# EMD Uranium (Nuclear Minerals) Committee

## 2016 EMD Uranium (Nuclear Minerals and REE) Committee Mid-Year Report

December 18, 2016

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**Michael D. Campbell, P.G., P.H., C.P.G., C.P.H., Chair**
Executive Vice President and Chief Geologist (Mining) / Chief Hydrogeologist (Environmental)
I2M Associates, LLC, Houston, TX
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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- **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
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- **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.**, Senior Geologist, 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) continues to monitor the activities within the nuclear power industry because it drives uranium exploration and development in the United States and overseas. Construction of new power plants and continued operation of the 100 existing nuclear power plants in the U.S., and 447 plants around the world, require large supplies of nuclear fuel (more). The uranium price is related to these demands and must be anticipated years ahead of actual sales, which in turn increases or decreases exploration as well as mining activities.

Input for this Mid-Year Report has also been provided by Henry M. Wise, P.G., C.P.G. (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration and mining; Steven Sibray, P.G., C.P.G., Vice Chair (University) on university activities in uranium, thorium, and rare-earth research; and by Robert Gregory, P.G., Vice Chair (Government) on governmental (State and Federal) activities in uranium, thorium, and rare-earth research, with special input from other members of the Advisory Group. On the latter group, we want to report that Karl S. Osvald in Wyoming has been ill over the past months and we hope for his fast recovery. 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

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) primarily because nuclear (uranium, thorium, radium, etc.) and REE minerals often occur in deposits together 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 |

## 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. This 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).

For a review of the coverage of the various sources of information on energy and associated topics, in the form of almost 4,700 abstracts of current technical reports and media articles from sources in the U.S. and around the world, see the Index to all fields covered in the I2M Web Portal (here).

The nature and impact of radiation, perceived or real, are receiving increasing coverage from a variety of anti-nuclear sources. We are also addressing these important issues as we began reporting with the UCOM (2005) and are addressing these issues as they relate to human health issues in greater detail over the past few years (more) and (more). We have added a section titled: *Ambient Radiation in the Atmosphere*, at the end of our report. This places radiation is context with our environment, on the ground, in the atmosphere, in the orbital reaches, and in space.

## Objectives of UCOM Reports

Based on our review of the various sources of information, the principal objective of our two reports each year is to provide a summary to the members of AAPG and to the general public of the important developments in uranium exploration and production of yellowcake or $U_3O_8$, (and the economics that drive the uranium prices in response to plant demand) to create fuel for the 100 reactors (and those planned, under construction, or unshuttered), and the storage of their waste products in the U.S. and that of the 455 and expanding number of nuclear power plants worldwide.

We also include and assess the status of thorium and rare-earth exploration (and development) because both are often encountered in some types of uranium deposits and the presence of both impact the economics of recovering all three products.

## EXECUTIVE SUMMARY

- The objectives of this report 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. 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.

- Uranium price has declined to about $18.00 in November but began to rise to about $20.00 / pound $U_3O_8$ in December, 2016, which is the lowest price in 10 years, but the long-term contract price has not changed since July, 2015; at $40.00 /pound $U_3O_8$ , but that may be rising in the near future.

- U.S. production of uranium concentrate in the third quarter 2016 was 818,783 pounds $U_3O_8$, up 10% from the second quarter 2016 and up 6% from the third quarter 2015.

- During the third quarter 2016, U.S. uranium was produced at seven U.S. uranium facilities, the same number as in the second quarter 2016.

- Through the first three quarters of 2016, U.S. uranium concentrate production totaled 2,190,611 pounds $U_3O_8$. This amount is 19% lower than the 2,718,929 pounds produced during the first three quarters of 2015.

- About 42% of 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.

- Over the past year, a transitional period has become apparent from burning coal, oil, and to using renewables, such as nuclear power and natural gas (to provide the grid power) and solar and wind (should the latter two prove to be economic).

- 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.

- Natural gas and nuclear power will continue to provide the grid power in the U.S. for years to come.

- 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.

- The planned 2017 production from the Republic of Kazakhstan will be reduced by approximately 10%  to conserve resources for higher prices. This will amount to a volume greater than 5 million lb $U_3O_8$) reduction in the 2017 planned output, which is about 3% of total global uranium production. This has set the stage for the recent increase of the spot price on the uranium world market by 10%, up to $24.25 /lb $U_3O_8$ .

- Six percent of the 57 million pounds $U_3O_8$ delivered in 2015 was U.S.-origin uranium at a weighted-average price of $43.86 per pound.

- 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.

- Other countries have taken Fukushima as a reason to change regulations, which has 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.

- China had a three-year hiatus from allowing any nuclear reactor project to be developed, as it rewrote its regulations, but now China has more than 35 nuclear power reactors in operation, 21 under construction, and others about to begin construction.

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

- **N**uclear energy has been vetted over more than five decades, especially after each environmental incident, and 100 nuclear plants, now with many more under construction, must be re-fueled every three to five years.

- The world's first nuclear reactors operated within the natural environment of very high-grade uranium deposits about two billion years ago in central Africa, moderated by groundwater.

- The current uranium production growth has already been built into the supply chain that has come on-line and ramping up production and this creates a larger amount of spot uranium to be sold into a weak market.

- One of the current impacts on the uranium price includes the U.S. government, which has just finished dumping their back-up yellowcake supply into the U.S. market. These sales are more than double the expected uranium production this year in the U.S.

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

- ❖ As new uranium supplies have come on-line and demand has not, a condition of oversupply has developed creating depressed prices.

- ❖ For the 2018–2019 periods, analysts suggest that a decline in production will occur and an expected significant rise in supply will create a shortage and therefore higher prices.

- ❖ 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.).

- ❖ Other countries have set forth regulations and laws that if the letter of the law is followed, permits would be available to continue development drilling and resource assessment, design mining approach, and to operate mines, for wastewater disposal, etc.

- ❖ But this has certainly not been the case in the U.S., where anti-uranium mining activists and their attorneys have introduced misinformation, exaggerations, and downright falsehoods to slow or complicate the otherwise natural development of in-situ uranium projects.

- ❖ 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.

- ❖ 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.

- ❖ 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.

- ❖ 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 and most of this growth will be in the developing world.

- ❖ 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.

- 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.

- 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.

- 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.

- The nuclear shutdown in Japan left a gap of around 30% in electricity supply in the country. This gap was closed mostly by expensive fossil fuels, primarily by liquefied natural gas (LNG), but also by oil and, from 2013 on, by coal. Since 2012, additional renewable electricity 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.

- 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, but this has occurred while their nuclear plants were shuttered. The economic stress created should be relieved over the next decade as the nuclear plants replace the need for imports and renewables.

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

- 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.

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

- 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).

- 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.

- One hundred 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 on economic grounds in competition with the currently low-priced natural gas and coal-burning power plants.

- The current technical media are filled with optimism for an expansion of nuclear power, 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.

- Small Modular Reactors (SMRs) continue to receive increased attention in 2016, 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.

- There are political indications that the Yucca Mountain facility may still be opened to meet its intended purpose, which is to store nuclear waste from the nation's nuclear power plants, now that the Senior Nevada Senator's influence has been markedly complicated via the recent Nevada elections, and reinforced more recently by many in Washington, D.C.

- 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.

- 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).

- 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 cost, 24/7 availability, and climate sensitivity.

- 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.

- 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 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 in the latter have provided reliable or stable electricity costs.

- Offshore wind systems do show significant cost advantages but their actual CAP and O&M costs remain unknown at present. Despite this, 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.

- Renewables still do not have established records in O&M within a scaled-up grid; the economics appear to be only attractive with substantial state and federal subsidies.

- 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.

- If the climate is to be a consideration, and if the cost of electricity, without local, state, and government subsidies, is to be included in an assessment of the best approach to energy selection, then nuclear power continues to prevail, that is, in balance with natural gas between costs and the environment.

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

- 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 where they are useful. 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.

- News items by the local media and blogs supported by solar and wind interests via commercial, university, or governmental funding express agendas that support the bias toward renewables with no mention of actual costs, especially O&M costs.

- 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.

- 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.

- Interest in uranium, thorium, and rare-earth element research has continued to decrease from the slump in commodity prices.

- The Wyoming Legislature has funded several studies during the last few years conducted by the Wyoming State Geological Survey (WSGS) including rare-earth elements, lithium, iron, and zeolite resources.

- 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 $17^{th}$, $18^{th}$, and $19^{th}$ 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.

- In the area of jobs, the lack of viable solutions to unemployment 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 is to begin 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.

- On the basis that the impact of radiation is difficult for many people to understand, a new section to the UCOM report for this Mid-Year Report to provide information regarding the minimum safe radiation exposure to humans.

## INTRODUCTION

The emphasis of this EMD Mid-Year Report (although it is by design near the end of the year) will continue to discuss 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 2015 Mid-Year Report (more)), energy competition among nuclear energy, coal, natural gas, and various forms of renewable energy, has resulted in projects based on the cost to produce electricity and on the impact on 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.

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) (more). Natural gas, hydroelectric power, and nuclear power will continue to provide the grid power in the U.S. for years to come (more).

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. and other countries.

All this results in unnecessary delays 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 somewhat if the new Administration fulfills its encouragement of nuclear power (more).

One of our focus areas treated in this report will be to discuss the main conventional types of nuclear reactor. For information on the more advanced types, see Advanced Reactors and Small Reactors, and also Generation IV reactors.

**Conventional Reactors: In the U.S. and Around the World**

Oddly enough, the world's first nuclear reactors operated within the natural environment of very-high grade uranium deposits about two billion years ago. These uranium deposits occurred in sandstone and were moderated by the rising and falling of water levels within a shallow groundwater system. The 17 separate sites known in the Oklo district of west Africa, each produced less than 100 kW thermal, and together consumed about six tonnes of that uranium once present in those deposits.

It is assumed that these were not unique worldwide, especially since the recent discoveries in Canada of high-grade uranium deposits associated with igneous and metamorphic rack and sandstone could also have gone thermal (more). However, these deposits seem to have been formed in deeper environments with somewhat less groundwater flow involved, although these high-grade deposits remain to be studied from that perspective.

Once these are being mined (likely by underground methods and by robotics, because of the very high radioactivity and associated radon exposure), any evidence of fissionable activity ($U_3O_8^{235, 238}$ and $Xe^{132, 131 \text{ and } 129}$ ratios) will become apparent as in the Oklo deposit (more).

The World Nuclear Association (WNO) understandably provides a range of reviews on the various features of how nuclear reactors produce and control the release of energy from continuous fission of the atoms of the fuel (i.e., from splitting the atoms of uranium and plutonium). In a reactor, the energy released is simply used as heat to make steam to generate electricity. But in a research reactor (located at various national laboratories and universities around the U.S.), the main purpose of research is to utilize the actual neutrons produced in the core to create conditions and products. In most naval reactors, steam drives a turbine directly for propulsion (more).

The principles for using nuclear power to produce electricity are the same for most types of reactors. The energy released from continuous fission of the atoms of the fuel is harnessed as heat in either a gas or water, and is used to produce steam. The steam is used to drive the turbines which produce electricity (as in most fossil fuel plants).

Today, reactors derived from designs originally developed for propelling submarines and large naval ships generate about 85% of the world's nuclear electricity. The main design is the pressurized water reactor (PWR) which has water at over 300°C under pressure in its primary cooling/heat transfer circuit, and generates steam in a secondary circuit. The less numerous boiling water reactor (BWR) makes steam in the primary circuit above the reactor core, at similar temperatures and pressure.

