which contains a narrative on objectives and reviews of selected media articles (more).

The objectives are to alert the members of AAPG and the general public to the vagaries of some reporters employed by local news media and news media in general around the country.

But some local public servants, activists, their attorneys, and some news media are sowing the seeds of misinformation, creating unnecessary controversy and mistrust around the U.S. This includes the dissemination of biased articles related specifically to inhibiting the expansion of nuclear power and associated uranium exploration and recovery, and of confusing climate change issues (more).

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

Campbell, *et al.* (more) concluded in the 2014 Mid-Year UCOM Report (top of page 16, more) that competition between energy sources should be encouraged as long as the selection is based on economics and environmental factors, but not on government-funded experiments that have not been proven to be on sound economic and operational grounds.

But media and commercial bias wrapped up in American Capitalism are trying to turn public opinions toward one extreme technologically or politically in making our decisions on energy sources selections and regarding other current issues like climate change. Like it or not, this is a characteristic of a democratic society protected under the U.S. Constitution and the Bill of Rights.

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

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

But like the balance needed between supporting industrial development and protecting the environment, the balance also needs to be understood between the common good and those who are the engines of our society.

Although confronted by risk, they place their confidence in science and technology, and in the rational selections that are realized. The real challenge of the future is to incorporate and integrate the society's primary resource, its people, into the technological solutions. The former cannot exclude the latter or our society will sooner or later become overloaded and the democratic systems will no longer function as anticipated (more) and (more).

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

Sociological research can only point the way. Since the Luddites raised the issue more than 150 years ago and the sociologists have been debating the issues involved for as long (more), solutions must be found soon for industry to contribute to the American society by incorporating more American jobs into the rapid technological developments currently underway in the U.S. and around the World. In the U.S., about 47% of jobs are expected to be replaced by smart machines and other forms of automated systems in the next decade or so (more).

The lack of viable solutions to widespread unemployment was part of the conditions that opened the door in the past to Karl Marx's left wing and later a right-wing counter solution to Adolph Hitler. Although there will be no simple solution, the challenge to all Americans then is to begin now to develop new approaches to this apparent conflict of attitudes within the people of industry and the government who encourage or allow jobs to go overseas, and build a new economy within the U.S., in partnership with other like-minded nations, into a system that encourages real contributions and lasting progress in technology that also offers U.S. employment in the decades ahead (more).

In response to the anticipated future lack of jobs (and of industry and government support) as automation continues to expand, Canada has just introduced a pilot program, called the universal basic income program (UBI).

Although most current economists discount the value of tariffs (or VAT taxes) in the economy to create jobs in the U.S. as they were used in the 17th, 18th, and 19th Centuries, it might be time to re-evaluate such methods to rebuild U.S. industry and therefore create jobs as current trade agreements are not eliminated, but modified to reflect a balance between the U.S. and its principal trade partners.

With a 2015 U.S. trade deficient balance of $463 Billion, mostly with China, but also with Japan, Germany, Korea, Saudi Arabia, and others, trade could be more balanced if the engines of the U.S. economy could be allowed tax breaks, and other allowances, to encourage their cooperation by bringing industry back to the U.S., and then to make it difficult for American companies to move overseas in the future if they intend to have markets in the U.S. The outline of this plan was discussed by Hartmann and Fingleton (more). However, other U.S. economists do not agree. A Hartmann - Wolff discussion discounts the merits of such plans (more).

But at the same time, current education by the American K-12 school systems remain deficient in science and mathematics, whereas the major graduate schools (geology and engineering) enroll nearly 50% of those who meet their requirements for research from overseas, e.g., China, India, Japan, Korea, etc.

The energy industry is at the forefront of providing employment of highly trained personnel from American graduate schools and remains one of the principal engines of society providing many jobs today in exploration, production, chemical by-products, and support industries including environmental remediation (more). However, problems have developed over the past 10 to 20 years of losing these well-trained individuals today to their countries of origin where in years past they remained in the U.S. to become American citizens (more), replacing indigenous professionals.

By improving the U.S. educational system and training programs, combined with limitations on student visas and other immigration programs, could stimulate the educational system in the U.S. and thereby increase the number of well-trained American workers and professionals in the U.S.

