EMD Uranium (Nuclear Minerals) Committee

2017 EMD Uranium (Nuclear Minerals and REE) Committee Mid-Year Report

November 26, 2017

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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)
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- **M. David Campbell, P.G.**, CEO, Vice President and Senior Project Manager, I2M Associates, LLC, Houston, TX
- **Robert A. Arrington**, VP, Exploration, Texas Eastern Nuclear, Inc. (retired), College Station, TX (Founding Member of EMD in 1977)
- **Jay H. Lehr, Ph. D.,** Science Director, Heartland Institute, Chicago (on Nuclear Power)

COMMITTEE ACTIVITIES

The AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earths) Committee (UCOM) monitors the uranium industry and the production of electricity within the nuclear power industry because that drives uranium exploration and development in the United States and overseas.

Input for this Annual Report has been provided by:

Henry M. Wise, P.G., C.P.G. (Vice-Chair: Industry) on industry activities in uranium, thorium, and rare-earth exploration and mining;

Steven Sibray, P.G., C.P.G., Vice Chair (University) on university activities in uranium, thorium, and rare-earth research; and

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

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

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

UCOM is also pleased to remind the reader as a regular feature of the UCOM reports that the *Jay McMurray Memorial Grant* is awarded annually to a deserving student(s) whose research involves uranium or nuclear fuel energy. This grant is made available through the AAPG Grants- In-Aid Program, and is endowed by the AAPG Foundation with contributions from his wife, Katherine McMurray, and several colleagues and friends.

Those students having an interest in applying for the grant should contact the UCOM Chair for further information and guidance. The biography of Mr. McMurray's outstanding contributions to the uranium industry in the U.S. and overseas is presented (AAPG Foundation, 2015).

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

Table 1

Recipients of the Jay M. McMurray Memorial Grant from AAPG

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

PUBLICATIONS AND NUCLEAR OUTREACH

The EMD co-sponsored Journal: *Natural Resources Research* has published the bi-annual *Unconventional Energy Resources: 2015 Review* in Volume 24, Issue 4, December, 2015 (more). The UCOM 2015 contribution begins on page 450 and is titled: *Energy Competition in the Uranium, Thorium, and Rare Earth Industries in the U.S. and the World: 2015*. Earlier versions include: the 2013 version (here); 2011 (here); 2009 (here); and 2007 (here).

The AAPG-EMD Memoir 101: *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space* was released in mid-2013 (more). The EMD's Uranium (Nuclear and REE Minerals) Committee and members of I2M Associates, LLC, contributed the final Chapter 9 entitled: *Nuclear Power and Associated Environmental Issues in the Transition of Exploration and Mining on Earth to the Development of Off-World Natural Resources in the 21st Century* (more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (more). James Conca, Ph.D., a member of the UCOM Advisory Group, continues to contribute popular articles to Forbes.com on many nuclear and associated energy topics. To review the chronological list of Dr. Conca's Forbes' 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 issues 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 uranium discoveries.

To support this coverage, the I2M Web Portal has just been upgraded and improved, both in response speed and layout, plus it now allows multi-word searches, whereas the previous version only permitted one-word searches (more). The UCOM can now focus on particular issues covered by the I2M Web Portal by conducting and presenting search-results that are automatically updated even after we have published the two UCOM reports each year.

We draw on the I2M Web Portal database, which now contains almost 7,500 abstracts and links to current technical reports and media articles from sources in the U.S. and around the world, (see the Index to all commodity fields covered in the I2M Web Portal (here)). The primary emphasis of the I2M Web Portal also reflects interests and objectives of UCOM (more).

The UCOM focus is on: a) uranium exploration (more); b) mining and processing (more), and marketing, as well as on topics related to: c) uranium recovery technology (more); d) nuclear-power economics (more), reactor designs (more), and operational aspects that drive uranium prices (more); and e) related environmental and societal issues involved in such current topics as energy resource selection and climate change (more). The latter have direct and indirect impact on the costs, mining, and utilization of uranium, thorium, and rare-earth fields.

Our coverage also includes summaries of 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).

The nature and impact of radiation, perceived and real, are receiving coverage from a variety of mining and nuclear power adversaries. In response, we have been addressing these important issues since the beginning in 2004) reporting within the UCOM (e.g., 2005) while continuing to address the issues surrounding human-health issues in greater detail over the past few years (more) and (more). We have added a section in our reports titled: *Ambient Radiation in the Atmosphere,* near the end of our reports. This places radiation in context with our environment, on the ground, in the atmosphere, in the orbital reaches, and in deep space.

Also, the I2M conditions of specific interest to geoscientists working under field conditions or others who manage the Web Portal includes the Alerts Program. I2M personnel monitors and reports on potentially hazardous such operations. This ranges throughout the various geological hazards, earthquakes, meteorological, and others (Field Alerts: more).

There are other on-going monitoring programs underway at I2M Associates, LLC via the I2M Web Portal. These include Security Alerts: (more), which covers computer hacking warning events and cyber security issues, and media bias monitoring (more).

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

OBJECTIVES OF UCOM REPORTS

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

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

We also include and assess the status of thorium and rare-earth exploration (and development) because both are often encountered in some types of hard-rock uranium deposits and the presence of both impact the economics of recovering uranium and rare earths, often with some revenue credit for thorium concentrates.

EXECUTIVE SUMMARY

General Summary

- The two primary objectives of this report are to alert the members of the Energy Minerals Division, of AAPG and the general public on the supply side regarding current activities within the uranium, thorium, and rare-earth industries in terms of prices, exploration, and environmental issues, combined with the impact of uranium production cuts in Canada and Kazakhstan and of the role Russian-owned companies have in the U.S. uranium mining industry.
- Some 99 Nuclear power plants in the U.S. remain in operation, a few are scheduled for retirement, two new reactors are being completed in Georgia.
- Japan is slowly upgrading and re-starting its fleet of nuclear power plants after Fukushima.
- China is rapidly building some 25 new plants and hundreds more are planned along with financially underwriting the construction of more than 40 projects in joint ventures with other countries.
- Russia is building new nuclear plants at home, and is testing a "fast breeder" design that consumes most waste. Russia also is building nuclear plants on behalf of other countries as well, and providing financing.
- India has turned to nuclear to ramp up electricity production to match population growth rates and is also working on "fast breeder" designs.
- Many other countries are also building nuclear plants funded by a variety of sources.

Factors Involved in Uranium Prices

- There is still an oversupply of uranium in the world and so there are no suggestions in the technical news that prices will increase over most of 2018.
- There have been numerous discoveries of high-grade uranium deposits in Canada and new low-grade deposits reported to be under development in Argentina and Peru.
- Senior U.S. uranium industry personnel indicate that mining in Texas may not be re-initiated for a number of years.

- ❖ Many uranium companies drilling new and established properties to establish an in place resource base in preparation for development sometime in the future.

- ❖ With hundreds of new nuclear power plants under construction in the world, it is only a matter of time until additional uranium supplies will be required, which will have to put pressure on the uranium price to increase substantially after 2020 and beyond.

- ❖ Russia is building new nuclear plants at home, testing a "fast breeder" design that consumes most waste. Russia also is building nuclear plants on behalf of other countries as well, and providing financing, including a floating nuclear power plant for Sudan.

Other Items

- ❖ New data from space suggest that genes in humans are "turned on" in space, and remain on after returning to Earth.

INTRODUCTION

The market for uranium intended as nuclear fuel is currently in balance regarding demand but having favored supply since Fukushima with yellowcake prices well below break-even levels for most production from U.S. mines [14]. Ownership of uranium properties in North America ranges from U.S. uranium companies to Canadian uranium companies (all funded by Toronto, Vancouver, and other stock exchanges in London, Germany, Australia, and South Africa). Russian and Chinese interests are also involved in North American uranium exploration, mining, and processing and milling.

As of the end of 2017, there are 70 nuclear reactors under construction worldwide, with 160 planned and 315 proposed. All new construction is outside the U.S. Altogether, uranium supplies need to increase by about 90 million pounds annually by 2020 to meet demand. But at current low spot prices, the industry can only supply half of that total although there have been a number of new discoveries in Canada, Argentina, Brazil, Peru, and elsewhere that are in various stages of development that could be ready by 2020 to provide any shortfall.

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

The uranium market is guided to a large extent by expectations displaced years ahead by today's nuclear power-plant operations, anticipated construction, and plant shuttering and retirement plans, as well as by the perceptions by government and industry leaders of the viability and safety of nuclear power used to generate electricity. As discussed previously (EMD UCOM 2016 Annual Report (more) and EMD UCOM 2016 Mid- Year Report (more)), energy competition among nuclear energy, coal, natural gas, and various forms of renewable energy, has resulted in projects based more on the consumer price of electricity than on the impact to the environment.

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

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

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

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

In this Mid-Year report, we are providing a brief assessment of Russian interests in uranium mining and processing projects in the U.S., Canada, and overseas. Russia, through Uranium One, a uranium holding company, once funded by the South African Stock Exchange (Figure 1), was purchased along with a

Canadian company (Urasia Energy), both now controlled by Russian government nuclear monopoly, the history of Rosatom [9, 11 15]. Uranium One, is on various stock exchanges as a subsidiary of Rosatom.

Figure 1: Stock Company History of Uranium One

Any uranium produced in the U.S. (by the currently operating Christensen Ranch/ Irigaray in-situ recovery mine in Wyoming [16], or by the Texas in-situ mine, El Mesquite, which is not currently operating), is sold for use in nuclear power reactors operated by utilities in the U.S., according to EIA. But U.S. owners and operators purchase the vast majority of their uranium from foreign sources. Only 11 percent of the 50.6 million pounds purchased in 2016 came from U.S. domestic producers, according to the 2017 EIA report [17].

Campbell, et al., (2017) evaluated the ownership of Uranium One and found that it once held 20 percent of licensed uranium in-situ recovery production capacity in the U.S., (not uranium resources), but that is no longer the case [18]. There were only four in-situ recovery facilities licensed by the NRC in 2010. Currently, there are 10 such facilities, so Uranium One's mining operations now account for an estimated 10 percent of in-situ recovery production capacity in the U.S. [19] But more recently, Uranium One has been responsible for no more than 5.9 percent of domestic production, according to a September, 2017 report by the U.S. International Trade Commission [20]. Further, such uranium production cannot be exported without an export license. EIA reported that Russia provided 22% of the foreign uranium enrichment services in 2016 (and returned that production to the U.S.) [17].

China is establishing long-term contracts with Canadian mines to help secure uranium supplies over the decades ahead to fuel their major nuclear plant construction program, and before the anticipated rise in prices over the next few years. Canadian resources include numerous high-grade uranium deposits, but most of which are deep requiring underground mining [21]. However, recent drilling results have uncovered especially shallow high-grade mineralization at the South Arrow project [22].

As the uranium price rises in the next few years, the in-situ mines in Wyoming, Texas, Utah, and South Dakota will come back on-line to reduce foreign imports, although the number of new discoveries continues to increase around the world, e.g., Canada, Peru, Argentina, Saudi Araba, etc. Whether these will go to mine are yet to be determined, with an emphasis on Canada's building a uranium reserve base [22].

Owning a uranium property requires drilling of uranium resources to obtain the actual in-place uranium mineralization, which then must undergo an assessment of the cost to mine and process the identified reserves to ultimately produce yellowcake [17]. Once a company produces a report of recoverable product then the project must undergo an independent economic assessment in the form of a N 43-101 report, or qualified persons report, for the Vancouver, Toronto, Australian and other stock exchanges. For the London Stock Exchange, a Competent Persons Report is required for new mining companies.

Not all Uranium One properties will produce uranium; the properties listed above would require detailed follow-up, independent investigations before their potential can be assessed for their development, from both an economic and environmental perspective. The U.S. Stock Exchanges require similar independent reports on mining and processing yellowcake and other minerals on the following properties owned/controlled by Uranium One:

A. Uranium One exploration property ownership in the U.S. consists of:

    (50%) Green River North, Emery County, Utah, U.S.(more)
    (50%) Green River South, Emery County, Utah, U.S.(more)
    (39.2% option) North Hansen Deposit, Colorado, U.S.(more)

B. Uranium One mining property ownership in the U.S. consists:

    (100%) Uranium One U.S.A., Inc.(more)
    (100%) Christensen Ranch / Irigaray, Wyoming, U.S.(more)
    (71%) El Mesquite, Malco, Texas, U.S. (more)

For actual uranium reserves, see company reports for the mines indicated above. For examples of independent reports on uranium properties, see (here).