Both types use water as both coolant and moderator, to slow neutrons. Because water normally boils at 100°C, they have robust steel pressure vessels or tubes to enable the higher operating temperature. Another type uses heavy water, with deuterium atoms, as moderator. Hence the term ‘light water’ is used to differentiate.

In review, on March 11, 2011, a 9.0-magnitude earthquake struck Japan and was followed by a 45-foot tsunami, resulting in extensive damage to the nuclear power reactors at the Fukushima Dai-ichi facility as the water rose over the retaining wall and flooded the back-up power supply that operated the pumps that provided cooling water over the used fuel. Once most of the water covering the old core began to boil off, hydrogen became concentrated in the core shed, eventually ignited by the electrical sparking created by the flooding blowing off the roof of the sheds and releasing some radioactivity into the air.

The story of what happened during and after the tsunami has now been written and the storyline followed the same characteristics as occurred during and after the Three Mile Island incident in the later 1970s. News stories appeared, based on generally circumstantial evidence, that large areas of farmland and villages had been impacted by the radioactivity. Large numbers of people were evacuated. Then, as the data were collected, it was determined that there was no widespread radiation damage, nor were there any deaths caused by radiation or even presented with radiation sickness.

People began to return to their villages but the fear of radiation, even without justification, made the process difficult for the people. Some older people have refused to return. In many cases, it is understandable that the Japanese people carried residual fears because of the end of WWII.

The history of the Fukushima incident can be gleaned by reviewing the summaries of reports as the villages began to recover (more). As a result, the NRC has taken significant action to enhance the safety of reactors in the U.S. based on the lessons learned from this accident. A navigation hub is available to follow the NRC's progress in implementing the many different lessons-learned activities (more).

The restarts in Japan have been slow. Other countries have treated the Fukushima incident as a reason to change regulations, which has 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. China, for example, had a three-year hiatus from allowing any nuclear reactor project to be developed, as it rewrote its regulations, but now China has more than 35 under construction. Sweden has changed its mind and even Germany has begun to re-evaluate their position after observing the impact of burning brown coal, of having to buy natural gas, and of attempting to get renewables into operation has demonstrated the true value of nuclear power (more).

Nuclear energy has been vetted over more than five decades, especially after each environmental incident, and 100 nuclear plants, with more under construction, must be re-fueled every three to five years. Uranium company exploration activities are influenced by uranium prices, and especially in developing mining operations. Low-cost operations such as in-situ mining or high-grade mining of underground or shallow open-pit operations can produce yellowcake while prices are low but higher cost operations cannot operate at much of a profit.

At present, about 42% of 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. In total this mined uranium accounts for 84% of annual nuclear power station requirements (more). Either short-term spot prices or long-term contracted prices control supply according to the anticipated demand coming from utilities or owners of nuclear power plants.

**Uranium Prices**

Regor (2016) reports that there are two parts to why the spot uranium price has not recovered. First, the current November-December 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 in addition to slow re-starts in Japan after Fukushima. And with surplus production growth already been built into the supply chain that has come on-line and ramping up production at low cost and creating a large amount of spot uranium is available to be sold into a weak market. Cameco Corp.'s Cigar Lake operations are an example of operating in a weak market.

The extra pressure on the spot market, but as for contract pricing, has remained relatively stronger in the low $40s (per pound $U_3O_8$). Producers are making decisions based on the contract price, not the current spot price. So there is a current disconnect between spot and contract pricing and associated activities.

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:

- Additional reactors are planned, including some of the world's most advanced, to give a doubling of nuclear capacity to at least 58 GWe by 2020-21, then up to 150 GWe by 2030, and much more by 2050.
- The impetus for increasing nuclear power share in China is air pollution from coal-fired plants.
- China's policy is to have a closed nuclear fuel cycle.
- China has become largely self-sufficient in reactor design and construction, as well as other aspects of the fuel cycle, but is making full use of western technology (Westinghouse and GE), while adapting and improving it.
- China's policy is to 'go global' with exporting nuclear technology including heavy components in the supply chain.

On January 10th, 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. The strategic Kazakh 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. Their greater value will instead be realized when produced into improved markets in the coming years.

This has set the stage for the recent increase 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.

Other impacts on the uranium price include the U.S. government, which has just finished dumping their back-up yellowcake supply into the U.S. market (more). These sales are more than double the expected uranium production this year in the U.S. Proceeds from the sale of federal inventory are used to fund the cleanup of legacy federal government nuclear facilities, such as the former Paducah and Portsmouth uranium enrichment plants.

So, as the supply has come on-line and demand has not, a condition of oversupply has developed. As to 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, that is 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 below are from 2010 data, another example of EIA using out-of-date data and management.

Regor (2016) also 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.

Six percent 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).

Also, other countries have set forth regulations and laws that if the letter of the law is followed, permits would be 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 anti-uranium mining activists and their attorneys have introduced mis-information, exaggerations, and downright falsehoods to slow or complicate the otherwise natural development of in-situ uranium projects in Texas, Colorado, and South Dakota. Wyoming, on the hand, does not have similar opposition because of strong state support and because Wyoming has been a major producer for many years.

There are efforts being made to expose these activities as attempting to sow the seeds of misinformation, creating unnecessary controversy and mistrust around some rural areas in U.S. These areas are where uranium has formed in economic quantities and grade, such the Gulf Coast of Texas, Wyoming, and especially in southern Virginia, where a world class deposit was discovered a few years ago (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, started 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, started in 1978 and 1980) capable of generating a total of 1,863 megawatts.

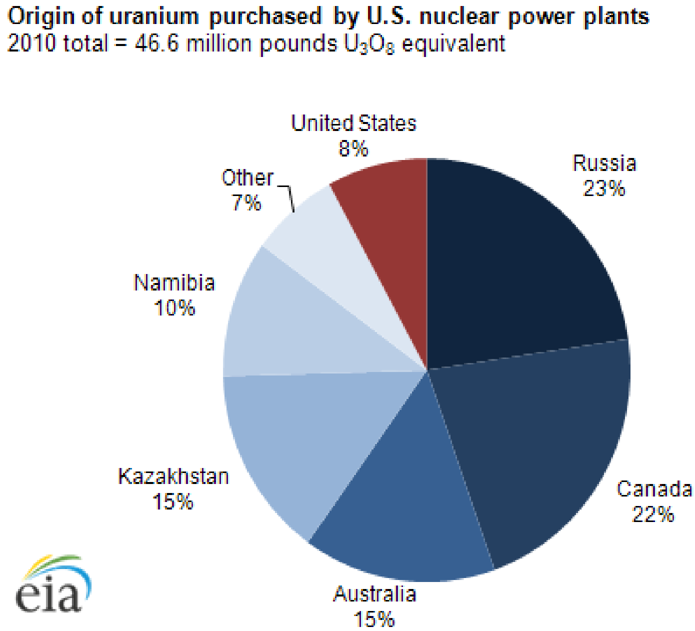
By having a local uranium fuel supply produced in Virginia, electricity prices should be stable for decades in Virginia and surrounding states. Once underway, the mine would generate local support, and diminish anti-nuclear opposition, and might even improve the energy markets in the state and surrounding areas minimizing electricity prices.

The opposition includes the dissemination of clearly biased articles, reports, all related specifically to inhibiting the 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 EPA (more , see page 4, Review #28).

EIA reported that during 2015, 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 $U_3O_8$e increased 6% compared with the 2014 total of 53 million pounds $U_3O_8$e. The 2015 weighted-average price of \$44.13 per pound $U_3O_8$ decreased 4% compared with the 2014 weighted-average price of \$46.16 per pound $U_3O_8$.

Six percent of the 57 million pounds $U_3O_8$e delivered in 2015 was U.S.-origin uranium 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, and others (see Figure 1).

**Figure 1**




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 (signed date) and as such could reflect some agreements of short and medium terms as well as longer term (more).

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).

But in the U.S., after some time, the spent fuel would be sufficiently cooled for shipment to the 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 in New Mexico has been in operation for some years (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 would be needed 5-10 years in the future to fuel the new plant and then the same every 3 to 5 years hence. This would stimulate new mine production or an expansion of existing mines, should the mines have such capabilities.

Some mines in Canada, Australia, and perhaps Kazakhstan, and other areas have been shown to have such expansion capabilities, e.g., Cigar Lake, McArthur River in 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 and other types of deposits elsewhere in the world (Peru, Uruguay and Paraguay, India, Iran, and Tanzania) so there will be no shortage of producing mines over the next few decades (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?

**Electrical Generation by Nuclear Power**

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.

World Nuclear News (WNN) reports that 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. 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.

But 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. 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, as per WNN.

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).  Nuclear energy, on the other hand, will be the third fastest growing after natural gas. 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 increase in nuclear generating capacity (15 GWe), the EIA notes. At the same time, reactor shutdowns in Canada and Europe, together with 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 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 to meet the fast-paced growth of energy demand, as per EIA.

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, they will create the greatest demand in the history of nuclear power for $U_3O_8$ production over the next decade (more). But the other countries will be creating serious demands as well; for the rest of the list, see reference (more).

But should the electricity demand increase 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.

## 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 $U_3O_8$e 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.

Around the world, not every reactor planned will happen. However, those already under construction will most likely get finished, and, by doing so, increased uranium demand by 8% in 2015, and will probably lift it another 14% by the end of 2016 or early 2017. Kazakhstan has recently cut production by 10% in order to conserve resources while low prices prevail, which should have a positive effect on prices.

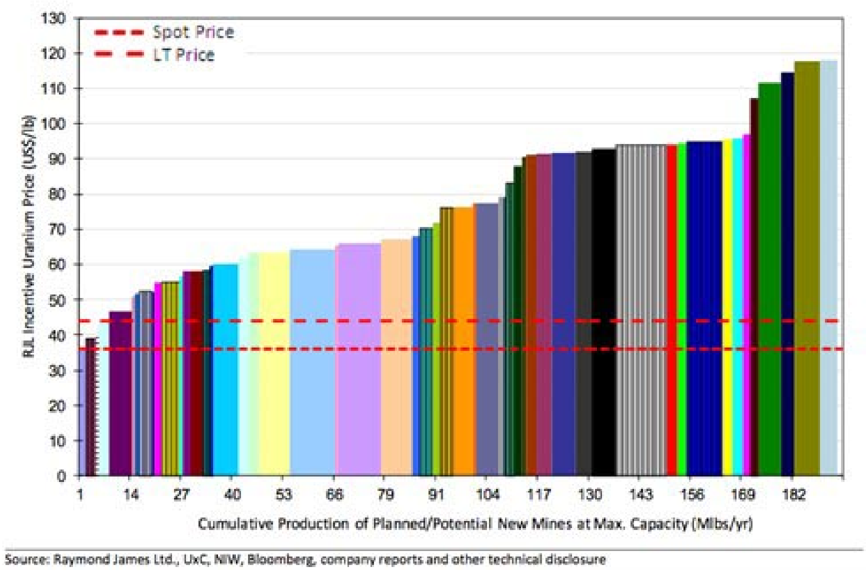



**Figure 2 – Cumulative Production of Planned/Potential New Mines at Maximum Capacity (Million Pounds $U_3O_8$/Year)**
(From: Raymond James)

Operators of nuclear reactors do not risk running out of fuel, because that would cause serious system problems. In addition, they cannot load 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 needs at least three years out, and often as much as a decade out.

Two years from now is 2019, and that is about when the major production shortfall is predicted to arrive, according to Raymond James chart (see Figure 2). During the uranium price spike in 2007, operators raced to sign supply deals out of concern that prices would stay very high, impacting their plant economics. Shortly thereafter, prices quickly reversed. Nevertheless, those contracts were binding, and many of them incorporated ten-year terms.