AMBIENT RADIATION IN THE ATMOSPHERE

On the basis that the impact of radiation is difficult to understand for many, we are continuing a new section to the UCOM report for this Annual Report to provide information 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).

Conca (2016) reports that, aside from exposure to the Sun causing skin cancers and to radon causing lung cancer to underground mining personnel, especially those who smoke, it is very rare for anyone to be damaged by any dose of radiation. Contrary to the hype and fear pandering by the media on Fukushima (more), and even Chernobyl, the observable radiation health effects from both accidents were small. In the case of Fukushima, it was near zero (more and more).

In the case of Chernobyl, although significant, it was much lower than originally assumed (more) and (more). The reason for this is that almost all radiation professionals have been using the wrong model to predict health effects from radiation at these levels, and only recently have the global health, nuclear and radiation agencies realized that error and are moving to correct this matter. However, as with most scientists, this change has been slow. And, the matter is also very political as it involves extensive investments over many years, time will be required to reset the records and widespread viewpoints.

But the heavily entrenched views, generally of the Liberal establishment, are suspicious of industry activities involving radioactivity particularly. Once the views are adjusted in the scientific and technical literature, however, the implications for removing artificial barriers and unnecessary regulations are enormous, especially in the nuclear power industry regulations and in

the exploration and development of off-world activities involving space flight. How the human body reacts to weightlessness is a much more pressing matter to prepare for than radiation in examining duration rather than exposure.

The latest scientific society to make clear that the model applied over the years is not appropriate is suggested by the most qualified independent group to understand this issue, the *Health Physics Society*. It is the scientific society that includes radiation protection scientists, and they recently put out a revised position statement in *Radiation Risk In Perspective* (more). In it, they advise against estimating health risks for people from exposures to ionizing radiation that are anywhere near natural background levels because statistical uncertainties at these low levels are great. In other words, claims of possible adverse health effects resulting from radiation doses below 10,000 mrem (100 mSv) are not defensible.

Background radiation across the Earth varies from 3 mrem/yr (0.03 mSv/yr) over the oceans to 10,000 mrem/yr (100 mSv/yr) in areas of high elevation made up of granitic rocks on the surface. Thus, it is not surprising that populations subjected to radiation levels of 10,000 mrem (100 mSv) or below, show radiation effects that are not statistically different from zero.

Cancer will develop naturally with no contribution from radiation.

If a large population is exposed to radiation levels ten times their normal radiation levels, 40,000 ± 1,600 will develop cancer over their lives (more). Of course, there could be a few dozen cases hiding in that huge error bar number, that plus or minus 1,600 is within the margin of error, but by definition, those will be statistically insignificant and should not be any cause for concern.

They are too few to ever be measured. The concern should be for the 40,000 natural cancers, the direct causes of these are the subject of ongoing, intensive medical research (i.e., Jaworowski (2010), WCR (2016), and others). The reasons for this 60-year overreaction to the incorrect model, called the Linear No-Threshold dose hypothesis, have been examined in some detail (more). LNT has been used in radiation protection to quantify radiation exposure and set regulatory limits.

First put forward after WWII, LNT assumes that the long term, biological damage caused by ionizing radiation (primarily the cancer risk) is directly proportional to the dose … increase the dose, increase the risk, increase the cancers, increase the deaths. But this model just sums exposure to all radiation, without taking into account dose levels or dose rates, or the fact that healthy organisms have immune systems that are very effective at repairing cellular damage from

normal, natural doses of radiation. Conca (2016) provides additional compelling evidence regarding the "low dose" impact. He emphasized that this model was used incorrectly to estimate public health effects. Hundreds of thousands of people were unnecessarily evacuated because of the overestimation of adverse health effects by radiation exposure as predicted by the LNT, incurring a much larger risk from the perils of the evacuation. As a result, many thousands of deaths occurred, not from radiation, but from panic, depression and alcoholism. This applies to all of the incidents at Three-Mile Island (1979), Chernobyl (1986), and at Fukushima (2011), all created by a fear-pandering media and ignorant public service support systems.