Uranium One Property/Company Ownership in the World:

(50%) Karatau LLP, Kazakhstan (more)
(50%) JSC Akbastau, Kazakhstan (more)
(49.98%) Zarechnoye joint venture, Kazakhstan (more)
(100%) UrAsia Energy Ltd.(more), 100% owned

Additional mining claim ownership and subsidiaries of UrAsia Energy Ltd, 100% by SXR Uranium One, Inc., 2nd Half: (more).

(100%) Energy Metals Corp., U.S.(more)

Additional mining claim ownership and subsidiaries of Energy Metals Corporation, 100% owned by Uranium One, Inc. 1st Half: (more).

(13.9%) Mantra Resources, Ltd, Tanzania (more)
Mkuju River project, Tanzania (more)
Bahi North project, Tanzania (more)
Zambezi Valley Project, Mozambique (more)

On Sep. 11, 2017, Rosatom announced that Uranium One, a ROSATOM global mining company, has opened a new trading company, under the name Uranium One Trading AG in Zug (Switzerland). The Kazakhstan uranium mining company has also opened a trading company in Switzerland), for more, see: (more).

In the U.S., owners and operators of civilian nuclear power reactors (civilian owner/ operators) purchase about 50 million pounds of yellow cake deliveries from U.S. and foreign mines during the past few years, at a weighted-average price of $42.43 per pound U_3O_8 . The 2016 total of 50.6 million pounds U_3O_8 was 10% lower than the 2015 total of 56.5 million pounds U_3O_8 . The 2016 weighted-average price of $42.43 per pound U_3O_8 was 4% lower than the 2015 weighted-average price of $44.13 per pound U3O8 (yellow cake) (17). These prices are likely to be similar for the year 2017 as well.

Eleven percent of the 50.6 million pounds yellow cake delivered in 2016 was of U.S.- origin at a weighted-average price of $43.92 per pound [17]. Foreign-origin uranium accounted for the remaining 89% (45 million pounds yellowcake) of deliveries at a weighted average contract price of $42.26 per pound. Sources and shares of purchases of uranium produced in U.S. and other countries in 2016 are listed below.

U.S. Source of Uranium

U.S. Origin: ……. 11%

Foreign Origin: … 89%

	Of the 89%
Canada:	25% [23]
Kazakhstan:	24% [24]
Australia:	22% [25]
Russia:	14% [26]
Uzbekistan:	4% [27]
Malawi+Namibia+Niger+and+South Africa:	9% [28]
Brazil [29]+ Bulgaria [30]+China [31]+Czech Republic [32]+Germany [33], and+Ukraine [34]:	2%

Barrasso (2018) has recently raised the issue about the above disparagy by indicating that the U.S. and its allies have plenty of uranium resources, but that the U.S. still buys from insecure overseas sources. Uranium plays a vital role in maintaining America's national security. The element powers nearly a quarter of the U.S. Navy's fleet and provides the electricity for about 20% of American homes and businesses. So the question is raised "Why is the U.S. relying on adversaries, or at least foreign countries, to supply the U.S. with uranium fuel?"

In the past two years, DOE has given contractors more than double the amount of uranium that America generates. Even though U.S. uranium producers suffer harm from this treatment because they don't have the standing to challenge the government in court. The result is that American uranium producers now supply less than 5% of American nuclear fuel, and the number of American uranium workers was cut in half between 2011 and 2016. In early 2017, Energy Secretary Rick Perry took a first step when he announced that his department would begin to reduce uranium bartering with contractors. But the Energy Department is still paying its contractors by barter in uranium. If the new administration ends this ill-advised policy, it will open up significant opportunities for American uranium producers to supply America's nuclear power plants.

As reported, the new administration may or may not take action against state-owned and state-subsidized producers in Russia, Kazakhstan and Uzbekistan, but these nations are unfairly flooding the U.S. with uranium produced at an economic loss (with the differences made up by foreign governments), as they appear to be more interested in gaining political leverage over the U.S. than conducting normal business. Two American uranium producers recently petitioned the Commerce Department to investigate these abuses (more). Any cost differences between U.S.- and Foreign-produced uranium would be minor in terms of actual fuel costs to generate electricity by nuclear power, especially relative to coal, and other fossil fuels.

ENERGY SUBSIDIES

Governments (both federal and state) have also been supporting the energy industry for decades and has been applied in various forms. Although this support has not been for the uranium mining, it has been historically for oil and gas production in a variety way. Much of the confusion regarding subsidies involves the definition of a subsidy. There are direct, indirect, and so-call externalities (human health and environment) that are considered a type of subsidy (more). The latter is especially impacted by coal, which is expected to continue to decline for burning to produce electricity not only because of human health concerns (of humans working underground and carbon-lung issues, as well as underground methane leaks and associated explosions), but also because of the impact on climate change because of burning with CO_2 , mercury, and particulate emissions (more). The center issue with coal use now is in the deterioration of jobs in the coal industry, but other uses of coal are under study on a broad front (more).

States are beginning to address the issues surrounding energy competition by attempting to level the market by including subsidies for nuclear power production of electricity for parity with renewables (more), and to counter low gas prices, which are expected to rise in the future if not modulated by regulation with subsidies or other tax allowances (more). The few articles or reports that address subsidies were written to support a particular agenda, but these complicate matters even further with selective reasoning (more). An independent report is clearly needed on the subject of energy subsidies because the energy selection by utilities, states, and other entities making such decisions are impacted economically by subsidies. It appears, however, that the oil and gas industries now receive far fewer state and federal subsidies than the renewable energy industries, the highest going to wind, solar, biomass, etc. The lowest subsidy going to nuclear energy.

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

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

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

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

The WNA discussed energy subsidies in February, 2018 summarized the circumstances as follows:

- Substantial amounts have been invested in energy R&D over the last 50 years. Much of this has been directed at developing nuclear energy – which now supplies 11% of world electricity.
- Today, combined investment in energy efficiency, renewables and hydrogen & fuel cells is about twice that of nuclear, but with less to show for it in terms of electricity supply.
- Nowhere in the world is nuclear power subsidized per unit of production. In some countries, however, it is taxed because production costs are so low.
- Renewables have received heavy direct subsidies in the market by various means, but these are being scaled back in many places due to the rapidly increasing cost to consumers.
- Fossil fuels receive indirect subsidies in their waste disposal as well as some, increasingly controversial, direct subsidies.

The World Trade Organization (WTO), in its 2006 World Trade Report, defined three types of government programs that constitute subsidies:

- Financial transfers made by the government that result in (actual or potential) budgetary outlays, as well as transfers that are made by private entities, as mandated by government.
- Programs that involve the provision of goods or services at no cost or below market price.
- Regulatory policies or preferential rules that result in transfers from one group to another, conferring a benefit to the recipient.

The WTO definition explicitly recognizes that subsidies need not come from government directly. Rather, government can require private entities such as electricity consumers to pay subsidies by creating corresponding regulations or legislation. There are three main areas where, broadly speaking, subsidies or other support for energy may apply:

- Energy R&D – government research & development (R&D) for particular technologies.
- Direct subsidies – per unit of production (or conceivably per unit of capacity), including costs imposed on dis-incentivized alternatives. Quota obligations are another form of widely used direct subsidy.
- Indirect subsidies – the allowance of external costs which are either paid by the community at large or paid later by governments, e.g., waste management, environmental clean-up, etc.

Government intervention in energy markets, such as in the UK under its Electricity Market Reform (EMR), may result in subsidization or taxation. They are ‘trade distortions’ according to the WTO’s definition, but may be justified as a means of environmental protection. In the U.S., federal and states are stepping into reviewing possibly forms of subsidies. See I2M Web Portal search results re “subsidies” (more).

THE URANIUM PRICES

The uranium price of the fuel for the nuclear power industry is obviously affected by the economic health of the nuclear power industry in the U.S., at least. The more plants, the higher the demand for fuel from China, India, and other countries. As new uranium supplies from new mines have come on-line and demand has not yet increased as expected, a condition of oversupply still persists creating depressed prices, which now shows some potential increase as production have been limited by some large producers, i.e., Kazakhstan (more). The principal impact on current prices is the overhang of uranium supplies remaining in the market (from a lack of consumption) resulting from the slow recovery of nuclear operations in Japan (more) in the period between before the impact of new requirements from China and India, etc. (more). As indicated above, other impacts on the uranium price include the U.S. government, which has been dumping some of their back-up yellowcake supply into the U.S. market (more).

The U.S. government sales are more than double the expected uranium production in 2017 in the U.S. However, proceeds from the sale of federal uranium inventory were used to fund the cleanup of legacy federal government nuclear facilities, such as the Paducah and Portsmouth uranium enrichment plant sites. This is an example of the government attempting to pay by bartering for its own activities albeit at the expense of the uranium industry (more).

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

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

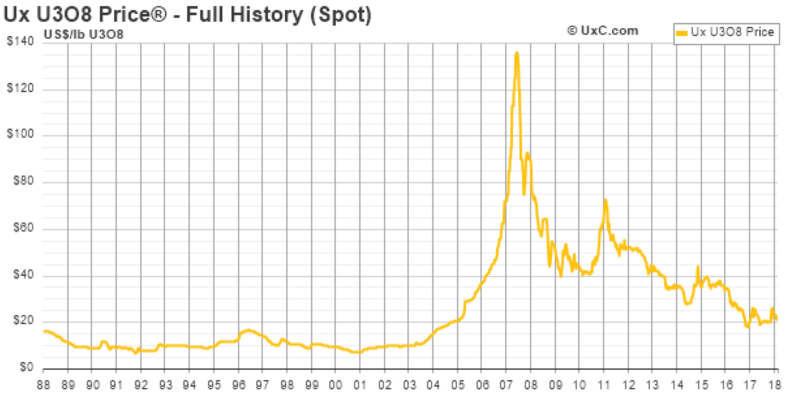


Figure 2

Historical Spot Price of Uranium: 1988 tp 2018 ($/U_3O_8$)
From (UXC)

Even at the current low prices, only 6% of the 57 million pounds U_3O_8 delivered in 2015 was U.S.-origin uranium at a weighted-average contract price of $43.86 per pound (committed to individual utilities). Foreign-origin uranium accounted for the remaining 94% of U.S.-contracted deliveries at a weighted-average contract price of $44.14 per pound U_3O_8. Uranium originating in Kazakhstan, Russia, and Uzbekistan accounted for 37% of the 57 million pounds. However, the prices have fallen further during the latter 2017 with a spot price around $20.00 /pound U_3O_8 and long-term contract prices around $30.00 /pound U_3O_8.

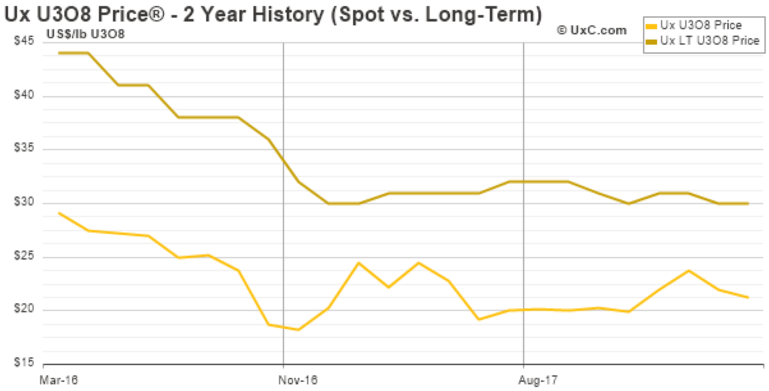


Figure 3

2016 - 2018 Spot Price of Uranium (U_3O_8)
From (UXC)

Industry Response to Uranium Price Fluctuations

In the U.S., Energy Fuels and UEC are positioning themselves for the approaching price rise, expected in the future. Large overseas projects are also moving forward on expectations of future price increases (more). For example, the new Greenland projects has the added advantage of future production of uranium and rare-earths products, which supports the economic models from both uranium and rare-earth revenue streams. Only if prices collapse for both would such a project become untenable (more). Greenland is in the technical and media news for reasons relating to climate change research, astrogeology, and to the development of uranium, thorium, rare earths, and other metals, some of which may have had their origin in the large impact structures identified a few years ago (more). This project will likely begin production soon if only because of its multi-product output and resulting supporting revenues received even when uranium prices are relatively low. But the Greenland project could stock-pile their uranium production now and wait until prices improve, just as the large Kazakhstan uranium mines have announcement earlier this year.