That means that many supply contracts will run out this year (2017). As a result, nuclear operators are uncomfortably uncovered three years out. They haven't signed new contracts to replace those about to expire because they have been able to pick up cheap uranium on the spot market for years. But time is running out for this bargain**.** Operators are evaluating the supply and demand data, at contract timelines and price predictions, and they have concluded the market is set to tighten.

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.

COOs 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 (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, COOs signed 54 new purchase contracts with deliveries in 2015 of 12 million pounds $U_3O_8$e at a weighted-average price of $37.97 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.

COOs 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 for COOs 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 $U_3O_8$.

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 COOs.

**Uranium Feed, Enrichment Services, Uranium Loaded**

In 2015, COOs 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).

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. 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 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.

The Focus Economics (2016) report states that prices have been under pressure since the nuclear incident in Fukushima in 2011, but which led to a sharp decrease in demand for the metal and the closure of numerous nuclear reactors around the world. Moreover, the uranium market remains 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.

## URANIUM PRODUCTION IN THE U.S.

### 3rd Quarter 2016

U.S. production of uranium concentrate in the third quarter 2016 was 818,783 pounds $U_3O_8$, up 10% from the second quarter 2016 and up 6% from the third quarter 2015. During the third quarter 2016, U.S. uranium was produced at seven U.S. uranium facilities, the same number as in the second quarter 2016. The 4th Quarter and final 2016 production data were not available for this report.

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

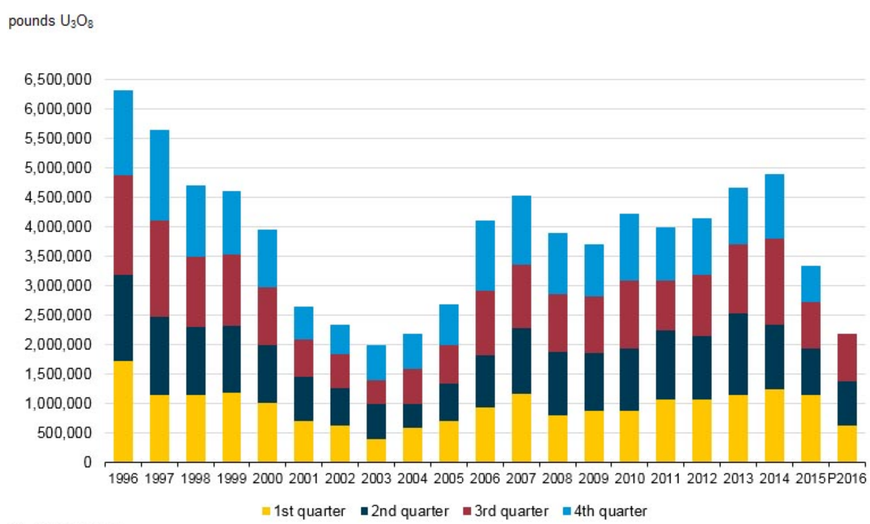
White Mesa Mill (Utah)

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

Crow Butte Operation (Nebraska)
Lost Creek Project (Wyoming)
Nichols Ranch ISR Project (Wyoming)
Ross CPP (Wyoming)
Smith Ranch-Highland Operation (Wyoming)
Willow Creek Project (Wyoming)

First, through the first three quarters of 2016, U.S. uranium concentrate production totaled 2,190,611 pounds $U_3O_8$. This amount is 19% lower than the 2,718,929 pounds produced during the first three quarters of 2015, see Figure 3.

**Figure 3**
Uranium concentrate production in the United States, 1996 - 3rd quarter 2016




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

The status of the in-situ recovery plants in the U.S. are presented in Table 2. Notice that there are 19 such facilities in various states of readiness.

Domestic Uranium Production Report 3rd Quarter 2016
Release Date: November 30, 2016
Next Release Date: February 2017

**Table 2**

**U.S. Uranium In-Situ Recovery Plants by Owner, Capacity, & 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 |
|---|---|---|---|---|---|---|---|
| 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 |
| Azarga Uranium Corp | Dewey Burdock Project | *Fall River and Custer, South Dakota* | 1,000,000 | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed |
| Cameco | Crow Butte Operation | Dawes, Nebraska | 1,000,000 | Operating | Operating | Operating | Operating |
| Hydro Resources, Inc. | Church Rock | *McKinley, New Mexico* | 1,000,000 | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed |
| Hydro Resources, Inc. | Crownpoint | *McKinley, New Mexico* | 1,000,000 | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed | Partially Permitted And Licensed |
| Lost Creek ISR LLC | Lost Creek Project | Sweetwater, Wyoming | 2,000,000 | Operating | Operating | Operating | Operating |
| Mestena Uranium LLC | Alta Mesa Project | Brooks, Texas | 1,500,000 | Standby | Standby | Standby | Standby |
| Power Resources, Inc. dba Cameco Resources | Smith Ranch-Highland Operation | Converse, Wyoming | 5,500,000 | Operating | Operating | Operating | Operating |
| South Texas Mining Venture | Hobson ISR Plant | Karnes, Texas | 1,000,000 | Operating | Standby | Standby | Standby |
| South Texas Mining Venture | La Palangana | Duval, Texas | 1,000,000 | Operating | Standby | Standby | Standby |
| Strata Energy Inc | Ross CPP | Crook, Wyoming | 375,000 | Changing License to Operational | Operating | Operating | Operating |
| URI, Inc. | Kingsville Dome | Kleberg, Texas | 1,000,000 | Restoration | Restoration | Restoration | Restoration |
| URI, Inc. | Rosita | Duval, Texas | 1,000,000 | Reclamation | Reclamation | Reclamation | Reclamation |
| URI, Inc. | Vasquez | Duval, Texas | 800,000 | 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 |
| Uranium Energy Corp. | Goliad ISR Uranium Project | *Goliad, Texas* | 1,000,000 | Permitted And Licensed | Permitted And Licensed | Permitted And Licensed | Permitted And Licensed |
| Uranium One Americas, Inc. | Jab and Antelope | *Sweetwater, Wyoming* | 2,000,000 | Developing | Developing | Developing | Developing |
| Uranium One Americas, Inc. | Moore Ranch | *Campbell, Wyoming* | 500,000 | Permitted And Licensed | Permitted And Licensed | Permitted And Licensed | Permitted And Licensed |
| Uranium One USA, Inc. | Willow Creek Project (Christensen Ranch and Irigaray) | Campbell and Johnson, Wyoming | 1,300,000 | Operating | Operating | Operating | Operating |
| **Total Production Capacity:** | | | **26,975,000** | | | | |

Notes: Production capacity for 3rd Quarter 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."

Note: **Ctrl-Click to Enlarge Table 2**

## URANIUM EXPLORATION IN THE U.S.

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 "dramatic" price increases finally occurs. 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).

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 mining in the U.S. has been conducted in Wyoming, Nebraska, Utah, South Dakota, Texas, Colorado, Alaska, and New Mexico, with numerous other states having some potential (more).

## SIGNIFICANT FIELD ACTIVITIES IN EXPLORATION AND MINING

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 grades at depth (more),

Fission has made a major discovery in the Patterson Lake area (more), and

Top 10 Mines: Canada (1+), Kazakhstan (5), Australia (1), Niger (1), Russia (1), and Nambia (1).

## OPERATIONS IN THE U.S.

One hundred 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.

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).

## NUCLEAR POWER PLANT CONSTRUCTION OVERSEAS

2016 data confirms that construction overseas 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).

## SMALL MODULAR REACTORS

Small Modular Reactors (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).

## SPENT-FUEL STORAGE

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 markedly reduced via the recent Nevada elections (here) and more recently by many Washington, DC. observers (more).

Bipartisan support and Republican efforts to reinstate the Yucca Mountain facility are getting some support from a number of sources, including the new administration. Even though the 'store in place" plan is viable, the nuclear power plants are not getting what they have been paying decades for and what has been mandated by law, a secure place to store (not dispose) the 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 history of the growing support and the opposition against opening the Yucca Mountain facility are 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).

## 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).

## RENEWABLE ENERGY SYSTEMS

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.

Enter SMRs. 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).

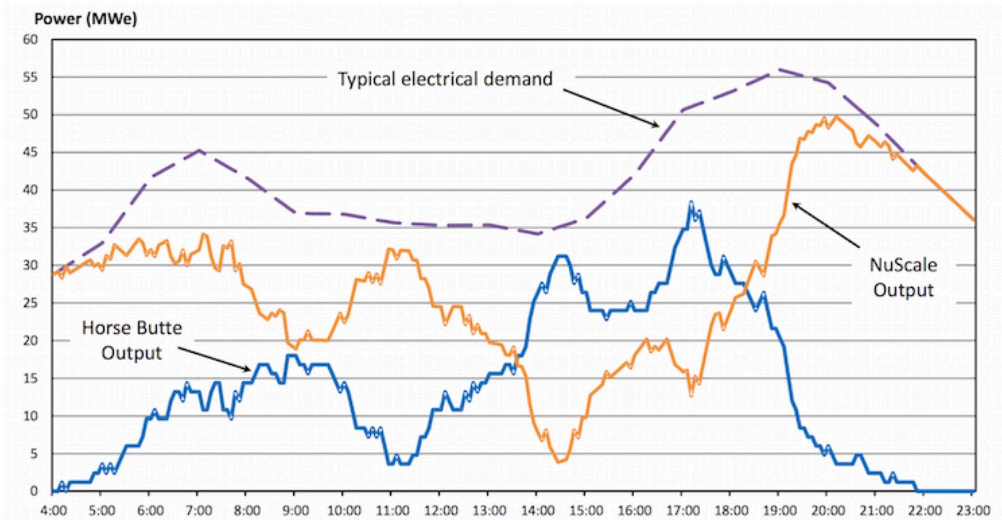



**Figure 4 – Typical Grid Support of Renewables add Wind Farm and SMR**

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 (see Figure 4).

SMRs 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.

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).

## 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 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 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.

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

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

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

## RARE-EARTH ACTIVITIES

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

China has not only the largest proportion of the total global rare-earth resources in production on Earth, but also the most extensively developed total supply chain for rare earths, and perhaps most important of all, the overwhelming majority of rare earths R&D implemented by the largest group of scientists and engineers devoted to rare earths studies and manufacturing on Earth. Some evidence exists that 90-95% of all rare earth R&D today takes place in China (more). Thus, it would appear that the rare earths industry is much more important to China than it could ever be to any other nation currently.

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 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 what China is doing (see above p. 39).

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".

Campbell and Biddle (1977, pp. 6-10) conducted some early work on hydrochemical issues around the Morton Rach 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 few 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 are available on WSGS's website. This included 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, and descriptions of the various steps of the nuclear fuel cycle. R. W. Gregory is the author of this resource and it is available for download from the WSGS website (more).

The U.S. Geological Survey (USGS), in cooperation with the Texas Bureau of Economic Geology, released an assessment last year 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 five 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 (more).

Additional uranium research subjects investigated by the U. S. Geological Survey are available for review via the I2M Web Portal (more).

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

**Social Issues Impact on Energy Selection**

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)

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 17$^{th}$, 18$^{th}$, and 19$^{th}$ 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 economists do not agree. A Hartmann and 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 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).

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 Mid-Year 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 hurt 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 as close to zero as one can get. In the case of Chernobyl, although significant, it was much lower than originally assumed (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. 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're 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, has 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 cancer and death 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 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.