The damage at the Fukushima Daiichi Power Plant following the devastating tsunami in Japan has proven costly in many ways, politically, economically and emotionally. But the feared radiation-induced cancers and deaths are not occurring, as claimed by many adversaries. According to UNSCEAR, no radiological health effects have resulted from the Fukushima incident in the public, neither cancers, deaths nor radiation sickness. No one received enough dose, even the 20,000 workers who have worked tirelessly to recover from this event.

A recently published paper by Cuttler and Welsh (2015) in the *Journal of Leukemia* pointed to two important aspects of this issue. UNSCEAR unequivocally reported that "Radiation exposure has never been demonstrated to cause hereditary effects in human populations," a finding supported by recent research (more), and the health data from Hiroshima on about 96,800 humans suggest there is an acute radiation threshold at about 50 rem (500 mSv) for excess leukemia incidence. This is consistent with the conservative threshold dose of 10 rem (100 mSv) for all cancers.

The large numbers of cancers and deaths predicted for Chernobyl and for Fukushima that have flooded the media were all generated by applying this incorrectly-applied model. It is now up to the scientific community, which generally avoids political controversy, to weigh in on this subject and decide whether being conservative is worth the pain and suffering it will cause the public if (or when) another incident occurs.

Radiation Perspectives

Of particular importance is the knowledge that since the large earthquake and tsunami causing the nuclear reactor meltdown in Japan during and after March 11, 2011, there have been no deaths directly caused by the radiation leak from the nuclear plant in Fukushima. The latest update (in April) by the World Nuclear Association on the Fukushima disaster states that there have been no deaths or cases of radiation sickness caused by that nuclear accident (more).

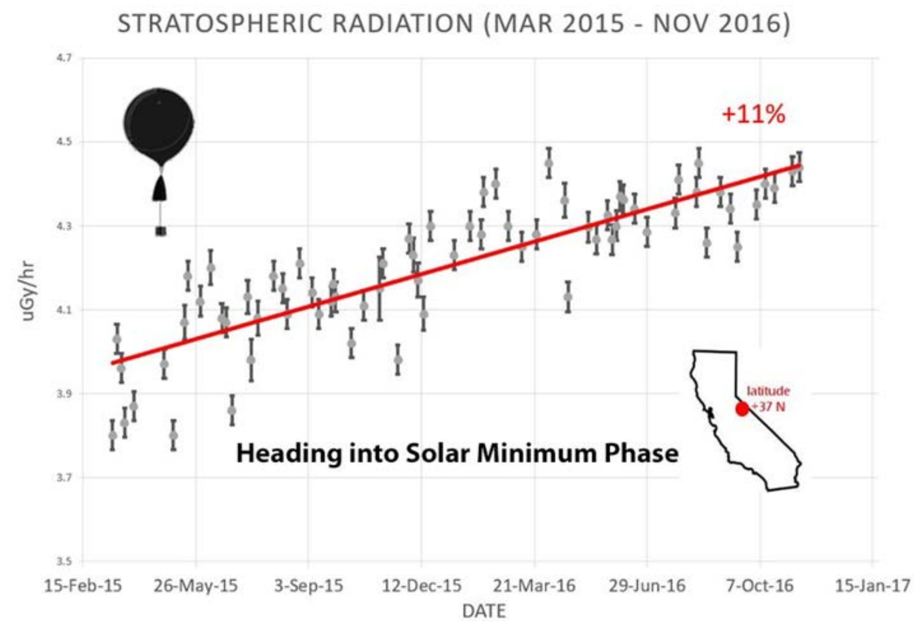
Sources of Radiation

Our Sun, at present, is in its Solar Minimum phase. As sunspots vanish, the extreme ultraviolet output of the sun decreases. This causes the upper atmosphere of Earth to cool and collapse, decreasing orbital resistance. Space junk remains in orbit longer. Also during Solar Minimum, the heliosphere shrinks, bringing interstellar space closer to Earth. Galactic cosmic rays penetrate the inner solar system with relative ease. Indeed, a cosmic ray surge is already underway as indicated in Figure 12 (more).

As indicated in previous UCOM reports, radiation (from cosmic rays) measurements are being recorded on regular flights of space-weather balloons (more). Approximately once a week, the students of *Earth to Sky Calculus* fly space weather balloons into the stratosphere over California, the data from which are presented on *Spaceweather.com* and elsewhere (more).These balloons are equipped with radiation sensors that detect cosmic rays, a form of space weather.