Their rare-earth production alone could support the Greenland mine in the meantime. This process would aid in increasing the lifetime of the Greenland operations and would serve to optimize profits (and increase and extend royalties for the Greenlanders).

THE IMPACT OF JAPAN

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 (more). Reactors have now for the most part received safety-review approvals from the Nuclear Regulation Authority, some of which still must secure permissions from local towns and prefectures, and final NRA approval of preoperational tests before it can load nuclear fuel and begin operations 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 Ohma nuclear unit, which is under construction and could come online by the end of 2021 (more).

Progress continues in Japan in restarting their idle nuclear power plants, but not without some academic criticism (more). Even more detailed surveys of health issues report that the thyroid cancers identified so far are unlikely to be due to radiation exposure, and are more likely to be the result of screening using highly sophisticated ultrasound techniques.

However, long-term screening is continuing to evaluate whether the risk of childhood and adolescent thyroid cancer is due to radiation exposure increases or not (more).

URANIUM PRODUCTION IN THE U.S.

4th Quarter 2017

U.S. production of uranium concentrate in the fourth quarter 2017 was 622,987 pounds U3O8, down 3% from the third quarter 2017 and down 14% from the fourth quarter 2016. During the fourth quarter 2017, U.S. uranium was produced at seven U.S. uranium facilities, the same number as in the third quarter 2017. U.S. uranium mill in production.

1. White Mesa Mill (Utah)

U.S. uranium in-situ leach plants in production:

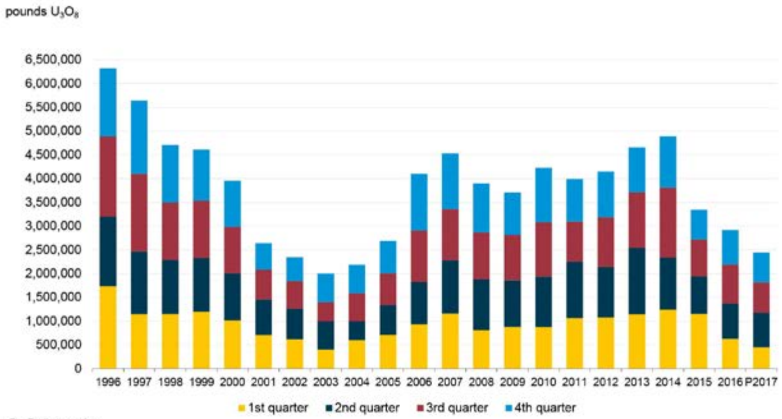
1. Crow Butte Operation (Nebraska)
2. Lost Creek Project (Wyoming)
3. Nichols Ranch ISR Project (Wyoming)
4. Ross CPP (Wyoming)
5. Smith Ranch-Highland Operation (Wyoming)
6. Willow Creek Project (Wyoming)

Total 2017 U.S. Production

Total preliminary U.S. uranium concentrate production totaled 2,442,789 pounds U_3O_8 in 2017. This amount was 16% lower than the 2,916,558 pounds produced in 2016 and the lowest annual U.S. production since 2,282,406 pounds were produced in 2004. Production reflects primary source uranium from the six operating in-situ leach facilities as well as primary, alternate and recycled feed at the White Mesa Mill in Utah. Much of the recycled uranium feed has already been counted at some point in previous production totals and in 2017, this contribution comprises a significant portion of the total uranium production (see Figure 4 and Table 2).

The owner of the White Mesa Mill, Energy Fuels Inc., provides additional information on the mill's operations in its financial filings, including the amount of U_30_8 produced from alternative feeds. The company's financial filings are, at this writing, are available (here).

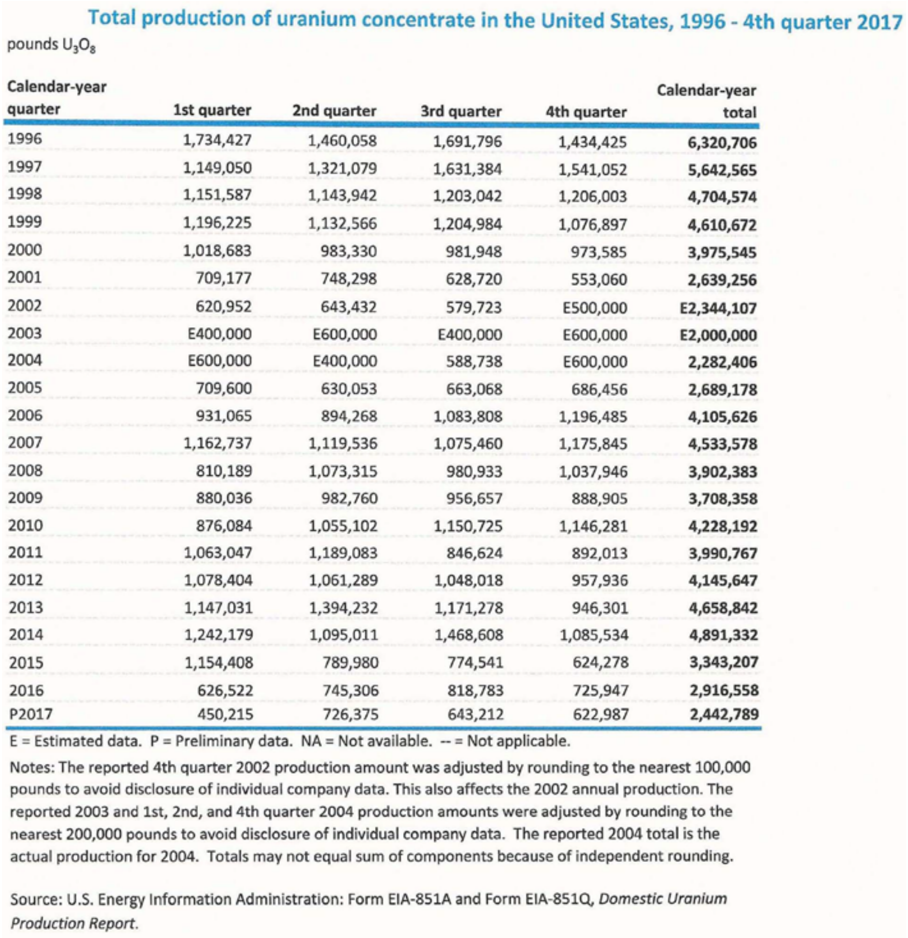
Figure 1. Uranium concentrate production in the United States, 1996 - 4th quarter 2017



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

Figure 4 **(EIA-2017)**

Table 2
(EIA-2017)



Total production of uranium concentrate in the United States, 1996 - 4th quarter 2017

pounds U_3O_8

Calendar-year quarter	1st quarter	2nd quarter	3rd quarter	4th quarter	Calendar-year total
1996	1,734,427	1,460,058	1,691,796	1,434,425	**6,320,706**
1997	1,149,050	1,321,079	1,631,384	1,541,052	**5,642,565**
1998	1,151,587	1,143,942	1,203,042	1,206,003	**4,704,574**
1999	1,196,225	1,132,566	1,204,984	1,076,897	**4,610,672**
2000	1,018,683	983,330	981,948	973,585	**3,975,545**
2001	709,177	748,298	628,720	553,060	**2,639,256**
2002	620,952	643,432	579,723	E500,000	**E2,344,107**
2003	E400,000	E600,000	E400,000	E600,000	**E2,000,000**
2004	E600,000	E400,000	588,738	E600,000	**2,282,406**
2005	709,600	630,053	663,068	686,456	**2,689,178**
2006	931,065	894,268	1,083,808	1,196,485	**4,105,626**
2007	1,162,737	1,119,536	1,075,460	1,175,845	**4,533,578**
2008	810,189	1,073,315	980,933	1,037,946	**3,902,383**
2009	880,036	982,760	956,657	888,905	**3,708,358**
2010	876,084	1,055,102	1,150,725	1,146,281	**4,228,192**
2011	1,063,047	1,189,083	846,624	892,013	**3,990,767**
2012	1,078,404	1,061,289	1,048,018	957,936	**4,145,647**
2013	1,147,031	1,394,232	1,171,278	946,301	**4,658,842**
2014	1,242,179	1,095,011	1,468,608	1,085,534	**4,891,332**
2015	1,154,408	789,980	774,541	624,278	**3,343,207**
2016	626,522	745,306	818,783	725,947	**2,916,558**
P2017	450,215	726,375	643,212	622,987	**2,442,789**

E = Estimated data. P = Preliminary data. NA = Not available. -- = Not applicable.

Notes: The reported 4th quarter 2002 production amount was adjusted by rounding to the nearest 100,000 pounds to avoid disclosure of individual company data. This also affects the 2002 annual production. The reported 2003 and 1st, 2nd, and 4th quarter 2004 production amounts were adjusted by rounding to the nearest 200,000 pounds to avoid disclosure of individual company data. The reported 2004 total is the actual production for 2004. Totals may not equal sum of components because of independent rounding.

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

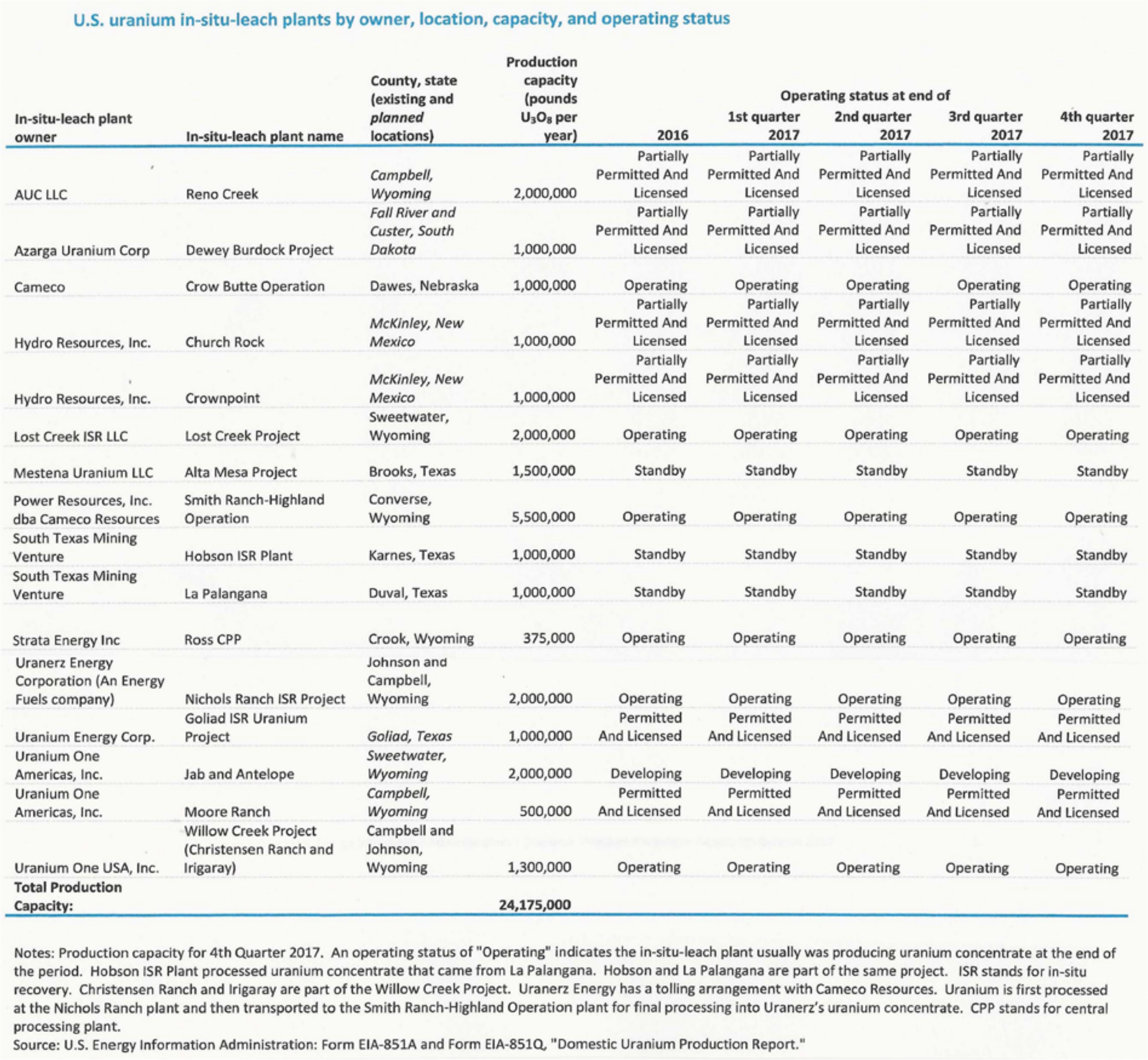
The status of the in-situ recovery plants in the U.S. are presented in Table 3. Notice that there are 19 such facilities in various states of readiness.