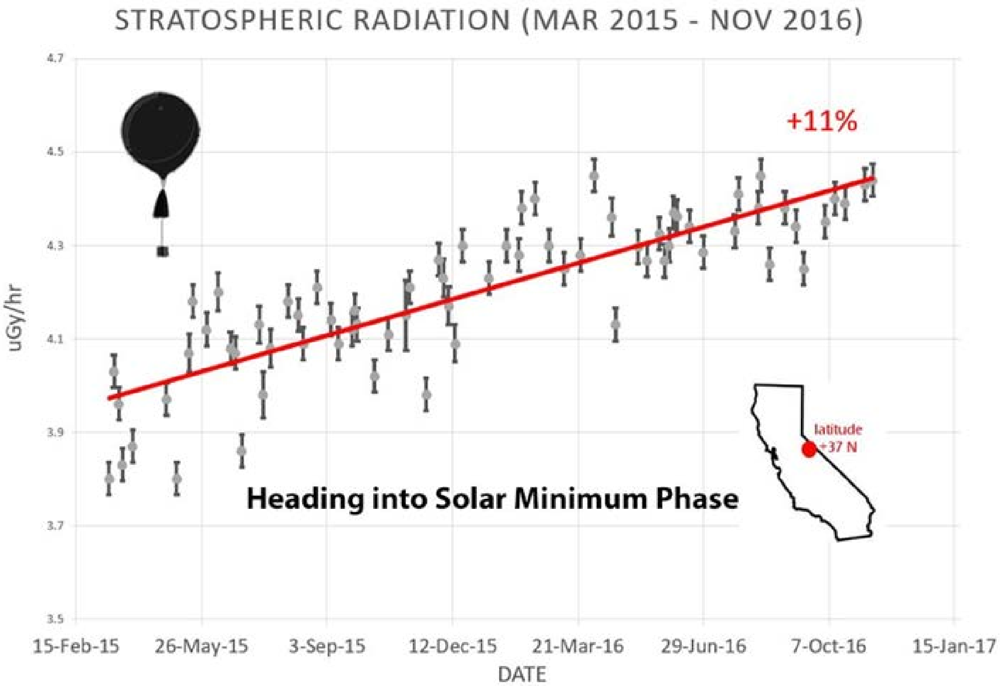
**Sources of Radiation**

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 5 (more).

As indicated in previous UCOM reports, radiation (from cosmic ray) measurements are being made 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).

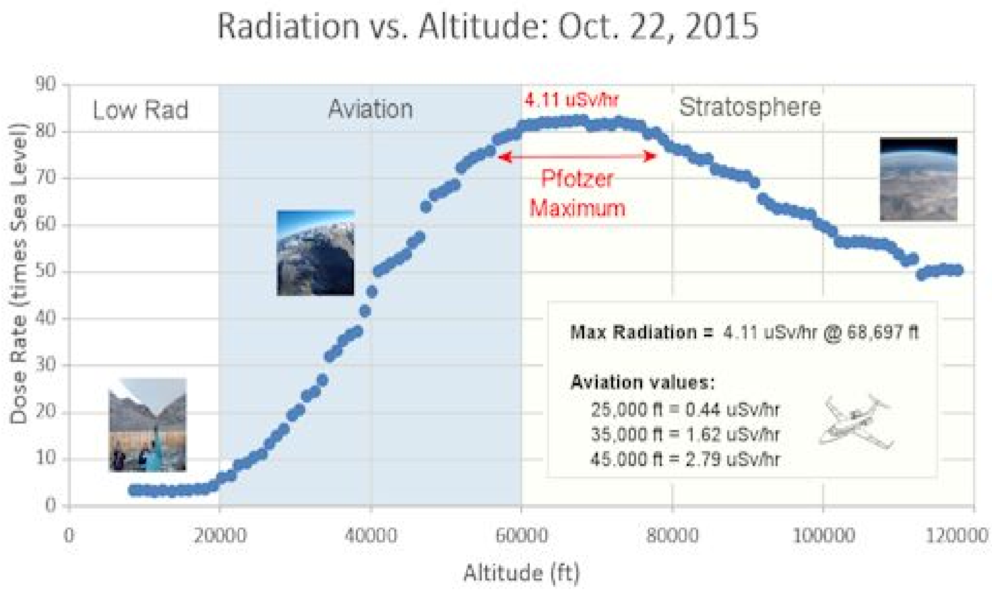
**Figure 5**




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.

As a guide, Figure 6 is the plot from the October 22, 2015 flight. The plot below shows the data recorded for increasing altitude vs. radiation dose rate during the balloon flight, which reach a maximum altitude of 120,000 feet above sea level. Figure 6 also shows the aviation range of radiation exposure.

**Figure 6**




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 7 through 10.

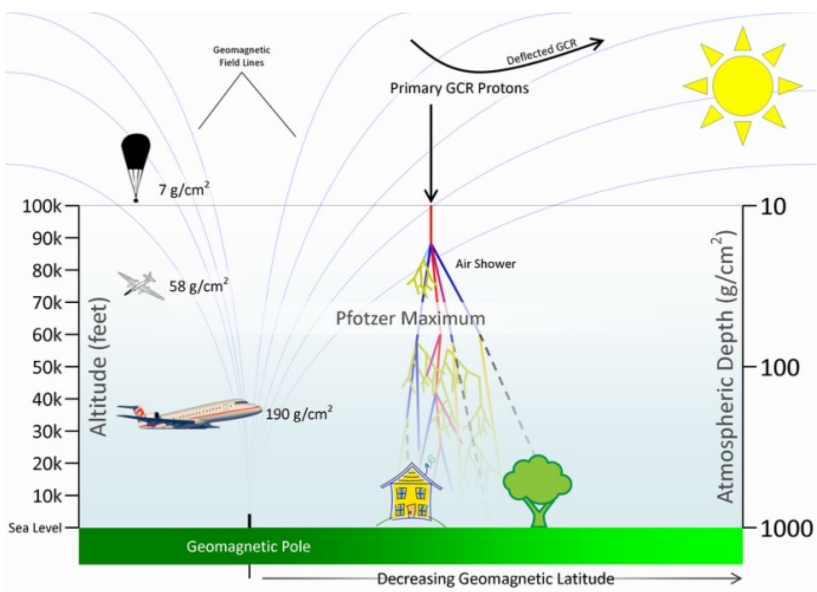



**Figure 7 – Location of the Pfotzer Maximum Radiation (Spaceweather.com)**

**Figure 8 – Activities During a Balloon Launch**
**([Spaceweather.com])**

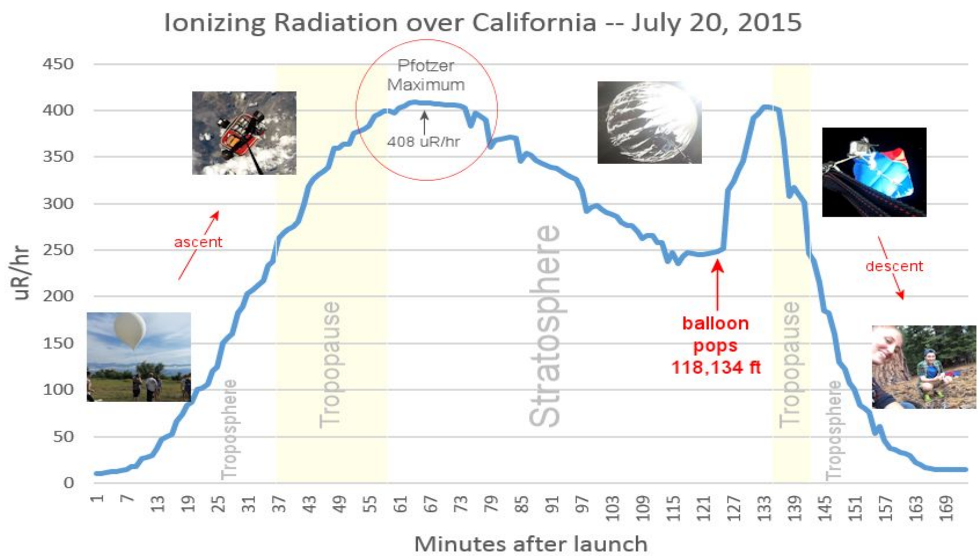



**Figure 9 – Difference in Maximum Radiation**
**([Spaceweather.com])**

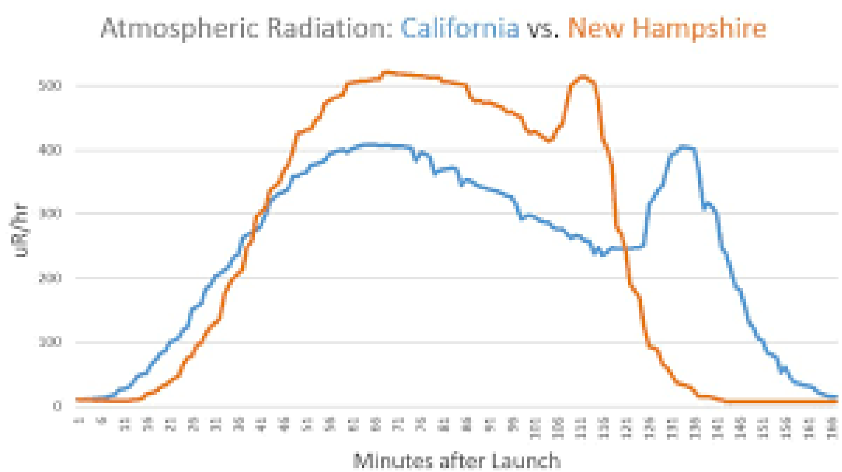
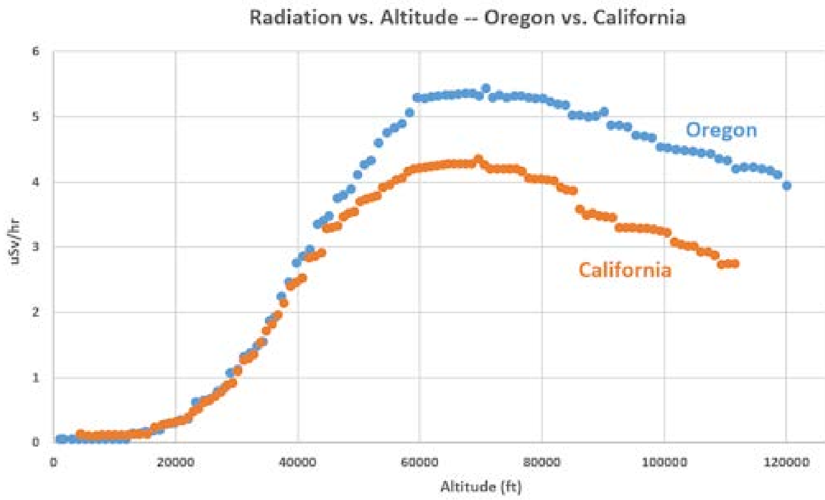


**Figure 10 - Difference in Maximum Radiation**
**([Spaceweather.com](Spaceweather.com))**




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.