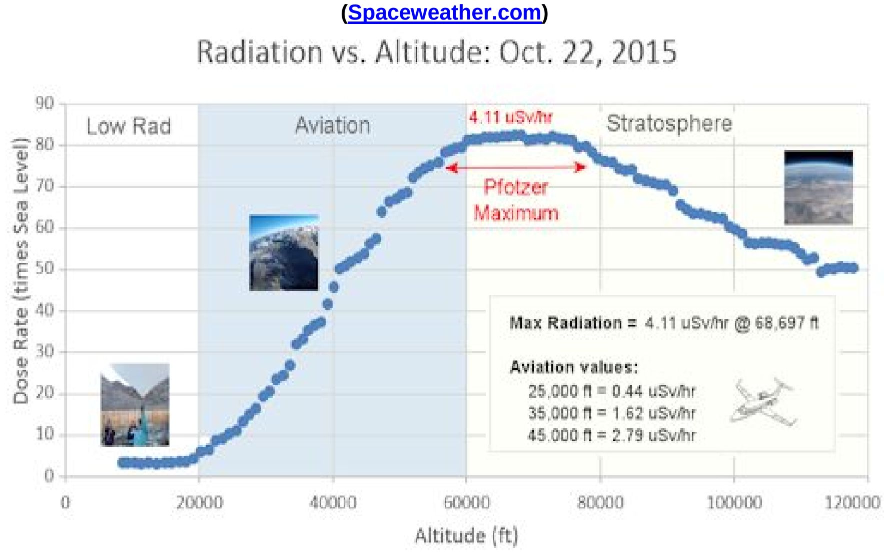
Cosmic rays can seed clouds (more), trigger lightning (more), and penetrate commercial airplanes (more). The measurements show that a person flying back and forth across the continental U.S., just once, can absorb as much ionizing radiation as 2 to 5 dental X-rays.

Figure 12
(Spaceweather.com)



As a guide, Figure 13 is the plot neutron flux 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 13 also shows the aviation range of radiation exposure.

Figure 13
(Spaceweather.com)



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, New Hampshire, Oregon, and now Kansas (more), see Figures 14 through 18:

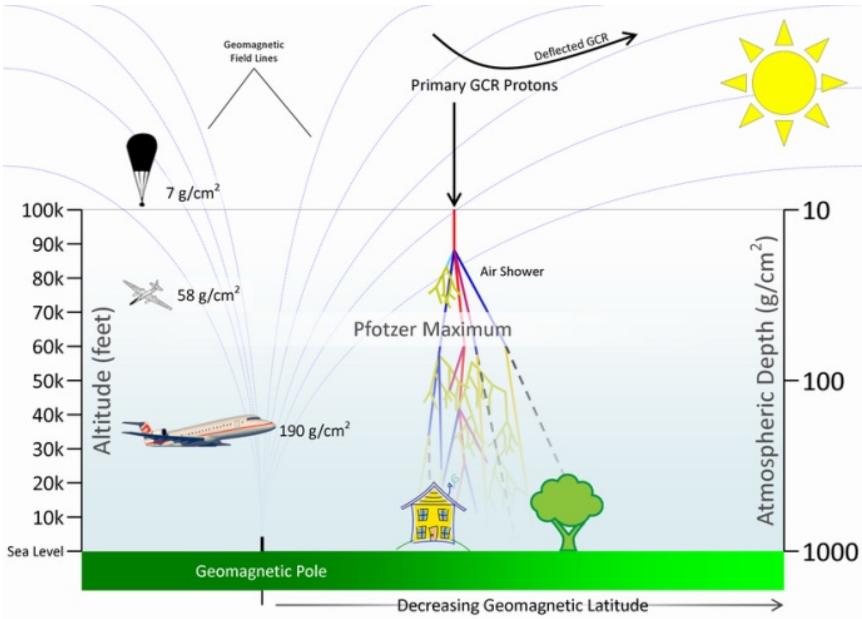


Figure 14

Location of the Pfotzer Maximum Radiation
(Spaceweather.com)

Figure 15

Activities During a Balloon Launch
(Spaceweather.com)