URANIUM PRODUCTION IN THE U.S.

U.S. commercial nuclear reactors use slightly refined uranium dioxide (UO_2) as a fuel to create electricity. About 50 million pounds of uranium were required to operate the commercial nuclear power reactors in the U.S. These reactors generate 800 billion kilowatt hours of electricity, or about 20% of total U.S. electricity in recent years.

The nuclear fuel cycle consists of *front-end* steps that prepare uranium for use in nuclear reactors and *back-end* steps to safely manage, prepare, and dispose of highly radioactive spent nuclear fuel. Chemical processing of spent fuel material to recover any remaining product that could undergo fission again in a new fuel assembly is technically feasible, but is not permitted in the United States.

Table 3
(EIA-2017)



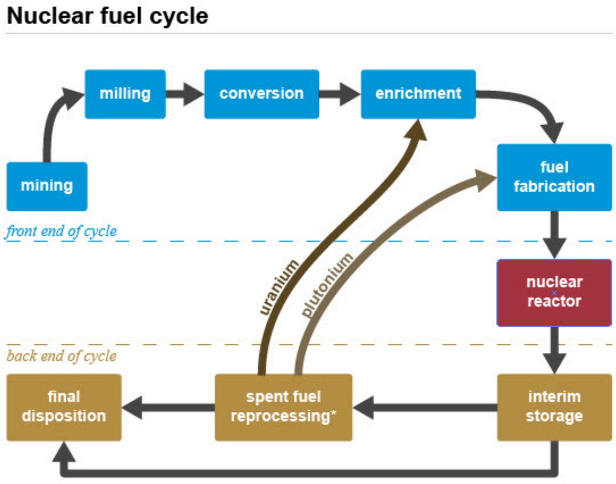
U.S. uranium in-situ-leach plants by owner, location, capacity, and operating status

In-situ-leach plant owner	In-situ-leach plant name	County, state (existing and *planned* locations)	Production capacity (pounds U_3O_8 per year)	Operating status at end of				
				2016	1st quarter 2017	2nd quarter 2017	3rd quarter 2017	4th quarter 2017
AUC LLC	Reno Creek	*Campbell, Wyoming*	2,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Azarga Uranium Corp	Dewey Burdock Project	*Fall River and Custer, South Dakota*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Cameco	Crow Butte Operation	Dawes, Nebraska	1,000,000	Operating	Operating	Operating	Operating	Operating
Hydro Resources, Inc.	Church Rock	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Hydro Resources, Inc.	Crownpoint	*McKinley, New Mexico*	1,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed	Partially Permitted And Licensed
Lost Creek ISR LLC	Lost Creek Project	Sweetwater, Wyoming	2,000,000	Operating	Operating	Operating	Operating	Operating
Mestena Uranium LLC	Alta Mesa Project	Brooks, Texas	1,500,000	Standby	Standby	Standby	Standby	Standby
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	Converse, Wyoming	5,500,000	Operating	Operating	Operating	Operating	Operating
South Texas Mining Venture	Hobson ISR Plant	Karnes, Texas	1,000,000	Standby	Standby	Standby	Standby	Standby
South Texas Mining Venture	La Palangana	Duval, Texas	1,000,000	Standby	Standby	Standby	Standby	Standby
Strata Energy Inc	Ross CPP	Crook, Wyoming	375,000	Operating	Operating	Operating	Operating	Operating
Uranerz Energy Corporation (An Energy Fuels company)	Nichols Ranch ISR Project	Johnson and Campbell, Wyoming	2,000,000	Operating	Operating	Operating	Operating	Operating
Uranium Energy Corp.	Goliad ISR Uranium Project	*Goliad, Texas*	1,000,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One Americas, Inc.	Jab and Antelope	*Sweetwater, Wyoming*	2,000,000	Developing	Developing	Developing	Developing	Developing
Uranium One Americas, Inc.	Moore Ranch	*Campbell, Wyoming*	500,000	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed	Permitted And Licensed
Uranium One USA, Inc.	Willow Creek Project (Christensen Ranch and Irigaray)	Campbell and Johnson, Wyoming	1,300,000	Operating	Operating	Operating	Operating	Operating
Total Production Capacity:			**24,175,000**					

Notes: Production capacity for 4th Quarter 2017. 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."

The Front End of the Nuclear Fuel Cycle



**Spent fuel reprocessing* is omitted from the cycle in most countries, including the United States.

Click to enlarge »

Figure 5

Source: Pennsylvania State University Radiation Science and Engineering Center.

Uranium Exploration

The nuclear fuel cycle starts with exploration for uranium and the development of mines to extract the uranium ore, usually produced as U_3O_8, which is only slightly radioactive. A variety of techniques are used to locate uranium, such as airborne radiometric surveys, hydrochemical sampling of groundwater and geochemical sampling of soils, and exploratory drilling to understand the underlying geology (see Campbell and Biddle (1977)). Once uranium ore deposits are located, the mine company usually follows up with more closely spaced *in fill,* or development drilling, to determine how much uranium is available and what it might cost to recover it (see Dickinson and Duval (1977)).

Uranium Mining

When ore deposits that are economically feasible to recover are located, the next step in the fuel cycle is to mine the ore using one of the following techniques (see Figure 5):

- underground mining
- open pit mining
- in-place (in-situ) solution mining
- heap leaching

Before 1980, most U.S. uranium was produced using open pit and underground mining techniques (Hunkin, 1977). Today, most U.S. uranium is produced using a solution mining technique commonly called in-situ-recovery (ISR). This process extracts uranium that coats the sand and gravel particles of groundwater reservoirs. The sand and gravel particles are exposed to a solution with a pH that has been elevated slightly by using oxygen, carbon dioxide, or caustic soda. The uranium dissolves into the groundwater, which is pumped out of the reservoir and processed at a uranium mill (Campbell, et al., (2007)(2009)).

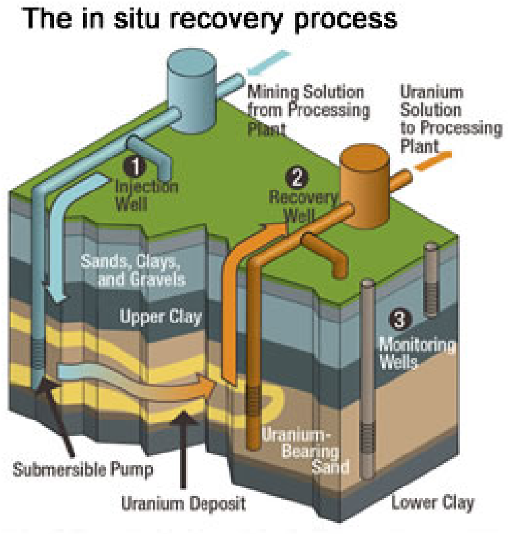


Figure 6
Source: United States Nuclear Regulatory Commission

Uranium Milling

After the uranium ore is extracted from an open pit or underground mine, it is refined into uranium concentrate at a uranium mill. The ore is crushed, pulverized, and ground into a fine powder. Chemicals are added to the fine powder, which causes a reaction that separates the uranium from the other minerals. Groundwater from solution mining operations is circulated through a resin bed to extract and concentrate the uranium.

The concentrated uranium product is typically a soft, bright yellow or orange powder called *yellowcake* (U_3O_8). The solid waste material from pit and underground mining operations is called *mill tailings*. The processed water from solution mining is returned to the groundwater reservoir where the mining process is repeated (see Figure 6).

Uranium Conversion

The next step in the nuclear fuel cycle is to convert yellowcake into uranium hexafluoride (UF_6) gas at a converter facility. Three forms (isotopes) of uranium occur in nature: U-234, U-235, and U-238. Current U.S. nuclear reactor designs require a stronger concentration (enrichment) of the U-235 isotope to operate efficiently. To separate the three types of uranium isotopes, the UF6 gas is sent to an enrichment plant where the individual uranium isotopes are separated.

Uranium Enrichment

The uranium hexafluoride gas produced in the converter facility is called *natural UF6* because the original concentrations of uranium isotopes are unchanged. The United States currently has two operating enrichment plants (where isotope separation takes place). One plant uses a process called gaseous diffusion to separate uranium isotopes, and the other plant uses a gas centrifuge process. Because the smaller U-235 isotopes travel slightly faster than U-238 isotopes, they tend to leak (diffuse) faster through the porous membrane walls of a diffuser, where they are collected and concentrated. The final product has about a 4% to 5% concentration of U-235 and is called *enriched UF6*. Enriched UF6 is sealed in canisters and allowed to cool and solidify before it is transported to a nuclear reactor fuel assembly plant by train, truck, or barge.

Another enrichment technique is the gas centrifuge process, where UF_6 gas is spun at high speed in a series of cylinders to separate $^{235}UF_6$ and $^{238}UF_6$ isotopes based on their different atomic masses. Atomic vapor laser isotope separation (AVLIS) and molecular laser isotope separation (MLIS) are new enrichment technologies currently under development. These laser-based enrichment processes can achieve higher initial enrichment (isotope separation) factors than the diffusion or centrifuge processes and can produce enriched uranium more quickly than other techniques.

Uranium Reconversion and Nuclear Fuel Fabrication

Once the uranium is enriched, it is ready to be converted into nuclear fuel. The United States has five nuclear reactor fuel fabrication facilities where the enriched UF6 gas is reacted to form a black uranium dioxide powder. The powder is then compressed and formed into small ceramic fuel pellets. The pellets are stacked and sealed into long metal tubes that are about 1 centimeter in diameter to form fuel rods. The fuel rods are then bundled together to make up a fuel assembly. Depending on the reactor type, each fuel assembly has about 179 to 264 fuel rods. A typical reactor core holds 121 to 193 fuel assemblies (see Figure 7).

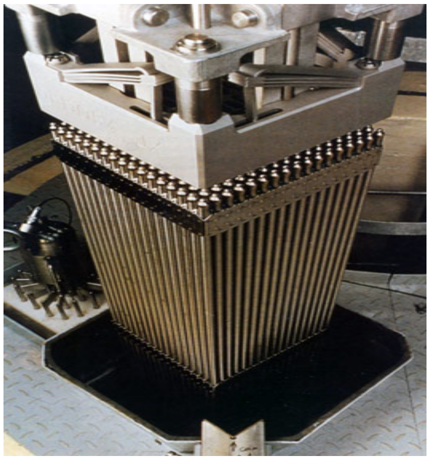


Figure 7 - A Nuclear Fuel Assembly in the Reactor

Source: Commissariat à l'Énergie Atomique

Once they are fabricated, trucks transport the fuel assemblies to the reactor sites. The fuel assemblies are stored onsite in *fresh fuel* storage bins until the reactor operators need them. At this stage, the uranium is only mildly radioactive, and essentially all radiation is contained within the metal tubes. Typically, reactor operators change out about one-third of the reactor core (40 to 90 fuel assemblies) every 12 to 24 months. The reactor core is a cylindrical arrangement of the fuel bundles, about 12 feet in diameter and 14 feet high, that is encased in a steel pressure vessel with walls that are several inches thick.

The reactor core has essentially no moving parts except for a small number of control rods that are inserted to regulate the nuclear fission reaction. Placing the fuel assemblies next to each other and adding water initiates the nuclear reaction.