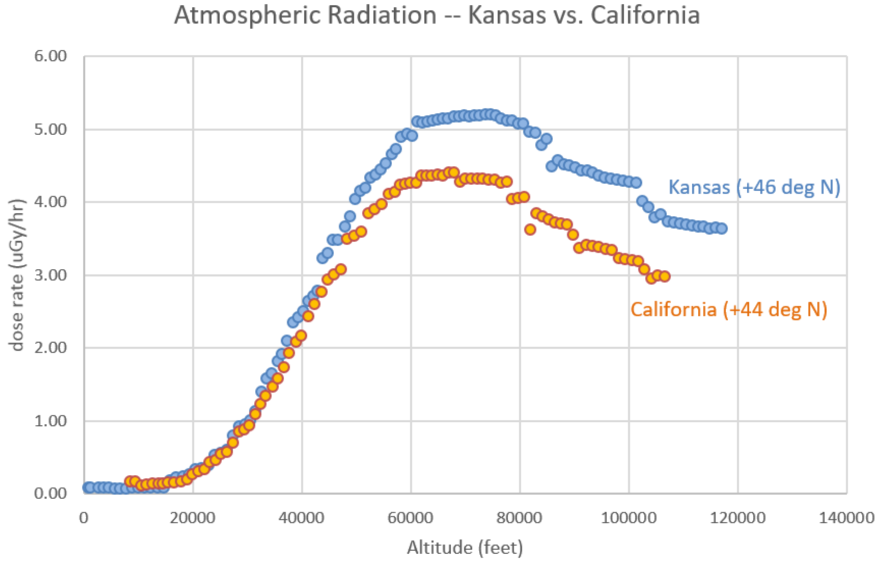
The students of the Earth to Sky Calculus have found something somewhat surprising in the November, 2016 balloon reporting data. X-ray and gamma radiation in the atmosphere over Kansas is stronger than expected. Figure 11 compares dose rates vs. altitude for Kansas and their regular launch site in central 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 10.

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 12).

But note in Figure 6 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 11 - Difference in Maximum Radiation**

**([Spaceweather.com](Spaceweather.com))**



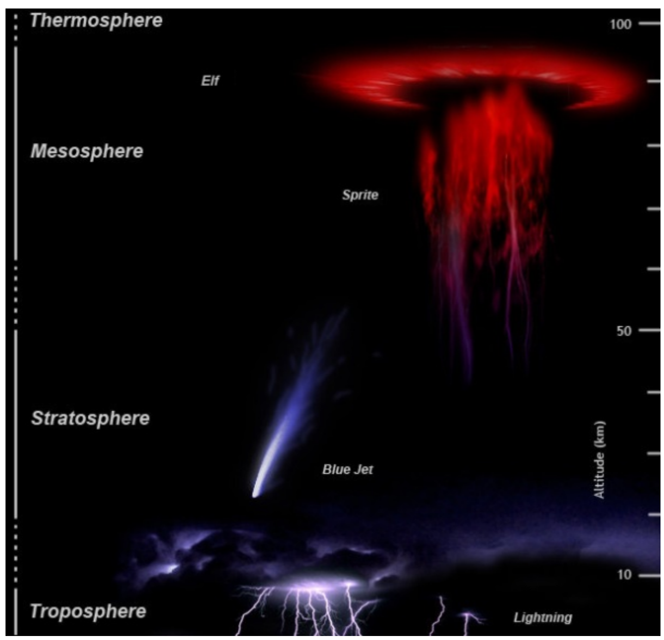




**Figure 12** – **Sprites and Jet "Lightning" above Large Thunderstorms**
**(**[HAARP](HAARP))
(Click to Enlarge Graphic)

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

A list of references for additional reading on the subjects discussed in this report is presented below:

## REFERENCES CITED AND LINKED

Ambrose, William A., James F. Reilly II, and Douglas C. Peters (eds), 2013, "Energy Resources for Human Settlement in the Solar System and Earth's Future in Space," EMD-AAPG Memoir 101: Nine Chapters, 2013 p.,: http://i2massociates.com/downloads/Memoir101-T0fC2016.pdf

BBC News, 2011, "India:'Massive' Uranium Find in Andhra Pradesh," July 19: http://www.bbc.com/news/world-south-asia-14196372

Bagley, Katherine, and Naveena Sadasivam, 2015, "Climate Denial's Ugly Side: Hate Mail to Scientists," Dec 11: https://insideclimatenews.org/news/11122015/climate-change-global-warming-denial-ugly-side-scientists-hate-mail-hayhoe-mann

Brennan Weiss, 2015, "Nuclear energy may have big future in Virginia: study," June 10: http://www.washingtontimes.com/news/2015/jun/10/nuclear-energy-may-have-big-future-in-virginia-stu/

Brett Burk, "Radiation Risk in Perspective - Position Statement of The Health Physics Society," July 2010: http://hps.org/documents/risk_ps010-3.pdf

Campbell, M. D., *et al.*, 2005, "2005 EMD Uranium (Nuclear Minerals and REE) Committee: Recent Uranium Industry Developments, Exploration, Mining and Environmental Program in the U.S. and Overseas," Energy Minerals Division AAPG March 25, 2005: http://www.mdcampbell.com/EMDUraniumCommittee2005Report.pdf

Campbell, M. D., M. David Campbell, Jeffrey D. King and Henry M. Wise, 2014, "Coal, Just Not for Burning," AIPG Journal: The Professional Geologist 2014, pp. 21-25: http://www.i2massociates.com/downloads/CampbellJustNotforBurning-July19-2014Col.pdf

Campbell, M. D., 2014, "A Perspective on Nuclear Power, Uranium, and the Post-Fukushima Revival," EMD Uranium (Nuclear and Rare Earth Committee): http://i2massociates.com/downloads/NUCLEARPOWER-November1-2014.pdf

Campbell, M. D., *et al.*, 2014, "2014 EMD Uranium (Nuclear Minerals and REE) Committee Mid-Year Report," Nov 18: http://i2massociates.com/downloads/EMDUranium2014MidYearReportVer1.4.pdf

Campbell, M. D., *et al.*, 2015, "2015 EMD Uranium(Nuclear Minerals and REE) Committee Annual Report," May 20: http://www.i2massociates.com/downloads/2015-05-30-EMD-AnnualMeeting-Committee-Uranium.pdf

Campbell, M. D., *et al. 2015*, "2015 EMD Uranium Committee Mid-Year Report," Dec 29: http://i2massociates.com/downloads/EMDUranium2015Mid-YearReport.pdf

Campbell, M. D., *et al.*, 2016, "2016 EMD Uranium Committee Annual Report," June 18: http://i2massociates.com/downloads/2016EMDUraniumAnnualReport.pdf

Campbell, M. D., and Kevin T. Biddle, 1977, "Chapter 1: Frontier Areas and Exploration Techniques," : http://www.i2massociates.com/downloads/CamBidd77A.pdf

CERN Accelerating Science, "Could there be a link between galactic cosmic rays and cloud formation? An experiment at CERN is using the cleanest box in the world to find out,": http://home.cern/about/experiments/cloud

Colburn, Jamison, 2015, "NRC's Expected Supplemental EIS for Yucca: New Information?", Feb 19: http://www.nepalab.com/?p=640

Colorado State University, Department of Environmental & Radiological Health Sciences Department of Environmental & Radiological Health Sciences: http://www.i2massociates.com/Downloads/WhickerNaturalRadiation.pdf

Conca, James, 2013 "Beyond Earth's Atmosphere : Energy Needs For Space Colonization," May 5: http://www.forbes.com/sites/jamesconca/2013/05/05/beyond-earths-atmosphere-energy-needs-for-space-colonization/#1b9b103f2528

Conca, James, 2014, "Absurd Radiation Limits Are A Trillion Dollar Waste,"Jul 13: http://www.forbes.com/sites/jamesconca/2014/07/13/absurd-radiation-limits-are-a-trillion-dollar-waste/#78718a28127d

Conca, James, 2015, "Choking Our Health Care System With Coal,"Nov 5: http://www.forbes.com/sites/jamesconca/2015/11/05/choking-our-health-care-system-with-coal/#4ed6864a182f

Conca, James, 2015, "The Fukushima Disaster Wasn't Disastrous Because Of The Radiation,"Mar 16: http://www.forbes.com/sites/jamesconca/2015/03/16/the-fukushima-disaster-wasnt-very-disastrous/#363afb2e51e7

Conca, James, 2016, "TVA Way Ahead Of The Pack With Nuclear And Solar," Jun 7: http://www.forbes.com/sites/jamesconca/2016/06/07/tva-way-ahead-of-the-pack-with-nuclear-and-solar/#655208ad2805

Conca, James, 2016, "World-Wide Risk From Radiation Very Small,"Jun 24: http://www.forbes.com/sites/jamesconca/2016/06/24/radiation-poses-little-risk-to-the-world/#344b49e348b5

Christopher, Peter A., 2007, "Technical Report on the Coles Hill Uranium Property Pittsylvania County, Virginia," PAC Geological Consulting INC : https://www.nrc.gov/docs/ML0816/ML081630113.pdf

Desjardins, Jeff , 2013, "Athabasca Basin: The World's Highest Grade Uranium District," Aug 6: http://www.visualcapitalist.com/athabasca-basin-the-worlds-highest-grade-uranium-district/

Desjardins, Jeff, 2015, "Mapping Every Power In the United States," Visual Capitalist, August 18: http://www.visualcapitalist.com/mapping-every-power-plant-in-the-united-states/

Edwards, Tony, and Anthony Ferner, 2002, "The Renewed 'American Challenge': A Review of Employment Practice in U.S. Multinationals," June: http://onlinelibrary.wiley.com/doi/10.1111/1468-2338.00222/abstract

Els, Frik, 2016, "Graphic: Uranium Juniors Defy Bear Market Pricing," Jun 1: http://www.mining.com/chart-uranium-juniors-defy-bear-market-pricing/

Energy Innovation, 2015, "Comparing the Costs of Renewable and Conventional Energy Sources," Feb 7: http://energyinnovation.org/2015/02/07/levelized-cost-of-energy/

Energy Minerals Division (AAPG), 2015, "Unconventional Energy Resources: 2015 Review," in *Natural Resources Research*: http://i2massociates.com/ downloads/EMDNRR2015.pdf

Energy Minerals Division (AAPG), 2013, "Unconventional Energy Resources: 2013 Review," in *Natural Resources Research*: http://www.i2massociates.com/ downloads/NRR-2013.pdf

Energy Minerals Division (AAPG), 2011, " Unconventional Energy Resources: 2011 Review," in *Natural Resources Research*: http://www.aapg.org/divisions/emd

Energy Minerals Division (AAPG), 2009, " Unconventional Energy Resources: 2009 Review," in *Natural Resources Research*: http://www.aapg.org/divisions/emd

Energy Minerals Division (AAPG), 2007, " Unconventional Energy Resources: 2007 Review," in *Natural Resources Research*: http://www.i2massociates.com/ downloads/NRRJournal_2007.pdf

FocusEconomics, 2016, "Uranium Price Outlook,": http://www.focus economics.com/commodities/energy /uranium

Futurism, 2016, "Universal Basic Income: What if the Problem isn't Automation but Work Itself?": https://futurism.com/universal-basic-income-what-if-the-problem-isnt-automation-but-work-itself/

Gallegos, T.J., K.M. Campbell, R.A. Zielinski, P.W. Reimus, J.T. Clay, N. Janot, John R. Bargar and William M. Benzel, 2015, "Persistent U(IV) and U(VI) Following In-Situ Recovery(ISR) Mining of a Sandstone Uranium Deposit, Wyoming, USA," in *Applied Geochemistry*: http://www.sciencedirect.com/science/article/pii/S0883292715300342

Gayathri Vaidyanathan, 2015, "Nuclear Power Must Make a Comeback for Climate's Sake," Dec 4: https://www.scientificamerican.com/article/nuclear-power-must-make-a-comeback-for-climate-s-sake/?WT.mc_id=SA_WR_20151209

GoviEx,2016, "GoviEx Uranium - Part of the Nuclear Energy Solution," Nov: http://www.goviex.com/ pdf/Goviex_Uranium_November_2016.pdf