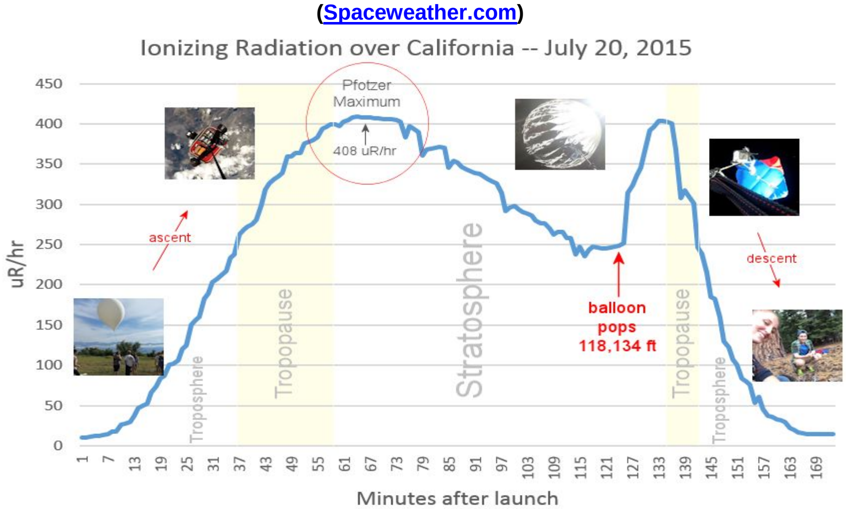


Figure 16 also includes radiation reporting as gamma rays and neutrons.

Figure 16

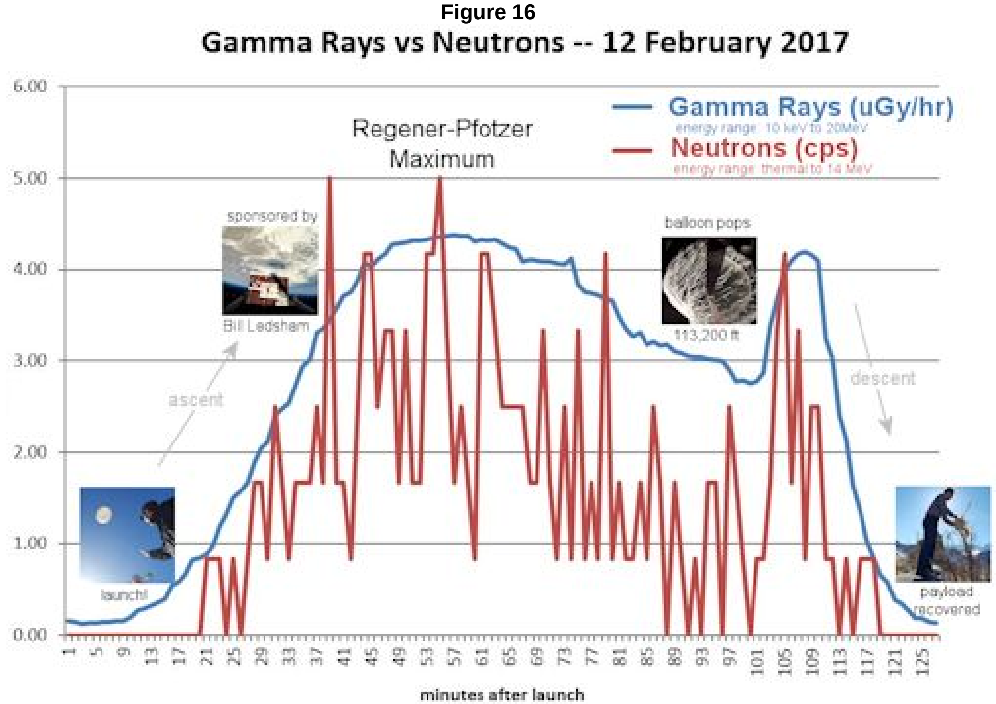


Figure 17

Difference in Maximum Radiation
(Spaceweather.com)