Interim Storage and Final Disposal

After use in the reactor, fuel assemblies become highly radioactive and must be removed and stored at the reactor under water in a spent fuel pool for several years. Even though the fission reaction has stopped, the spent fuel continues to give off heat from the decay of radioactive elements that were created when the uranium atoms were split apart. The water in the pool serves to both cool the fuel and block the release of radiation. From 1968 through June 2013, 241,468 fuel assemblies had been discharged and stored at 118 commercial nuclear reactors operating in the United States.

Within a few years, the spent fuel cools in the pool and may be moved to a dry cask storage container for storage at the power plant site. An increasing number of reactor operators now store their older spent fuel in these special outdoor concrete or steel containers with air cooling.

The final step in the nuclear fuel cycle is the collection of spent fuel assemblies from the interim storage sites for final disposition in a permanent underground repository. The United States currently has no permanent underground repository for high-level nuclear waste. For additional information, see pages 33 to 34 (this report).

U.S. NUCLEAR POWER PLANT ACTIVITY

The World Nuclear Association (WNA) reviewed the conditions within the U.S. as of February, 2108:

- The U.S. is the world's largest producer of nuclear power, accounting for more than 30% of worldwide nuclear generation of electricity.

- The country's 99 nuclear reactors produced 805 billion kWh in 2016, almost 20% of total electrical output. There are two reactors under construction.

- Following a 30-year period in which few new reactors were built, it is expected that two more new units will come online soon after 2020, these resulting from 16 license applications made since mid-2007 to build 24 new nuclear reactors.

- Government policy changes since the late 1990s have helped pave the way for significant growth in nuclear capacity.

- Some states have liberalized wholesale electricity markets, which makes the financing of capital-intensive power projects difficult, and coupled with lower gas prices since 2009, have put the economic viability of some existing nuclear power plants and proposed projects in doubt.

- The first zero-emission credit programs have commenced, in New York and Illinois.

In 2016, the U.S. electricity generation was 4,079 TWh (billion kWh) net, with 1,380 TWh (34%) of it from gas, 1,240 TWh (30%) from coal-fired plant, 805 TWh (19.7%) nuclear, 266 TWh from hydroelectric, 226 TWh from wind, and 117 TWh from other renewables (EIA data).

Annual electricity demand is projected to increase to 5,000 billion kWh in 2030, though in the short term it is depressed and has not exceeded the 2007 level. Annual per capita electricity consumption in 2013 was 11,955 kWh. Total net summer capacity is 1,060 GWe, less than 10% of which is nuclear.

Nuclear power plays a major role. The U.S. has 99 nuclear power reactors in 30 states, operated by 30 different power companies, and in 2016 they produced 805 TWh. Since 2001 these plants have achieved an average capacity factor of over 90%, generating up to 807 TWh per year and accounting for about

20% of total electricity generated. The average capacity factor has risen from 50% in the early 1970s, to 70% in 1991, and it passed 90% in 2002, remaining at around this level since. In 2016, it was a record 92.5%, compared with wind 34.7% (based on 2018 EIA data). The industry invests about $7.5 billion per year in maintenance and upgrades of the plants. Average nuclear generation costs have come down from $40/MWh in 2012 to $34/MWh in 2016.

There are 65 pressurized water reactors (PWRs) with combined capacity of about 64 GWe and 34 boiling water reactors (BWRs) with combined capacity of about 35 GWe – for a total capacity of 99,062 MWe (see Nuclear Power in the U.S. Appendix 1: U.S. Operating Nuclear Reactors). Almost all the US nuclear generating capacity comes from reactors built between 1967 and 1990. Until 2013 there had been no new construction starts since 1977, largely because for a number of years when gas generation was considered more economically attractive and because construction schedules during the 1970s and 1980s had frequently been extended by opposition, compounded by heightened safety fears generated by the Fonda movie spewing falsehoods about nuclear radiation (more) before and following the Three Mile Island accident in 1979. A further PWR – Watts Bar 2 – started up in 2016 following Tennessee Valley Authority's (TVA's) decision in 2007 to complete the construction of the unit.

Despite a near halt in new construction of more than 30 years, U.S. reliance on nuclear power has grown. In 1980, nuclear plants produced 251 billion kWh, accounting for 11% of the country's electricity generation. In 2008, that output had risen to 809 billion kWh and nearly 20% of electricity, providing more than 30% of the electricity generated from nuclear power worldwide. Much of the increase came from the 47 reactors, all approved for construction before 1977, that came on line in the late 1970s and 1980s, more than doubling US nuclear generation capacity. The U.S. nuclear industry has also achieved remarkable gains in power plant utilization through improved refueling, maintenance and safety systems at existing plants. Average generating cost in 2014 was $36.27 per MWh ($44.14 at single-unit sites and $33.76 at multi-unit sites), including fuel and capital, and average operating cost was $21/MWh.

While there are plans for a number of new reactors, two more new units will come online by 2021. Since about 2010, the prospect of low natural gas prices continuing for several years has dampened plans for new nuclear capacity. In May 2016 the Energy Information Administration (EIA) said that nearly 19 GWe of new gas-fired generation capacity was expected online by 2019, mostly using shale gas. It later reported that 9 GWe of gas capacity had come online in 2016, along with 8.7 GWe wind and 7.7 GWe solar. There was a net capacity gain in 2016 of 15 GWe after about 12 GWe retirements.

The two AP1000 reactors under construction at Vogtle are eligible for subsidies similar to but significantly less than those applied to wind power generation. Under the Energy Policy Act (EPA) 2005, up to 6000 MWe of new nuclear is eligible for production tax credits (PTCs). PTCs are divided pro-rata among those applicants which had filed combined construction and operating license (COL) applications by the end of 2008, commenced construction of advanced plants by 2014, and which enter service by 2021. At the start of 2018, an extension to the PTC was passed by the US Senate and Congress. This was critical for the Vogtle plant, where unit 3 is not expected to enter operation until 2021, with unit 4 a year later. The level of the PTC is 1.8 cents per kWh, for eight years, and cannot be claimed until an asset is producing electricity. There is an annual payment limit of $125 million for each 1000 MWe of capacity (more).

In addition to granting an extension, the new act passed in February 2018 allows non-profit and municipal owners of the new Vogtle units to trade their credits to a profitmaking company involved in the construction of the reactors. (Non-profit and municipal power companies do not pay taxes and therefore could not benefit from the credits.) The largest owners of each project are for-profit utilities, Georgia Power for Vogtle and South Carolina Electric & Gas for Summer. Allowing the municipal and non-profit owners to transfer their tax credits to a company involved in the ownership or construction of the units will save ratepayers money and would “correct a disparity of current law.” For more information, see section on Financial incentives below.

In February 2013, Duke Energy's 860 MWe Crystal River PWR in Florida was decommissioned due to damage to the containment structure sustained when new steam generators were fitted in 2009-10, under previous owner Progress Energy. Its 40-year operating license was due to expire in 2016. Some $835 million in insurance was claimed. Dominion Energy's 566 MWe Kewaunee PWR in Wisconsin was decommissioned in May 2013, after 39 years operation. Then in June 2013 the two 30-year old PWR reactors (1070 & 1080 MWe) at San Onofre nuclear plant in California were retired permanently due to regulatory delay and uncertainty following damage in the steam generators of one unit. An economic study claimed that Californian generating costs rose by $350 million in the following year and carbon emissions by 9 million tonnes per year as a result (more), In August 2013 Entergy announced that its 635 MWe Vermont Yankee reactor would be closed down at the end of 2014 as it had become uneconomic, and this was done.

Ten other nuclear plants (13 reactors) were considered (at the start of 2014) to be at risk of closure, all but one of these in the northeast of the country, in deregulated states. The factors giving rise to uncertainty are high costs with low power prices, regulatory issues, and local concerns with safety and reliability. The Nuclear Energy Institute (NEI) said in December 2015 that "total electric generating costs at US nuclear plants have increased 28% – to an industry average $36.27 per MWh – over the past 12 years," including fuel, capital and operation and maintenance costs. It announced an initiative coordinated with the Nuclear Regulatory Commission (NRC) to cut electricity production costs by 30% by 2018.

Coal is projected to retain the largest share of the electricity generation mix to 2035 unless some interrupts the projection, though over 2002-16, while about 20 GWe of coal-fired capacity was added, more than 53 GWe was retired according to the EIA, due to environmental constraints and low efficiency, coupled with a continued drop in the fuel price of gas relative to coal, and tax policies favoring renewables. A further decrease to 2020 is expected, and most operating coal-fired plants are older than 35 years. Coal-fired capacity in 2015 was 280 GWe. The EIA projects 13 GWe of new gas-fired capacity, mostly CCGT, coming online in 2017, adding to the existing 431 GWe, and with 2 GWe to be retired. This trend is expected to continue to about 2020. The predominance of CCGT is driven by low gas prices, strict regulation of coal-fired plants, though the need to back up intermittent renewables input favors less-efficient OCGT. Natural gas prices over 2015 to March 2017 ranged from $1.50 to $3.80/million BTU (more).

Given that nuclear plants generate nearly 20% of the nation’s electricity overall and 63% of its carbon-free electricity, even a modest increase in electricity demand would require significant new nuclear capacity by 2025 in addition to the two nuclear reactors currently under construction in order to maintain this share. If current nuclear plants retire after 60 years of operation, 22 GWe of new nuclear capacity would be needed by 2030, and 55 GWe by 2035 to maintain a 20% nuclear share.

About half of U.S. generating capacity is over 30 years old, and major investment is also required in transmission infrastructure. This creates an energy investment crisis which was recognized in Washington, D.C. along with an increasing bipartisan consensus on the strategic importance and clean air benefits of nuclear power in the energy mix.

Low natural gas prices continue to depress the prospects for commitment to further nuclear power plant construction. Today, the importance of nuclear power in the U.S. is geopolitical as much as economic, reducing dependency on oil and gas. The operational cost of nuclear power in existing plants is very competitive with alternatives. In 2012 it was 2.4 ¢/kWh, compared with gas 3.4 ¢/kWh and coal 3.3 ¢/kWh. But plans for new nuclear capacity are starting to take account of opportunities for small reactors (SMRs) as well as large ones.

From 1992 to 2005, some 270,000 MWe of new gas-fired plant was built, and only 14,000 MWe of new nuclear and coal-fired capacity came on line. But coal and nuclear supply almost 70% of U.S. electricity and provide price stability. When investment in these two technologies almost disappeared, unsustainable demands were placed on gas supplies and prices quadrupled, forcing large industrial users of it offshore and pushing gas-fired electricity costs towards 10 ¢/kWh. As of early 2108 due to the advent of shale gas, such costs are much lower.

The reason for investment being predominantly in gas-fired plant was that it offered the lowest investment risk. Several uncertainties inhibited investment in capital-intensive new coal and nuclear technologies considered that natural gas prices need to recover to $8/GJ or /MMBtu before there is renewed confidence in deregulated states. In regulated states, a longer-term outlook is possible. SMRs provide possible relief from major upfront finance burdens, and these will soon have design certification from the NRC.

There are three regulatory initiatives which in recent years have enhanced the prospects of building new nuclear power plants. First is the design certification process, second is provision for early site permits (ESPs) and third is the combined construction and operating license (COL) process (‘Part 52’) as an alternative to the ‘Part 50’ two-step process of construction permit followed by operating license. All have some costs shared by the DOE.

U.S. Nuclear Power Plants Under Construction

Of the above, for the first four AP1000 units, construction is well underway at Vogtle, Georgia, with about $4 billion invested in the project before it was technically 'under construction'. Construction was also well underway at Summer, South Carolina, but has been put on hold. In addition to sites listed above, Southern Company is evaluating several possible sites, including existing plants and greenfield locations, for additional AP1000 reactors (more). However the economic outlook since 2013-14 suggests that merchant plants are not prospectively viable, and that some kind of assured market is necessary to underwrite the high capital costs on nuclear plants.

Design Certification

As part of the effort to increase U.S. generating capacity, government and industry have worked closely on design certification for advanced Generation III reactors. Design certification by the Nuclear Regulatory Commission (NRC) means that, after a thorough examination of compliance with safety requirements, a generic type of reactor (say, a Westinghouse AP1000) can be built anywhere in the U,S., only having to go through site-specific licensing procedures and obtaining a combined construction and operating license before construction can begin. Design certification needs to be renewed after 15 years.