Harris, Michael, 2014, "U.S. has 65 GW of untapped hydroelectric power potential, DOE report says", HydroVision International, April 29: http://www.hydroworld.com/articles/2014/04/u-s-has-65-gw-of-untapped-hydroelectric-power-potential-doe-report-says.html

I2M Natural Resources Group, 2017, "Confronting Media and other Bias against Uranium Exploration and Mining, Nuclear Power, and Associated Environmental Issues," Jan 16: http://i2massociates.com/downloads/ConfrontingBias.pdf

I2M Web Portal Search Result (1), 2017, "Uranium Committee-EMD - Henry M. Wise,": http://www.aapg.org/about/aapg/overview/committees/emd/articleid/26353/committee-emd-uranium

I2M Web Portal Search Result (10), 2017, "Uranium Recovery Technology,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=In-Situ+Mining&PageNumber=1

I2M Web Portal Search Result (100), 2017, "Renewable Energy by any Other Name does not Smell as Sweet,": http://web.i2massociates.com/categories/renewable-energy-by-any-other-name-does-not-smell-as-sweet.asp

I2M Web Portal Search Result (101), 2017, "Google Rejects Renewables,": http://web.i2massociates.com/categories/Google-Rejects-Renewables.asp

I2M Web Portal Search Result (102), 2017, "O and M Solar Costs,": https://www.google.com/search?q=O+and+M+Solar+Costs&cad=h

I2M Web Portal Search Result (103), 2017, "O and M Wind Costs,": https://www.google.com/search?q=O+and+M+Wind+Costs&oq=O+and+M+Wind+Costs&aqs=chrome..69i57.10719j0j8&sourceid=chrome&es_sm=122&ie=UTF-8

I2M Web Portal Search Result (104), 2017, "4 Factors Shaping the Wind Energy Industry in 2009,": http://web.i2massociates.com/categories/wind-energy-economics.asp

I2M Web Portal Search Result (105), 2017, "Bat Killings by Wind Energy Turbines Continue,": http://web.i2massociates.com/categories/bat-killings-by-wind-energy-turbines-continue.asp

I2M Web Portal Search Result (106), 2017, "Could Hydroelectric Power Flood America with New Power?": http://web.i2massociates.com/categories/could-hydroelectric-power-flood-america-with-new-power.asp

I2M Web Portal Search Result (107), 2017, "The Hidden Cost of Hydroelectric Power,": http://web.i2massociates.com/categories/the-hidden-cost-of-hydroelectric-power-2015201110224846BC.asp

I2M Web Portal Search Result (108), 2017, "The 2014 State of Wind Energy - Desperately Seeking Subsidies,": http://web.i2massociates.com/categories/the-2014-state-of-wind-energy-desperately-seeking-subsidies.asp

I2M Web Portal Search Result (109), 2017, "Wind Energy: Pros and Cons,": http://web.i2massociates.com/categories/wind-energy.asp

I2M Web Portal Search Result (11), 2017, "Nuclear-power Economics,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=nuclear+power+economics&PageNumber=1

I2M Web Portal Search Result (110), 2017, "Nuclear Power,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=nuclear+power&PageNumber=1

I2M Web Portal Search Result (111), 2017, "Vietnam,": http://energyfromthorium.com/

I2M Web Portal Search Result (112), 2017, "Thorium,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Thorium&PageNumber=1

I2M Web Portal Search Result (113), 2017, "Rare Earth,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Rare+Earth&PageNumber=1

I2M Web Portal Search Result (114), 2017, "Rare Earths Statistics and Information,": https://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/

I2M Web Portal Search Result (115), 2017, "Wyoming State Geological Survey,": http://sales.wsgs.wyo.gov/uranium-geology-and-applications/

I2M Web Portal Search Result (116), 2017, "Carbon Sequestration,": http://web.i2massociates.com/categories/climate-change-anthropocene-associated issues.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded

I2M Web Portal Search Result (117), 2017, "Luddites Employment and Technology,": https://scholar.google.com/scholar?q=Luddites+employment+and+technology&btnG=&hl=en&as_sdt=0%252%20C44&as_vis=1

I2M Web Portal Search Result (118), 2017, "Futurism,": https://futurism.com/chrome-frame/

I2M Web Portal Search Result (119), 2017, "Discussion by Hartmann and Fingleton,": https://www.youtube.com/watch?v=J8QPDdydC2c

I2M Web Portal Search Result (12), 2017, "Reactor Designs,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=reactor+design&PageNumber=1

I2M Web Portal Search Result (120), 2017, "Discussion by Hartmann and Fingleton2,": https://www.youtube.com/watch?v=3klabW-pptk

I2M Web Portal Search Result (121), 2017, "Division of Environmental Geosciences,": http://www.aapg.org/divisions/deg

I2M Web Portal Search Result (122), 2017, "Radiation,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=radiation&PageNumber=1

I2M Web Portal Search Result (123), 2017, "Health & Safety - Mining, Environmental, Cyber,": http://web.i2massociates.com/categories/radiation-poses-little-risk-to-the-world.asp

I2M Web Portal Search Result (124), 2017, "Chernobyl Accident 1986,": http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx

I2M Web Portal Search Result (125), 2017, "Journal of Leukemia,": https://www.esciencecentral.org/journals/leukemia-and-ionizing-radiation-revisited-2329-6917-1000202.php?aid=65327

I2M Web Portal Search Result (126), 2017, "Spaceweather.com,": http://www.spaceweather.com/

I2M Web Portal Search Result (127), 2017, "Earth to Sky Calculus,": https://www.facebook.com/earthtoskycalculus/

I2M Web Portal Search Result (128), 2017, "Radiation Dose Chart,": http://www.ela-iet.com/EMD/radiation.jpg

I2M Web Portal Search Result (129), 2017, "Can You Believe They Can Do This,": http://beforeitsnews.com/science-and-technology/2013/11/he-who-controls-the-weather-rules-the-world-campaign-blue-jets-lightning-haarp-and-red-sprites-videos-2651790.html

I2M Web Portal Search Result (13), 2017, "Operational Aspects that Drive Uranium Prices,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=nuclear+power&PageNumber=1

I2M Web Portal Search Result (130), 2017, "X-Ray,": https://en.wikipedia.org/wiki/X-ray

I2M Web Portal Search Result (14) about climate change, 2017,: http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Climate+Change&PageNumber=1

I2M Web Portal Search Result (15), 2017, "Thorium,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=thorium&PageNumber=1

I2M Web Portal Search Result (16), 2017, "Helium 3,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Helium-3&PageNumber=1

I2M Web Portal Search Result (17), 2017, "Fusion Research,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=fusion+energy&PageNumber=1

I2M Web Portal Search Result (18), 2017, "Environmental and Societal Issues Related to Nuclear Waste Storage and Handling,": http://web.i2massociates.com/categories/environmental-impact%20-%20cases-nuclear-wastes.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded

I2M Web Portal Search Result (19), 2017, "Current Research Developments in the Rare-Earth Commodities,":http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Rare+earth&PageNumber=1

I2M Web Portal Search Result (2), 2017, "Uranium Committee-EMD - Steven Sibrary,": http://www.aapg.org/about/aapg/overview/committees/emd/articleid/26353/committee-emd-uranium

I2M Web Portal Search Result (20), 2017, "The Index to All Fields in the I2M Web Portal,": http://web.i2massociates.com/

I2M Web Portal Search Result (21), 2017, "Human Health Issues in Greater Details,": http://web.i2massociates.com/categories/uranium-nuclear-minerals-related-environmental-issues.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded

I2M Web Portal Search Result (22), 2017, "EMD UCOM 2016 Annual Report": http://web.i2massociates.com/categories/2016-emd-uranium-nuclear-minerals-and-ree-committee-annual-report-to-the-emd.asp

I2M Web Portal Search Result (23), 2017, "EMD UCOM 2015 Mid-Year Report" http://web.i2massociates.com/categories/2015-emd-uranium-nuclear-minerals-and-ree-committee-mid-year-report.asp

I2M Web Portal Search Result (24), 2017, "Trump Administration Seeking to Save Nuclear Power Plants?": http://web.i2massociates.com/categories/trump-administration-seeking-to-save-nuclear-power-plants.asp

I2M Web Portal Search Result (25), 2017, "Advanced Nuclear Power Reactors,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx

I2M Web Portal Search Result (26), 2017, "Small Nuclear Power Reactors,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

I2M Web Portal Search Result (27), 2017, "Generation IV Nuclear Power Reactors,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/generation-iv-nuclear-reactors.aspx

I2M Web Portal Search Result (28), 2017, "Nuclear Fuel Cycle,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle.aspx

I2M Web Portal Search Result (29), 2017, "Nuclear Power Reactors,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

I2M Web Portal Search Result (3),2017, "Uranium Committee-EMD - Robert Gregory,": http://www.aapg.org/about/aapg/overview/committees/emd/articleid/26353/committee-emd-uranium

I2M Web Portal Search Result (30), 2017, "Fukushima,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Fukushima&PageNumber=1

I2M Web Portal Search Result (31), 2017 , "Uranium Mining,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx

I2M Web Portal Search Result (32), 2017 , "Nuclear Power In China,": http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx

I2M Web Portal Search Result (33), 2017, "Uranium Energy Corp,": http://www.uraniumenergy.com/projects/paraguay/

I2M Web Portal Search Result (34), 2017, "Uranium Mine Ownership - USA,": http://www.wise-uranium.org/uousa.html

I2M Web Portal Search Result (35), 2017, "Uranium Mine Ownership - Kazakhstan,": http://www.wise-uranium.org/uokz.html

I2M Web Portal Search Result (36), 2017, "Uranium Mine Ownership - Russia,": http://www.wise-uranium.org/uoru.html

I2M Web Portal Search Result (37), 2017, "Uranium Mine Ownership - Uzbekistan,": http://www.wise-uranium.org/uoasi.html#UZ

I2M Web Portal Search Result (38), 2017, "Uranium Mine Ownership - Australian,": http://www.wise-uranium.org/uoaus.html#GEN

I2M Web Portal Search Result (39), 2017, "Uranium Mine Ownership - Canada,": http://www.wise-uranium.org/uocdn.html

I2M Web Portal Search Result (4), 2015, "AAPG Foundation - Jay M. McMurray,": http://foundation.aapg.org/gia/mcmurray.cfm

I2M Web Portal Search Result (40), 2017, "Uranium Mine Ownership - Europe,": http://www.wise-uranium.org/uoeur.html

I2M Web Portal Search Result (41), 2017, "Uranium Mine Ownership - Czech Republic,": http://www.wise-uranium.org/uoeur.html#CZ

I2M Web Portal Search Result (42), 2017, "Uranium Mine Ownership - Malawi,": http://www.wise-uranium.org/upmw.html

I2M Web Portal Search Result (43), 2017, "Uranium Mine Ownership - Namibia,": http://www.wise-uranium.org/uona.html

I2M Web Portal Search Result (44), 2017, "Uranium Mine Ownership - Niger,": http://www.wise-uranium.org/uoafr.html#NE

I2M Web Portal Search Result (45), 2017, "Uranium Mine Ownership - South Africa,": http://www.wise-uranium.org/uoza.html

I2M Web Portal Search Result (46), 2017, "Uranium Mining Overview,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx

I2M Web Portal Search Result (47), 2017, "Virginia,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Virginia&PageNumber=1

I2M Web Portal Search Result (48), 2017, "Nuclear Power in Virginia,": http://www.virginiaplaces.org/energy/nuclearpower.html