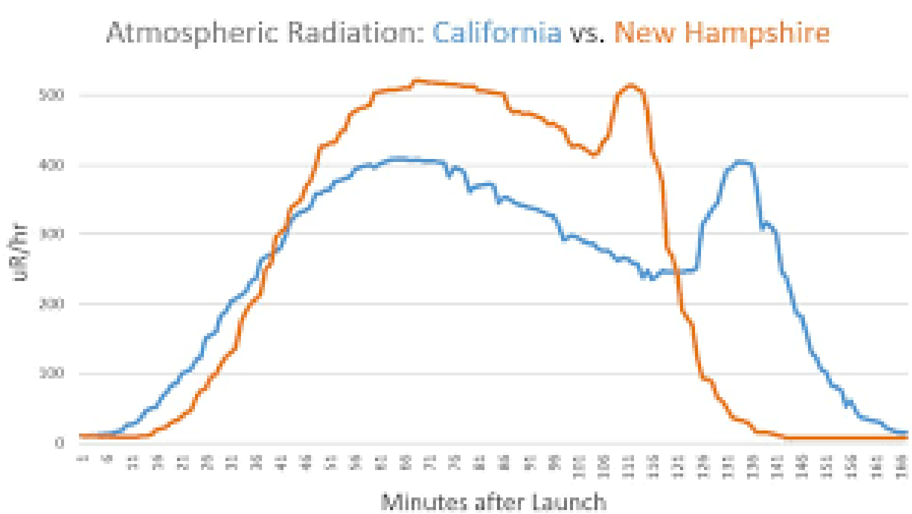
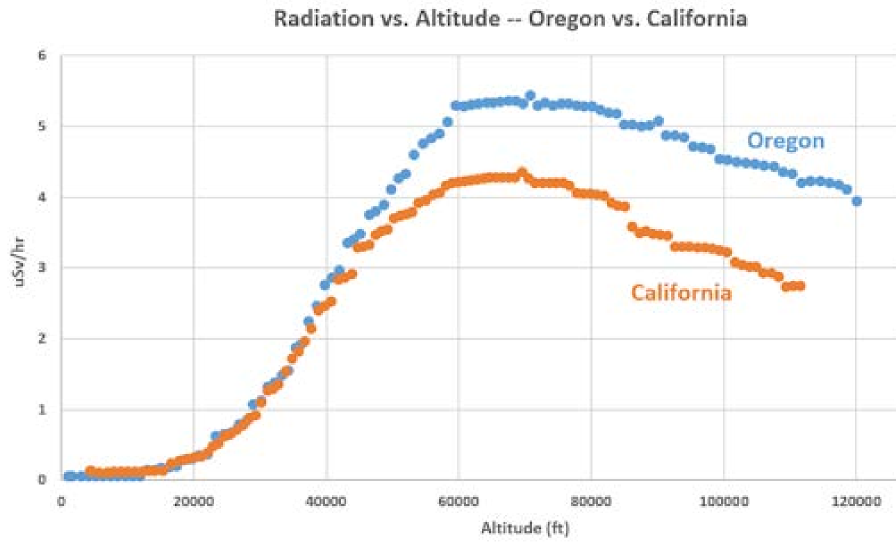


Figure 18

Difference in Maximum Radiation
(Spaceweather.com)



From ground level to 40,000 feet, the two curves are similar. In terms of radiation, California and Oregon are much the same at altitudes where planes fly. Above 40,000 feet, however, the curves diverge. Peak radiation levels detected in the stratosphere over Oregon were more than 25% higher than California. The reason for this difference is, again, likely related to the Earth's magnetic field.

The students of the Earth to Sky Calculus have found something somewhat surprising in the November, 2016 balloon reporting data. X-ray and gamma radiation in the atmosphere over Kansas is stronger than expected. Figure 19 compares dose rates vs. altitude for Kansas and their regular launch site in central California. Although the two sites are at nearly the same magnetic latitude, their radiation levels are quite different, although similar to the Oregon data in Figure 18.