Designs now having U.S. design certification and being actively marketed are:

- The GE Hitachi advanced boiling water reactor (ABWR) of1300-1500 MWe. Several ABWRs are now in operation in Japan, with more under construction there and in Taiwan. Some of these have had Toshiba involved in the construction, and more recently it has been Toshiba that promoted the design most strongly in the U.S. (more). Both the Toshiba and the GE Hitachi versions need to have their design certification renewed from 2012, but NRC shows both as "applicant delayed, not scheduled". Toshiba withdrew its design certification renewal application in mid-2016.

- The Westinghouse AP1000 is the first Generation III+ reactor to receive certification (see notes (more)). It is a scaled-up version of the Westinghouse AP600 which was certified earlier. It has a modular design to reduce construction time to 36 months. The first four of many are being built in China, and four more in USA.

- GE Hitachi's Economic Simplified BWR (ESBWR) of 1600 MWe gross, developed from the ABWR. The ESBWR has passive safety features and is currently included in the COL applications of two companies in USA. GE Hitachi submitted the application in August 2005, design approval was notified in March 2011, and design certification was in September 2014. The first COL with it was approved in May 2015.

Reactor designs undergoing US design certification or soon expected to do so are:

- The Korean APR1400 reactor, which is operating in South Korea since 2016 and under construction in the United Arab Emirates. Following 11 pre-application meetings, Korea Hydro & Nuclear Power submitted a design certification application to the NRC in October 2013. However, further detail was requested, and the revised submission was accepted by the NRC in March 2015. The final safety report is expected late in 2018.

- The Mitsubishi US-APWR, a 1700 MWe design developed from that for a 1538 MWe reactor planned for Tsuruga in Japan. The application was submitted in December 2007 and certification was expected to be completed in February 2016, but Mitsubishi delayed the NRC schedule for “several years”. European certification for the almost identical EU-APWR was granted in October 2014. Two US-APWR reactors were proposed in the Luminant-Mitsubishi application for Comanche Peak, but Mitsubishi has withdrawn from this project.

- The Russian VVER-1200 reactor which is operating at Novovoronezh II and being bult at Leningrad II may be submitted for U.S. design certification through Rusatom Overseas, according to Rosatom.

A reactor design formerly undergoing U.S. design certification was the U.S. Evolutionary Power Reactor (U.S. EPR), an adaptation of Areva's EPR to make the European design consistent with U.S. electricity frequencies. The main development of the type was to be through UniStar Nuclear Energy, but other U.S. proposals also involved it. The application was submitted in December 2007 and the design certification rule was expected after mid-2015, with delays due to the complexity of digital instrumentation and control systems. Areva then delayed the NRC schedule and in March 2015 indefinitely suspended the application. The 1600 MWe EPR is being built in Finland, France, and Guangdong in China, and is planned for U.K.

Additional information on new reactor designs, including those certified but not marketed in the U.S., is available on Advanced Nuclear Power Reactors, and on small modular reactors (Small Nuclear Power Reactors).

U.S. Small Modular Reactors (SMRs)

In addition, several designs of small modular reactors (SMRs) are proceeding towards NRC design certification application or the alternative two-step route of construction permit then operating license:

- A demonstration unit of the 160 MWe Holtec SMR-160 PWR (with external steam generator) is proposed at Savannah River with DOE support, and a construction permit application is likely, or a similar application in Canada. In September 2016 Mitsubishi Electric Power Products and its Japanese parent became a partner in the project, to undertake the I&C design and help with licensing. In 2017 SNC-Lavalin joined the project. South Carolina and NuHub also back the proposal.

- A demonstration unit of the NuScale multi-application small reactor, a 50 MWe integral PWR planned for the Idaho National Laboratory. Subsequent deployment of 12-module power plants in western states is envisaged under the Western Initiative for Nuclear. The NRC accepted NuScale's design certification application in 2017 and a COL application is planned early in 2018. Nuscale had spent some $170 million on licensing to mid-2015, and expects the NRC review to take 40 months, with the first unit operating in the mid-2020s. In 2013 NuScale secured up to $226 million DOE support for the design, and applied for the second part of its loan guarantee in September 2017. Further details under the section on UAMPS below.

- SCEG is evaluating the potential of X-energy's Xe-100 pebble-bed SMR (50 MWe, a high temperature gas-cooled reactor) to replace coal-fired plants, in 200 MWe 'four-pack' installations.

- In August 2015, Russia's AKME-Engineering received a US patent for its modular SVBR-100 lead-bismuth cooled integral fast reactor. The company said that it wants to protect its intellectual property as it prepares for the construction of a prototype SVBR-100 unit at Dimitrovgrad. No plans for the U.S. have been announced.

In February 2014 the NRC said that its most optimistic scenario for awarding design certification for small reactors such as SMRs was 41 months, assuming they were light water types (PWR or BWR). However, the SMR development seems to be picking up momentum in the U.S. and U.K. (more).

Nuclear Waste Storage

The debate continues in the U.S. on when and where to store the nuclear waste material generated by 99 nuclear power plants in the U.S. (more). The new administration was pressing for the Yucca Mountain facility to be completed after spending billions of dollars on its development to date. However, alternatives are also being considered. Conca (2018) reports that the U.S. Nuclear Regulatory Commission has accepted Holtec International's license application for its proposed consolidated interim storage facility for spent nuclear fuel, called HI-STORE CIS.

To be located in southeastern New Mexico near Carlsbad, the facility would store spent nuclear fuel, which is better referred to as slightly used nuclear fuel, until a final disposal facility is built or until new fast reactors are available that will burn it, or it can be recycled it into new fuel.

Reactor fuel usually spends five years in the reactor, after which about 5% of the energy in the fuel is used, but fission by-products of the reactions have built-up to the point where the fuel must be replaced. After leaving the reactor, the spent fuel usually spends about 5 years in spent fuel pools of water, until heat and radiation have decreased sufficiently to allow the fuel to be passively cooled in a dry cask. These systems are indeed a temporary interim measure. The stainless-steel canisters are easily retrievable and ready for transport to whatever permanent solution is chosen, such as deep geologic disposal or burning in fast reactors. The canisters are designed, qualified, and tested to survive for centuries and prevent the release of radioactive material under the most adverse accident scenarios postulated by NRC regulations for both storage and transportation.

As an add-on, Holtec is also seeking approval from NRC to use the heat generated by the waste, from just sitting on the pad, to make clean drinking water from dirty water from industrial processes like drilling. New Mexico generates a lot of water contaminated with organics and salts, especially in the region where the interim storage facility will be located, and using their patented process-heat design would be quite a boon to this arid region (more).

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

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

INTERNATIONAL URANIUM EXPLORATION AND DEVELOPMENT

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

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

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

INTERNATIONAL URANIUM PRODUCTION

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

With more than 450 nuclear power plants in current operation worldwide, they require some 23 million pounds of yellowcake to be available for processing to fuel pellets to meet the various 3-5 year cycles of the plants. As each new plant construction is announced, an additional 50,000 pounds will be needed 5-10 years in the future to fuel the new plant and then the same every 3 to 5 years hence. This would stimulate new mine production or an expansion of existing mines, should the mines have such capabilities.

Some mines in Canada, Australia, and perhaps Kazakhstan, and other areas have been shown to have such expansion capabilities, e.g., Cigar Lake, McArthur River in Canada. But new, large deposits (some very high grade) have been discovered nearby around the rim of the Athabasca Basin of Saskatchewan and Manitoba, Canada, breccia pipe deposits in Arizona (more), and roll- front deposits elsewhere in the world (i.e., Peru, Uruguay and Paraguay, India, Iran, and Tanzania.

So, there will be no shortage of producing mines over the next few decades at least (more). But, this might even create market conditions that will keep the price below $75.00 per pound ($U_3O_8$). All told to date, 35 countries account for about 5 million tonnes of U_3O_8 in the ground (equivalent to about 10 billion pounds U_3O_8), which would provide utilities with fuel for some 80 years based on a worldwide consumption rate of 50 million pounds U_3O_8/year over a 3-year fuel cycle for 450 reactors (more). Based on recent discoveries in Canada, its percent of acknowledged world reserves will increase considerably. One condition that could develop is a long-term over supply of uranium from a plethora of high- and low-grade deposits that would keep prices even below $50.00/ pound.

The second condition created by the production of very high grade, large reserves of uranium that are likely present around the periphery of the Athabasca Basin of Canada (where new discoveries have been made in the past few years) could be produced at prices lower than most other uranium mining projects. Some grades are so high that the beginning of robotics mining may well be in the offing. This may raise the cost to mine and transport in the beginning but decrease as the technology settles in (more).

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

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

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

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

INTERNATIONAL NUCLEAR POWER ACTIVITY

Middle East countries plan to add even more nuclear to their generation mix in the future. Nuclear electricity generation capacity in the Middle East is expected to increase from 3.6 gigawatts (GW) in 2018 to 14.1 GW by 2028 because of new construction starts and recent agreements between Middle East countries and nuclear vendors. The United Arab Emirates (UAE) will lead near-term growth by installing 5.4 GW of nuclear capacity by 2020.

The growth in nuclear capacity in the Middle East is largely attributable to countries in the region seeking to enhance energy security by reducing reliance on fossil fuel resources. Fossil fuels accounted for 97% of electricity production in the Middle East in 2017, with natural gas accounting for about 66% of electricity generation and oil for 31%. The remaining 3% of electricity generation in Middle East countries comes from nuclear, hydroelectricity, and other renewables.

Middle East countries are also adopting nuclear generation to meet increasing electricity demand resulting from population and economic growth. Regional electricity production was more than 1,000 billion kilowatthours (kWh) in 2017, and EIA expects electricity demand to increase 30% by 2028, based on projections in the latest *International Energy Outlook* (see Figure 8). This growth rate is higher than the average global growth rate of 18% over that same period, and higher than the 24% expected growth in non-OECD (Organization for Economic Cooperation and Development) countries.

Developments in building nuclear capacity in the region include (see Figure 9):

Iran is building a two-unit nuclear plant, Bushehr-II, which is designed to add 1.8 GW of nuclear capacity when completed in about 2026. Iran's original Bushehr-I facility, which came online in 2011, was the first nuclear power plant in the Middle East. Bushehr-I has one 1.0 GW reactor unit producing about 5.9 million kWh of electricity per year.

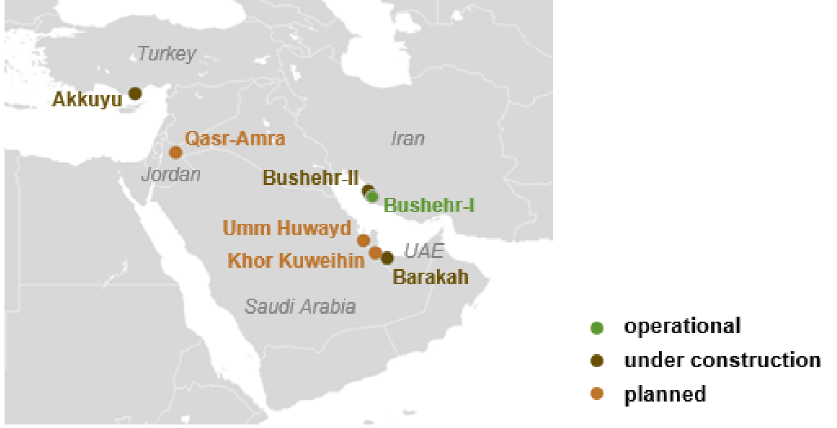
The **UAE** is currently constructing the four-unit Barakah nuclear power plant, which is expected to be completed by the end of 2020. The 1.3 GW Barakah unit 1, which was started in 2012 and completed in 2017, is expected to begin electricity production by mid-2018.

Turkey began construction of the Akkuyu nuclear power plant in late 2017. Akkuyu is a four-unit facility designed to add 4.8 GW of nuclear capacity to Turkey's generation mix. The first reactor unit is scheduled to be completed by 2025.

Saudi Arabia is planning to build its first nuclear power plant and is expected to award a construction contract for a 2.8 GW facility by the end of 2018. It has solicited bids from five vendors from the United States, South Korea, France, Russia, and China to carry out the engineering, procurement, and construction work on two nuclear reactors. Construction is expected to begin in about 2021 at one of the two proposed sites, either Umm Huwayd or Khor Duweihin.