I2M Web Portal Search Result (49), 2017, "Uranium Mining by Country,": https://en.wikipedia.org/wiki/Uranium_mining_by_country

I2M Web Portal Search Result (5), 2017, "Natural Resources Research,": http://www.springer.com/earth+sciences+and+geography/mineralogy+%26+sedimentology/journal/11053

I2M Web Portal Search Result (50), 2017, "Japan Nuclear Hydrogen Explosion Fukushima,": https://www.youtube.com/watch?v=p3tVy01Xi7M

I2M Web Portal Search Result (51), 2017, "U.S. Department of Energy,": http://www.wipp.energy.gov/wipprecovery/recovery.html

I2M Web Portal Search Result (52), 2017, "Arizona,": http://web.i2massociates.com/categories/Descriptive-Model-of-Solution-Collapse-Breccia-Pipe-Uranium-Deposits.asp

I2M Web Portal Search Result (53), 2017, "Uruguay Mining News,": http://www.mining.com/tag/uruguay/

I2M Web Portal Search Result (54), 2017, "Mantra to Start Uranium Mining in Tanzania,": http://web.i2massociates.com/categories/mantra-to-start-uranium-mining-in-tanzania.asp

I2M Web Portal Search Result (55), 2017, "List of Countries by Uranium Reserves,": https://en.wikipedia.org/wiki/List_of_countries_by_uranium_reserves

I2M Web Portal Search Result (56), 2017, "Increasing Productivity, Efficiency, and Safety in Mining with Robotics and Internet Technology,": http://web.i2massociates.com/categories/increasing-productivity-efficiency-and-safety-in-mining-with-robotics-and-internet-technology.asp

I2M Web Portal Search Result (57), 2017, "China CGN Mining Buys Stake in Canadian Fission Uranium,": http://web.i2massociates.com/categories/china-cgn-mining-buys-stake-in-canadian-fission-uranium.asp

I2M Web Portal Search Result (58), 2017, "Applications can be accepted from,": https://www.itu.int/ITU-D/youth/yes/2009/List%20of%20countries.pdf

I2M Web Portal Search Result (59), 2017, "EIA Sees Strong Growth in Nuclear Generation to 2040?": http://web.i2massociates.com/categories/eia-sees-strong-growth-in-nuclear-generation-to-2040.asp

I2M Web Portal Search Result (6), 2016, "The Chronological List of Dr. Conca's contributions to date,":http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Conca&PageNumber=1

I2M Web Portal Search Result (60), 2017, "Have Uranium Prices Finally Turned a Corner,": http://web.i2massociates.com/categories/have-uranium-prices-finally-turned-a-corner.asp

I2M Web Portal Search Result (61), 2017, "I2M Index,": http://web.i2massociates.com/categories/default.asp

I2M Web Portal Search Result (62), 2017, "Japan and Their Nuclear Restart,": http://web.i2massociates.com/categories/japan-and-their-nuclear-restart.asp

I2M Web Portal Search Result (63), 2017, "Japan,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Japan&PageNumber=1

I2M Web Portal Search Result (64), 2017, "Uranium Mergers and Acquisitions,": https://www.google.com/search?q=uranium%20mergers%20and%20acquisitions&rct=j

I2M Web Portal Search Result (65), 2017, "Uranium Exploration,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=uranium+exploration&PageNumber=1

I2M Web Portal Search Result (66), 2017, "Exploration,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=exploration&PageNumber=1

I2M Web Portal Search Result (67), 2017, "Coles Hill,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Coles+Hill&PageNumber=1

I2M Web Portal Search Result (68), 2017, "Uranium Mining in the United States,": https://en.wikipedia.org/wiki/Uranium_mining_in_the_United_States

I2M Web Portal Search Result (69), 2017, "Uranium Mine Ownership - China,": http://www.wise-uranium.org/upcn.html

I2M Web Portal Search Result (7), 2016, "About the I2M Web Portal," : http://i2massociates.com/web-portal/

I2M Web Portal Search Result (70), 2017, "Cameco Yeelirrie Uranium Mine in Western Australia Rejected by WA EPA?": http://web.i2massociates.com/categories/cameco-yeelirrie-uranium-mine-in-western-australia-rejected-by-wa-epa.asp

I2M Web Portal Search Result (71), 2017, "Operations": https://www.energyres.com.au/operations/

I2M Web Portal Search Result (72), 2017, "Nuclear Winner - The Case for South Australia Storing Nuclear Waste": http://web.i2massociates.com/categories/nuclear-winner-the-case-for-south-australia-storing-nuclear-waste.asp

I2M Web Portal Search Result (73), 2017, "NexGen": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=asc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=NexGen&PageNumber=1

I2M Web Portal Search Result (74), 2017, "A Major Uranium Discovery in Patterson Lake Area": http://web.i2massociates.com/categories/a-major-uranium-discovery-in-patterson-lake-area.asp

I2M Web Portal Search Result (75), 2017, "World-Class Uranium - Types of Uranium Deposits": http://web.i2massociates.com/categories/world-class-uranium-types-of-uranium-deposits.asp

I2M Web Portal Search Result (76), 2017, "Can Uranium be a Great Investment Again?": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Kazakhstan&PageNumber=1

I2M Web Portal Search Result (77), 2017, "Australia": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Australia&PageNumber=1

I2M Web Portal Search Result (78), 2017, "Niger": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Niger&PageNumber=1

I2M Web Portal Search Result (79), 2017, "Nambia": http://web.i2massociates.com/categories/namibian-uranium-production-to-triple-by-2017-in-southwest-africa.asp

I2M Web Portal Search Result (8), 2017, "Uranium Exploration,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=uranium+EXPLORATION&PageNumber=1

I2M Web Portal Search Result (80), 2017, "Economics": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=economics&PageNumber=1

I2M Web Portal Search Result (81), 2017, "Graphene": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Graphene&PageNumber=1

I2M Web Portal Search Result (82), 2017, "Shutter": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Shutter&PageNumber=1

I2M Web Portal Search Result (83), 2017, "Shuttering Nuclear Power Plants,": https://www.google.com/search?q=shuttering%20nuclear%20power%20plants&rct=j

I2M Web Portal Search Result (84), 2017, "Chinese,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Chinese&SearchCategoryID=64&PageNumber=1

I2M Web Portal Search Result (85), 2017, "Russia,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Russia&SearchCategoryID=64&PageNumber=1

I2M Web Portal Search Result (86), 2017, "Nuclear Power Plant Construction,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Nuclear+power+plant+Construction&PageNumber=1

I2M Web Portal Search Result (87), 2017, "SMR,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=SMR&PageNumber=1

I2M Web Portal Search Result (88), 2017, "TVA Way Ahead of the Pack With Nuclear and Solar?,": http://web.i2massociates.com/categories/tva-way-ahead-of-the-pack-with-nuclear-and-solar.asp

I2M Web Portal Search Result (89), 2017, "Small Modular Reactor List,": https://www.uxc.com/smr/uxc_SMRList.aspx

I2M Web Portal Search Result (9), 2017, "Mining and Processing,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=uranium+mining&PageNumber=1

I2M Web Portal Search Result (90), 2017, "Small Nuclear Power Reactors,": http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

I2M Web Portal Search Result (91), 2017, "Nuscale Power,": http://www.nuscalepower.com/why-smr

I2M Web Portal Search Result (92), 2017, "Bill Gates,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Bill+Gates&PageNumber=1

I2M Web Portal Search Result (93), 2017, "Yucca Mountain,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Yucca+Mountain&PageNumber=1

I2M Web Portal Search Result (94), 2017, "Yucca,": http://web.i2massociates.com/categories/default.asp?QS=True&resources=10&OrderDirection=desc&OrderField=codefixerlp_tblLink_flddateadded&SearchValue=Yucca&PageNumber=1

I2M Web Portal Search Result (95), 2017, "Rep. Dina Titus Critical of Congressional Effort to Push Yucca Mountain Project Forward,": http://web.i2massociates.com/categories/rep.-dina-titus-critical-of-congressional-effort-to-push-yucca-mountain-project-forward.asp

I2M Web Portal Search Result (96), 2017, "TVA Way Ahead of the Pack With Nuclear and Solar?,": http://web.i2massociates.com/categories/tva-way-ahead-of-the-pack-with-nuclear-and-solar.asp

I2M Web Portal Search Result (97), 2017, "Tennessee Solar Rebates and Incentives ,": http://www.cleanenergyauthority.com/solar-rebates-and-incentives/tennessee/tennessee-solar-power-financial-incentives/

I2M Web Portal Search Result (98), 2017, "Tennessee Solar Installers,": http://www.cleanenergyauthority.com/tennessee-solar-installers/

I2M Web Portal Search Result (99), 2017, "Green Power Providers,": https://www.tva.com/Energy/Renewable-Energy-Solutions/Green-Power-Providers

IER, "Will Renewables Become Cost-Competitive Anytime Soon?": http://instituteforenergyresearch.org/studies/will-renewables-become-cost-competitive-anytime-soon-the-siren-song-of-wind-and-solar-energy/

Ingersoll, D. T., C. Colbert, Z. Houghton, R. Snuggerud, J.W. Gaston and M. Empey, "Can Nuclear Power and Renewables be Friends?" NuScale Power, LLC Utah Associated Municipal Power Systems: http://www.nuscalepower.com/images/our_technology/nuscale-integration-with-renewables_icapp15.pdf

International Energy Agency, 2016 "Key World Energy Trends Excerpt from: World Energy Balances," http://www.iea.org/publications/freepublications/publication/KeyWorldEnergyTrends.pdf

International Energy Agency, 2016, "Energy Policies of IEA Countries - Japan," : http://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesJapan2016.pdf

I2M Web Portal Search Result (85), 2017, "Iran,": https://www.breakingisraelnews.com/ 48803/iran-announces-discovery-of-domestic-uranium-deposits-middle-east/#XYmdZMVPhez7UUVW.97

Jaworowski, Zbigniew, 2016, "The Chernobyl Disaster and How It Has Been Understood," WNA Personal Perspectives: http://www.world-nuclear.org/uploadedFiles/org/info/Safety_and_Security/Safety_of_Plants/jaworowski_chernobyl.pdf

Kathren, Ronald L., 2016, "Historical Development of the Linear Nonthreshold Dose-Response Model as Applied to Radiation," Washington State University United States Transuranium and Uranium Registries: http://scholars.unh.edu/cgi/viewcontent.cgi?article=1004&context=unh_lr

Kazatomprom, 2017, "Kazakhstan to Reduce Uranium Production By 10%," Jan 10: http://www.kazatomprom.kz/en/news/kazakhstan-reduce-uranium-production-10

Klepper, David, and Frank Eltman, 2017, "Experts: NY can absorb closing of Indian Point nuke plant," Jan 9: http://www.startribune.com/cuomo-ny-can-absorb-closing-of-indian-point-nuke-plant/410113515/

Lifton, Jack, 2015, "Lifton on Kingsnorth and the Global Rare Earth Market," Nov 30: https://investorintel.com/sectors/technology-metals/technology-metals-intel/lifton-on-kingsnorth-and-the-global-rare-earth-market/

Lommerud, Kjell Erik, 2004 "Globalization and Union Opposition to Technological Change," Stein Rokkan Center for Social Studies Unifob AS, December 2004: http://bora.uib.no/bitstream/handle/1956/1347/N27-04%5b1%5d.pdf?sequence=1

Malone, Michael S., 2014, "The Self-Inflicted U.S. Brain Drain," Oct 15: https://www.wsj.com/articles/michael-s-malone-the-self-inflicted-u-s-brain-drain-1413414239