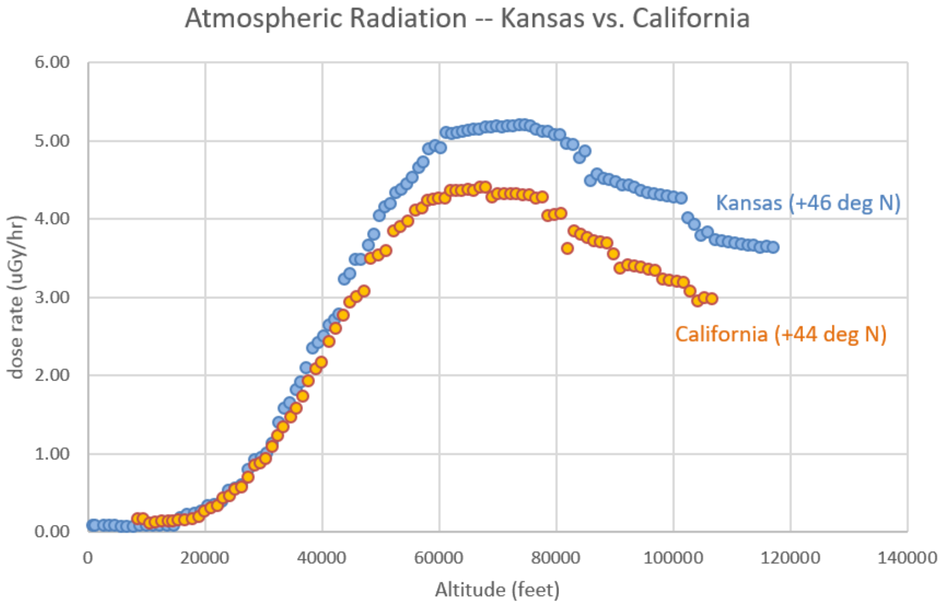
The Pfotzer Maximum (PM) extends from about 55,000 feet to 75,000 feet in altitude and is monitored to evaluate its response to solar storms. Most airplanes fly below it; satellites orbit high above it. Energy releases during large thunderstorms that recently have been identified are known as Jets, Sprites and Elves appear to be in the middle and above the Pfotzer Maximum zone but they also could contribute energy to the Earth's geomagnetic system in some way (see Figure 20).

But note in Figure 19 that the bottom of the Pfotzer Maximum is near 60,000 ft. This indicates that some high-flying aircraft are not far from the zone of maximum radiation (PM). 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 five hours. For context of such radiation; see Radiation Dose Chart (here).

Figure 19

Difference in Maximum Radiation

(Spaceweather.com)



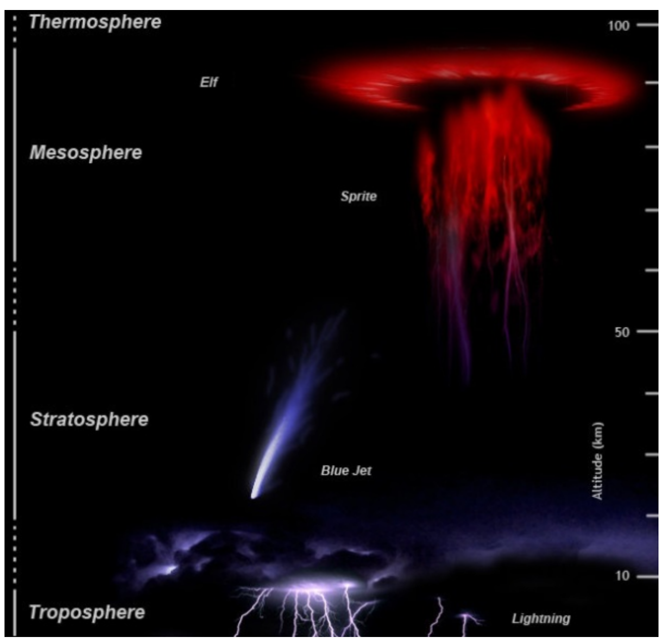


Figure 20 – Sprites and Jet "Lightning" above Large Thunderstorms

(HAARP**)**

(Click to Enlarge Graphic)

The radiation sensors onboard the helium balloons detect X-rays and gamma-rays in the energy range 10 keV to 20 MeV. As indicated, these energies span the range of medical X-ray machines and airport security scanners (more). High levels of ionizing radiation are dangerous to human health, but the levels discussed in this section are not, except for the altitude range of the PM. More research on the impact at these altitudes will be forthcoming in the near future as humans plan to spend more time passing through these altitudes on their way to orbital stations and beyond.

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