Jordan plans to install a two-unit 2.0 GW nuclear plant and has been conducting nuclear feasibility studies with Russia's Rosatom since 2016. In early 2017, Jordan solicited bids for supplying turbines and electrical systems, and construction is expected to begin in 2019 and to be completed by 2024.

Figure 8

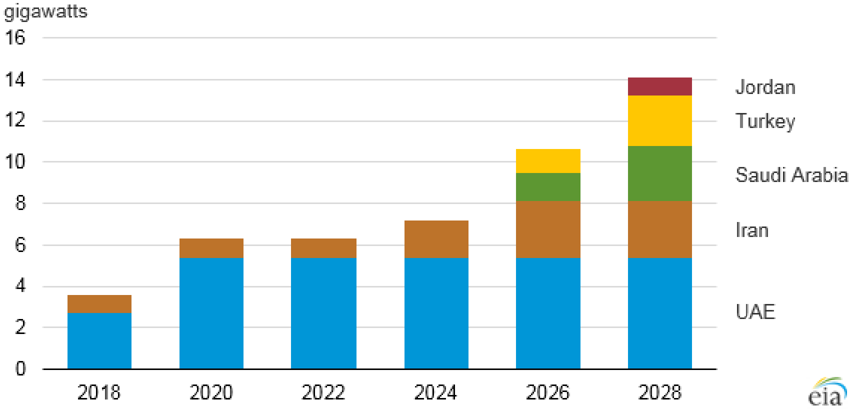


Middle East nuclear power plants

Source: U.S. Energy Information Administration, *International Energy Statistics*, International Atomic Energy Agency, Reuters, and Bloomberg

Figure 9

Middle East nuclear capacity



Source: U.S. Energy Information Administration, *International Energy Outlook 2017*, International Atomic Energy Agency, World Nuclear Association

OVERALL PERSPECTIVE Based on the Focus of the I2M Web Portal

1. Coal vs. Nuclear Power and Natural Gas (here)
2. Renewable Energy vs. Nuclear Power (here)
3. Industry Bias: Google Search Results: (here)
4. Academic Bias: Google Search Results: (here)

THORIUM ACTIVITIES

Thorium-Based Reactors continue development in the U.S., but especially in China and India (more). The WNA presents a 2017 status review of thorium reactor development to date (more).

1. I2M Web Portal: Search Results: Thorium (more)
2. University Research: Google Search: Thorium (more)
3. Industry Research: Google Search: Thorium (more)

RARE-EARTH ACTIVITIES

1. I2M Web Portal: Search Results "Rare Earth" REE (more)
2. University Research: Google Search Results (more)
3. Industry Research: Google Search Results (more)

PROPONENTS and ADVERSARIES to URANIUM MINING & NUCLEAR POWER DEVELOPMENT

1. Industry Media Bias (more)
2. Academic Bias (more)

AMBIENT RADIATION IN THE ATMOSPHERE

On the basis that the impact of radiation can be harmful both in the short-term and long-term exposure to humans, information regarding the minimum safe radiation (or hazardous) exposure to humans has over the years been debated widely (Conca, 2014). This matter has also been treated in some detail earlier by the UCOM committee (Campbell, et al., 2013, pp. 171-177), and others (I2M, 2018k).

Conca and others (2017) report that, aside from exposure to the Sun causing skin cancers and to radon causing lung cancer to underground mining personnel, especially those who smoke, it is very rare for anyone to be damaged by any dose of radiation. Contrary to the hype and fear pandering by the media on Fukushima (UNSCEAR, 2014), and even Chernobyl (I2M, 2018l), the observable radiation health effects from both accidents were small. In the case of Fukushima, it was near zero (Kant, 2017; and Karam, 2016).

In the case of Chernobyl, although significant, it was much lower than originally assumed (WNA, 2016) and WHO, 2005). 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 science, 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 are often suspicious of industry activities involving radioactivity particularly. Once the views are adjusted in the scientific and technical literature, however, the implications for removing artificial barriers and unnecessary regulations are enormous, especially in the nuclear power industry regulations.

But new information on humans in the exploration and development during recent off-world activities indicate that changes do occur, especially in how the human body reacts to weightlessness is a much more pressing matter to prepare for than radiation in examining duration rather than exposure. Information just released by NASA concerning the "twins study" is not good news (Specktor, 2018). The genetic code and some of the physical characteristics of the twin in space changed significantly. Interestingly, Scott Kelly has since shrunk back down to his initial pre-spaceflight height and suggests that the physical and mental stresses of Scott Kelly's year in orbit may have activated hundreds of "space genes" that altered the astronaut's immune system, bone formation, eyesight and other bodily processes. While most of the genetic changes reverted back to normal following Scott Kelly's return to Earth, about 7 percent of the astronaut's genetic code remained altered, and it may stay that way permanently.

More than 200 researchers in 30 states are helping to analyze the Kelly brothers' various off-world test results, looking for space-induced changes in Scott Kelly's cognition, metabolism, microbiome and many other physiological processes. NASA will publish the comprehensive findings of these tests in a single study later in 2018.

Concerning the impact of radiation on earth, the latest scientific society to make clear that the model applied over the years should not apply to humans on earth. They are the most qualified, independent group to understand this issue, the *Health Physics Society*. This is the scientific society that includes radiation protection scientists, and they recently put out a revised position statement in *Radiation Risk In Perspective* (HPS-2018). 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 (NIH, 2018). Of course, there could be a few dozen cases hiding in that huge error bar number, that plus or minus 1,600 is within the margin of error, but by definition, those will be statistically insignificant and should not be any cause for concern. They are too few to ever be measured.

The concern should be for the 40,000 natural cancers, the direct causes of these are the subject of ongoing, intensive medical research (i.e., Jaworowski, 2010), and others (I2M, 2018m).

The reasons for this 60-year overreaction to the incorrect model, called the Linear No-Threshold dose hypothesis, have been examined in some detail (Kathren, 2002). 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 (in 1979), at Chernobyl (in 1986), and at Fukushima (in 2011), all created by a fear-pandering media and ignorant public service support systems.

The damage at the Fukushima Daiichi Power Plant following the devastating tsunami in Japan has proven costly in many ways, politically, economically and emotionally. But the feared radiation-induced cancers and deaths are not occurring, as claimed by many adversaries. According to UNSCEAR (cited above), 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.

Cuttler and Welsh (2015) in the *Journal of Leukemia* pointed to two important aspects of the radiation issue. UNSCEAR unequivocally reported that "Radiation exposure has never been demonstrated to cause hereditary effects in human populations," a finding supported by recent research UNSCEAR (2001), and the health data from Hiroshima on about 96,800 humans suggest there is an acute radiation threshold at about 50 rem (500 mSv) for excess leukemia incidence. This is consistent with the conservative threshold dose of 10 rem (100 mSv) for all cancers.

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

Radiation Perspectives

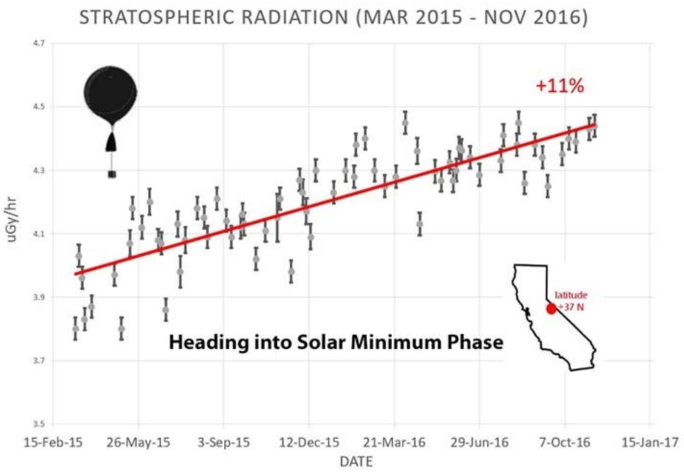
Of particular importance is the knowledge that since the large earthquake and tsunami causing the nuclear reactor meltdown in Japan during and after March 11, 2011, there have been no deaths directly caused by the radiation leak from the nuclear plant in Fukushima. The latest update (in April) by the World Nuclear Association on the Fukushima disaster states that there have been no deaths or cases of radiation sickness caused by that nuclear accident (WNA, 2017).

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 10 (Philipps, 2018).

Figure 10

(Spaceweather.com)

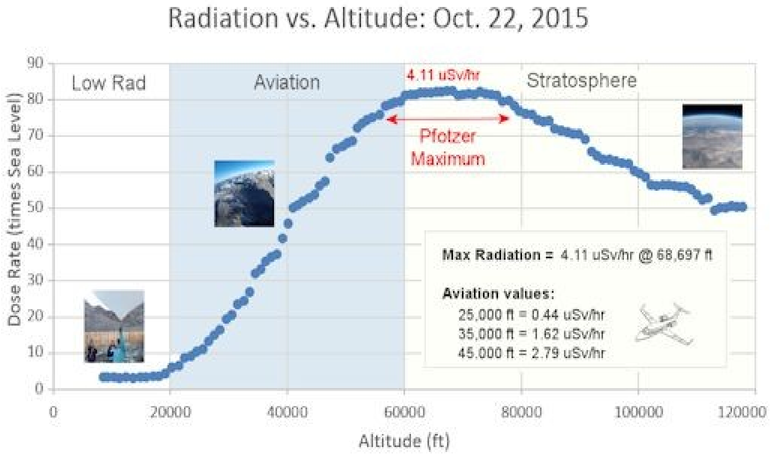


As indicated in previous UCOM reports, radiation (from cosmic rays) measurements are being recorded on regular flights of space-weather balloons. Approximately once a week, the students of *Earth to Sky Calculus* fly space weather balloons into the stratosphere over California, the data from which are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

Cosmic rays can seed clouds (CERN, 2018), trigger lightning (Moskvitch, 2013), and penetrate commercial airplanes (Phillips, 2018). 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 11 is the plot neutron flux from the October 22, 2015 flight. The plot below shows the data recorded for increasing altitude vs. radiation dose rate during the balloon flight, which reach a maximum altitude of 120,000 feet above sea level. Figure 11 also shows the aviation range of radiation exposure.

Figure 11

(Spaceweather.com)



Radiation levels peak at the entrance to the stratosphere in a broad region called the "Pfotzer Maximum." This peak is named after physicist George Pfotzer who discovered it using balloons and Geiger tubes in the 1930s. Radiation levels there are more than 80 times those at sea level and then decreases to 50 times. The reason for this decrease is likely related to the differing position of the Earth's geomagnetic field over California, New Hampshire, Oregon, and now Kansas, see Figures 12 through 19:

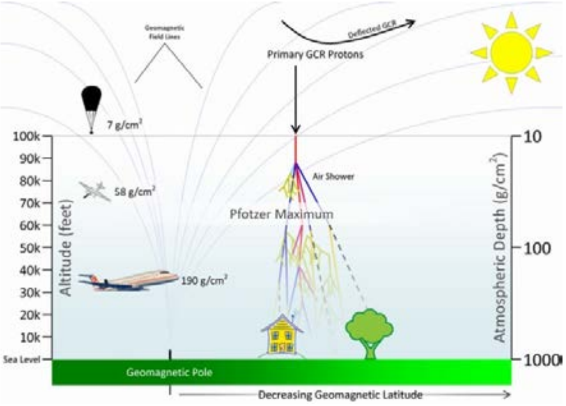


Figure 12
Location of thePfotzer Maximum Radiation
(Spaceweather.com)

Figure 13
Activities During a Balloon Launch
(Spaceweather.com)

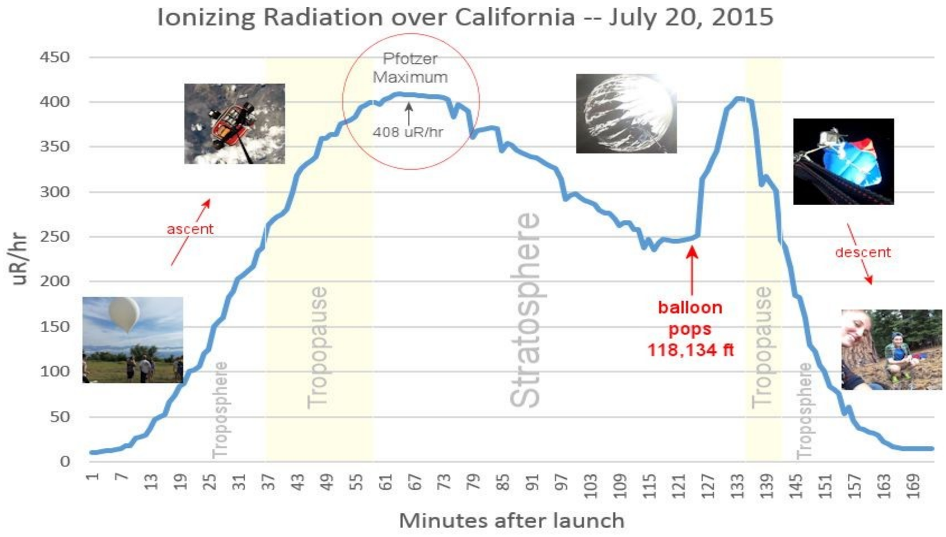


Figure 14 also includes radiation reporting as gamma rays and neutrons.