Meshik, Alex P., 2009, "The Workings of an Ancient Nuclear Reactor," *in Scientific American*, January 26: https://www.scientificamerican.com/article/ancient-nuclear-reactor/

Moskvitch, Katia, 2013, "Do Cosmic Rays Grease Lightning?" May 3: http://www.sciencemag.org/news/2013/05/do-cosmic-rays-grease-lightning

MarketWired, 2013, "Macusani Yellowcake Announces Positive Preliminary Economic Assessment for Uranium Deposits in Peru," Dec 05: http://www.marketwired.com/press-release/macusani-yellowcake-announces-positive-preliminary-economic-assessment-uranium-deposits-tsx-venture-yel-1859358.htm

Mining, 2016, "Graphic: Uranium Juniors Defy Bear Market Pricing,"Jun 1: http://www.mining.com/chart-uranium-juniors-defy-bear-market-pricing/

Mining-Technology, 2015, "A Country Divided: The Complexities of Australia's Uranium Mining Industry," Aug 6: http://www.mining-technology.com/features/featurea-country-divided-the-complexities-of-australias-uranium-mining-industry-4627974/

National Cancer Institute, 1998, "Cancer Stat Facts: Cancer of Any Site," : https://seer.cancer.gov/statfacts/html/all.html

New Energy and Fuel, 2012, "There's A Lot of New Uranium Resources," May 2: http://newenergyandfuel.com/http:/newenergyandfuel/com/2012/05/02/theres-a-lot-of-new-uranium-resources/

Nolan, Jason, and Karrie A. Weber, 2015, "Natural Uranium Contamination in Major U.S. Aquifers Linked to Nitrate," Department of Earth and Atmospheric Science University of Nebraska: http://pubs.acs.org/doi/pdfplus/10.1021/acs.estlett.5b00174

Nuclear Energy Institute, "Top 10 Facts About Yucca Mountain," https://www.nei.org/News-Media/News/News-Archives/Top-10-Facts-About-Yucca-Mountain

Obiko Pearson, Natalie, 2016, "Hong Kong Billionaire Li Bets on Uranium With NexGen Deal," Jun 2: https://www.bloomberg.com/news/articles/2016-06-02/hong-kong-billionaire-li-bets-on-uranium-with-nexgen-investment

OECD, 2016, "List of OECD Member countries - Ratification of the Convention on the OECD,": http://www.oecd.org/about/membersandpartners/list-oecd-member-countries.htm

Paladin Energy Ltd, 2015, "Paladin Corporate Brochure," July: http://www.paladinenergy.com.au/sites/default/files/15.07_Paladin_Corporate_Brochure_July_2015.pdf

Partrick McGeehan, 2017, "Cuomo Confirms Deal to Close Indian Point Nuclear Plant," Jan 9: https://www.nytimes.com/2017/01/09/nyregion/cuomo-indian-point-nuclear-plant.html?WT.mc_id=SmartBriefs-Newsletter&WT.mc_ev=click&ad-keywords=smartbriefsnl&_r=2

Phillips, Tony, 2015, "Radiation on a Plane," Nov 5: http://news.spaceweather.com/rads-on-a-plane-may-oct-2015/

Phillips, Tony, 2015, "Space Weather Ballooning - Results from the Lunar Eclipse," Sep 27: http://news.spaceweather.com/space-weather-ballooning-results-from-the-lunar-eclipse/

PR Newswire, 2015, "China Rare Earth Industry Report, 2014-2018," Jun 22: http://www.prnewswire.com/news-releases/china-rare-earth-industry-report-2014-2018-300102933.html

S&P Global Platts, 2015, "Infographic: Japan's Nuclear Restart," Oct 20: ohttp://blogs.platts.com/2015/10/20/infographic-japans-nuclear-restart/

Silver Doctors, 2016, "Sprott's Thoughts On Uranium," March 17: http://www.silverdoctors.com/headlines/finance-news/sprotts-thoughts-on-uranium/

Southern Andes Energy Inc., 2011, "Southern Andes Energy's New Uranium Discovery at Alpi-1 Project in Peru," Jan 12: http://www.marketwired.com/press-release/southern-andes-energys-new-uranium-discovery-at-alpi-1-project-in-peru-tsx-venture-sur-1379422.htm

Spaceweather.com, 2016, "Cosmic Rays Continue to Intensify," Nov 15:http://news.spaceweather.com/cosmicrays-intensify/

Stapczynski, Stephen and Yuji Okada, 2016, "Chinese Nuclear Firms Seen by U.S. Winning Deals With Financing," May 3: https://www.bloomberg.com/news/articles/2016-05-03/chinese-nuclear-firms-seen-by-u-s-winning-deals-with-financing

Sutherland, Wayne M. , and Elizabeth C. Cola, 2016, "A Comprehensive Report on Rare Earth Elements in Wyoming," Wyoming State Geological Survery: http://www.i2massociates.com/downloads/WyomingGeoSurveyRI-71C.pdf

Sutherland, Wayne M., Robert W. Gregory, Jacob D. Carnes, and Brett N. Worman, 2013, "Rare Earth Elements in Wyoming," Wyoming State Geological Survey: http://www.wsgs.wyo.gov/products/wsgs-2013-ri-65.pdf

The Committee for Skeptical Inquiry, 2014, "Deniers are not Skeptics," Dec 5: http://www.csicop.org/news/show/deniers_are_not_skeptics

The Energy Report, 2016, "When Will Uranium Emerge From The Shadow of Fukushima?" May 9: https://www.theenergyreport.com/pub/na/16958

U. S. Energy Information Administration, 2015, "Detailed State Data,": https://www.eia.gov/electricity/data/state/

U. S. Energy Information Administration, 2015, "Natural Gas, Renewables Projected to Provide Larger Shares of Electricity Generation," May 4: http://www.eia.gov/todayinenergy/detail.php?id=21072

U. S. Energy Information Administration, 2015, "Total Energy Subsidies Decline Since 2010, With Changes in Support Across Fuel Types," May 13: http://www.eia.gov/todayinenergy/detail.php?id=20352

U. S. Energy Information Administration, 2016, "Uranium Marketing Annual Report," May 24: http://www.eia.gov/uranium/marketing/

U. S. Energy Information Administration, 2015, "Uranium Marketing Annual Report," May 24: http://www.eia.gov/uranium/marketing/

U. S. NRC, 2016, "Japan Lessons Learned,": https://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard.html

United Nations Information Service, 2014, "Increase in Cancer Unlikely following Fukushima Exposure - UN Report," April 2: http://www.unis.unvienna.org/unis/en/pressrels/2014/unisous237.html

United Nations Scientific Committee on the Effects of Atomic Radiation, 2001, "Hereditary Effects of Radiation,": http://www.unscear.org/unscear/en/publications/2001.html

United Nations Scientific Committee on the Effects of Atomic Radiation, 2012,"UNSCEAR's Assessment of the Radiation Effects,": http://www.unscear.org/unscear/en/chernobyl.html

Uranium Investing, 2011, "Uranium Exploration in Paraguay," May 31: http://investingnews.com/daily/resource-investing/energy-investing/uranium-investing/uranium-exploration-in-paraguay/

Uranium Investing, 2017, "Is Thorium in Nuclear Energy's Future?" Jan 24: http://investingnews.com/daily/resource-investing/energy-investing/uranium-investing/thorium-nuclear-energy/

Uranium Resources International, 2016, "Temrezli Overview," : http://www.uraniumresources.com/projects/uranium/turkey/temrezli

USGS Circular 1336, 2009, "Thorium Deposits of the United States - Energy Resources for the Future?" U.S. Department of the Interior, U.S. Geological Survey: http://www.i2massociates.com/downloads/ThoriumUSC1336.pdf

USGS, 2015, "Estimates of Potential Uranium in South Texas Could Equal Five Years of U.S. Needs," in Science for a Changing World, Dec 2: https://energy.usgs.gov/GeneralInfo/EnergyNewsroomAll/TabId/770/ArtMID/3941/ArticleID/1194/Estimates-of-Potential-Uranium-in-South-Texas-Could-Equal-Five-Years-of-US-Needs.aspx

USGS, 2017, "Energy News and Current Publications," in Science for a Changing World, Jan 1: https://energy.usgs.gov/GeneralInfo/EnergyNewsroomAll/TabId/770/PID/3941/evl/0/CategoryID/23/CategoryName/Uranium/Default.aspx

USGS, 2017, "Rare Earth Research," in Science for a Changing World. Jan 1: https://energy.usgs.gov/PublicationsAdvancedSearch.aspx?sb-search=Rare+earth+research&sb-inst=0_dnn_Header1_avtSearch&sb-logid=400742-9e16plxqzqwu002w

USGS, 2017, "Uranium Resources and Environmental Investigations," in Science for a Changing World, Jan 1: https://energy.usgs.gov/OtherEnergy/Uranium.aspx

World Nuclear Association, 2017, "World Nuclear Power Reactors & Uranium Requirements,"Jan 1: http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx

World Nuclear News, 2015, "EIA Predicts up to 4% Fall in Nuclear Share of US Generation by 2040," April 16: http://www.world-nuclear-news.org/EIA-predicts-up-to-4-fall-in-nuclear-share-of-US-generation-by-2040-16041501.html

World Nuclear News, 2016, "EIA Sees strong growth in nuclear generation to 2040," May 12: http://www.world-nuclear-news.org/EE-EIA-sees-strong-growth-in-nuclear-generation-to-2040-1205164.html

World Nuclear News, 2016, "US Producers Call for Suspension of Federal Inventory Transfers," April 26: http://www.world-nuclear-news.org/UF-US-producers-call-for-suspension-of-federal-inventory-transfers-2604167.html

Worldwide Cancer Research, 2015, "The Path of True Love (and Research) Never Did Run Smooth," Dec 30: https://www.worldwidecancerresearch.org/news/?y=2015

## Reading List

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

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

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

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

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

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

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

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

Campbell, M. D., J. D. King, H. M. Wise, B. Handley, J. L. Conca, and M. David Campbell, 2013, "Nuclear Power and Associated Environmental Issues in the Transition of Exploration and Mining on Earth to the Development of Off-World Natural Resources in the 21st Century," *in* Chapter 9, *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space*, (eds) W. A. Ambrose, J. F. Reilly II, and D. C. Peters, AAPG-EMD Memoir 101, pp. 163 –213. http://i2massociates.com/downloads/Memoir101-CHAPTER09Rev.pdf

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

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

Conca, J., 2013, "Absurd Radiation Limits are a Trillion Dollar Waste," Forbes.com, July 13: http://www.forbes.com/sites/jamesconca/2014/07/13/absurd-radiation-limits-are-a-trillion-dollar-waste/

Conca, J. 2012 to Present: Search Results on Nuclear Power and Associated Issues: from I2M Web Portal (here).

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

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

I2M Associates, LLC, 2017,"Confronting Media and other Sources of Bias against Uranium Exploration and Mining, Nuclear Power, and Associates Environmental Issues, January 2, 8 p. http://i2massociates.com/downloads/ConfrontingBias.pdf

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

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

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

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

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

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

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

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

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

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

United Nations Scientific Committee on the Effects of Atomic Radiation, 2012, Report of 59th Session, May 21-25: http://www.un.org/ga/search/view_doc.asp?symbol=A/67/46

U. S. Energy Information Agency, 2015, ”Domestic Uranium Production Report – Annual,” April 30: http://www.eia.gov/uranium/production/annual/

Wicker, W., 2014, “Natural Radiation: Sources, Relevance and Uranium Levels Uranium Levels,”

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

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



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