Figure 14

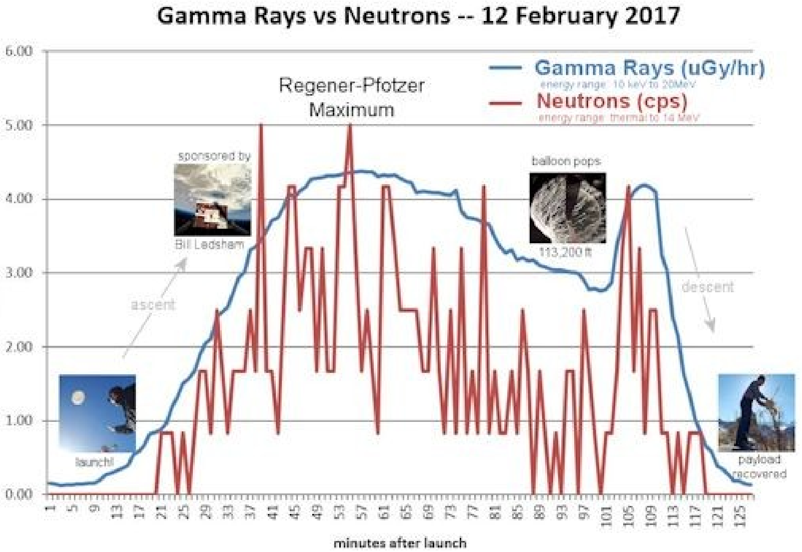


Figure 15
Difference in Maximum Radiation
([Spaceweather.com]())

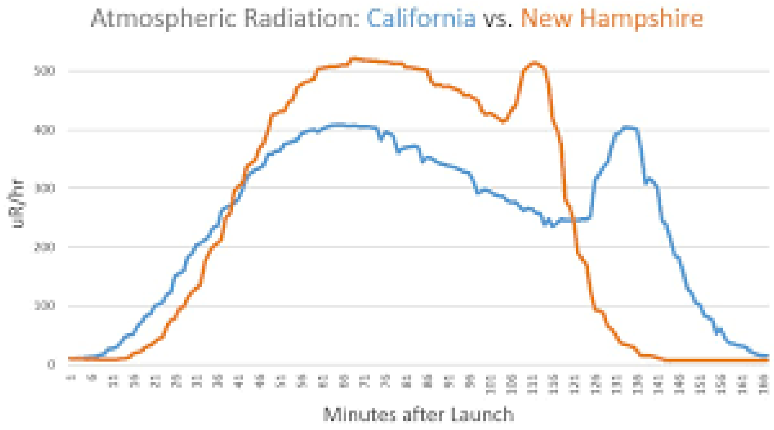
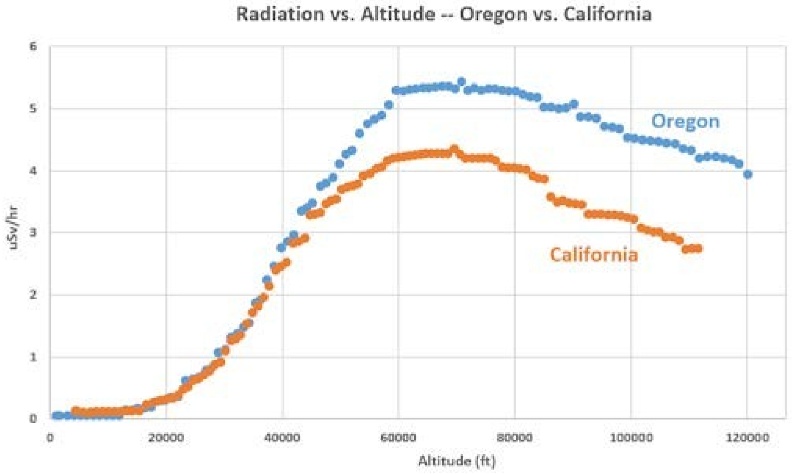


Figure 16
Difference in Maximum Radiation
([Spaceweather.com]())



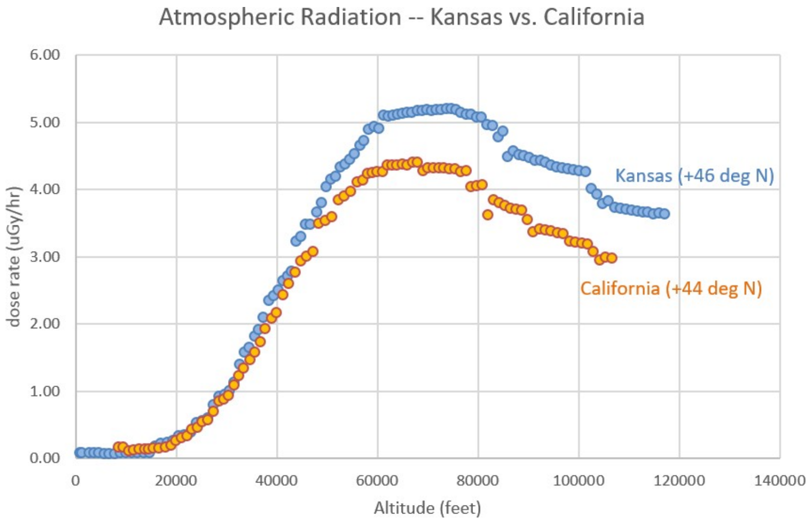
From ground level to 40,000 feet, the two curves are similar. In terms of radiation, California and Oregon are much the same at altitudes where planes fly. Above 40,000 feet, however, the curves diverge. Peak radiation levels detected in the stratosphere over Oregon were more than 25% higher than California.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

The students of the Earth to Sky Calculus have found something somewhat surprising in the November, 2016 balloon reporting data ([more]()). X-ray and gamma radiation in the atmosphere over Kansas is stronger than expected. Figure 17 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 16.

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 18).

But note in Figure 12 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 2017 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 (Munroe, 2014).

Figure 17
Difference in Maximum Radiation
(Spaceweather.com)



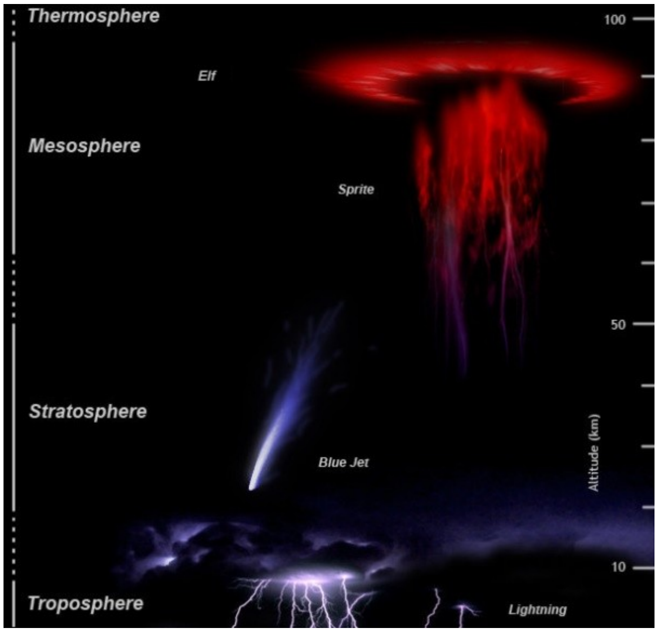


Figure 18

Sprites and Jet "Lightning" above Large Thunderstorms

(HAARP)

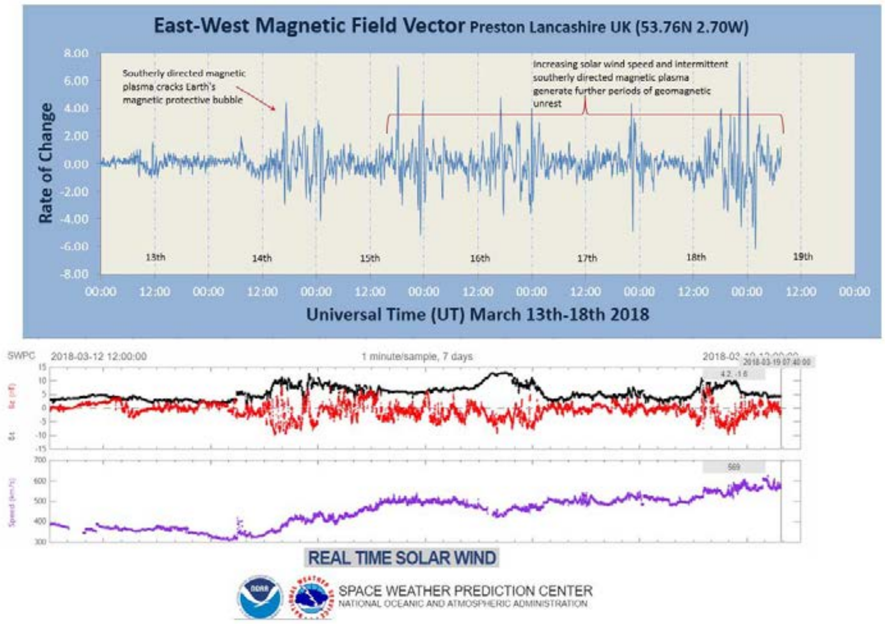
The radiation sensors onboard the helium balloons detect X-rays and gamma-rays in the energy range 10 keV to 20 MeV. As indicated, these energies span the range of medical X-ray machines and airport security scanners (see Wikipedia, 2018). High levels of ionizing radiation are dangerous to human health, but the levels discussed in this section are not, except for the altitude range of the PM. More research on the impact at these altitudes will be forthcoming in the near future as humans plan to spend more time passing through these altitudes on their way to orbital stations and beyond. Such research is available by NASA showing that there is no peak in the dose equivalent rate at the Pfotzer-Regener maximum as previously inferred. Instead, the dose equivalent rate keeps increasing with altitude as the influence of dose from primary cosmic rays becomes increasingly important. This result has implications for high altitude aviation, space tourism and, due to its thinner atmosphere, the surface radiation environment on Mars (Hands, et al., 2016).

Recent Flux in Magnetic Field

Recently, magnetometers around the globe are registering geomagnetic unrest as Earth continues to feel the effects of a recent stream of fast flowing solar wind emanating from a large coronal mass ejection from an opening in the Sun's atmosphere (NOAA/SWPC, 2018). However, it's not only the speed of the solar wind that is important, it is also the direction of the magnetic field embedded in the plasma that determines the severity of the geomagnetic response by Earth, as illustrated with reference to the NOAA data accompanying Green's magnetometer chart (see Figure 19).

Much of the unrest correlates with negative Bz, when the approaching field turns south (Green, 2018). The Bz parameter represents the z–component of the sun's magnetic field. When Bz goes negative, the solar wind strongly couples to the Earth's magnetosphere. The Bz component allows transfer of significant amounts of energy. The more negative Bz, the more energy can be transferred, resulting in more geomagnetic activity. Related parameters involved are the density and the solar-wind velocity; these determine just how much energy is transferred when Bz is negative.

Figure 19



Because the role of the changing magnetic field around the Earth centers mostly on its ability to deflect the solar wind and solar mass ejections, the impact of the anticipated magnetic pole reversals on humans and wildlife in general are unknown except that our vulnerability to rising radiation will be increased (Dovey, 2015).

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