Uranium, Thorium, and Associated Rare Earth Elements of Industrial Interest

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Introduction

Immediately after the Fukushima tsunami disaster in 2011, nuclear power seemed doomed, again. Japan shut down all 54 of its reactors. Germany, Switzerland and other countries announced grand plans to phase out nuclear completely and the price of uranium plummeted by more than 40%. But today, a shift back towards nuclear energy is underway. New reactors are in planning and more are beginning construction in the U.S. and around the world. Major export economies in Europe and Asia have energy-intensive industries that cannot eliminate nuclear power plants on a whim. Research shows nuclear power is gaining popularity in both governments and the general public around the world. Although the uranium spot price has been languishing in the low $40 range for some time, it is apparent to many that uranium is on the critical tipping point towards higher prices.

MIT's Ernest Moniz is President Obama's choice for Energy Secretary. Dr. Moniz, a MIT Professor, stated in *Foreign Affairs*, that "…the government and industry need to advance new designs that lower the financial risk of constructing nuclear power plants..." Moniz (2011). He supports development of small, modular reactors for economy of manufacturing (Wald, 2013a). He also described the growth in domestic shale-gas production over the past few years as paradigm-shifting from coal to natural gas and nuclear power (Wald, 2013b).

It is apparent that coal and associated carbon-rich natural resources such as lignite can be converted to form high-grade carbon through heat and pressure, producing material similar to the naturally occurring anthracite coal and graphite (Conca, 2013e). Both of these are composed of (at the submicroscopic level) stacked sheets of "graphene", so named for the one-atom thick, honeycomb carbon lattices present. It appears at the atomic-scale like chicken wire made of carbon atoms and their covalent bonds. (See Figure 1) Graphene is the strongest material in nature (Science Daily, 2013) and is an important material for the construction of both historical and modern nuclear reactors because it is one of the purest materials manufactured at industrial scale and it retains its physical and electrical properties (including strength) at high temperatures. It is used for components in heating nuclear fuel and in the cool-down process and can absorb heat up to 3,000 degrees Celsius without any significant consequences (Prassher, 2010). It is clear that carbon materials are increasingly important and useful resources being used to drive the expansion of a new carbon-based industry not only in the nuclear industry but in many other industries as well.

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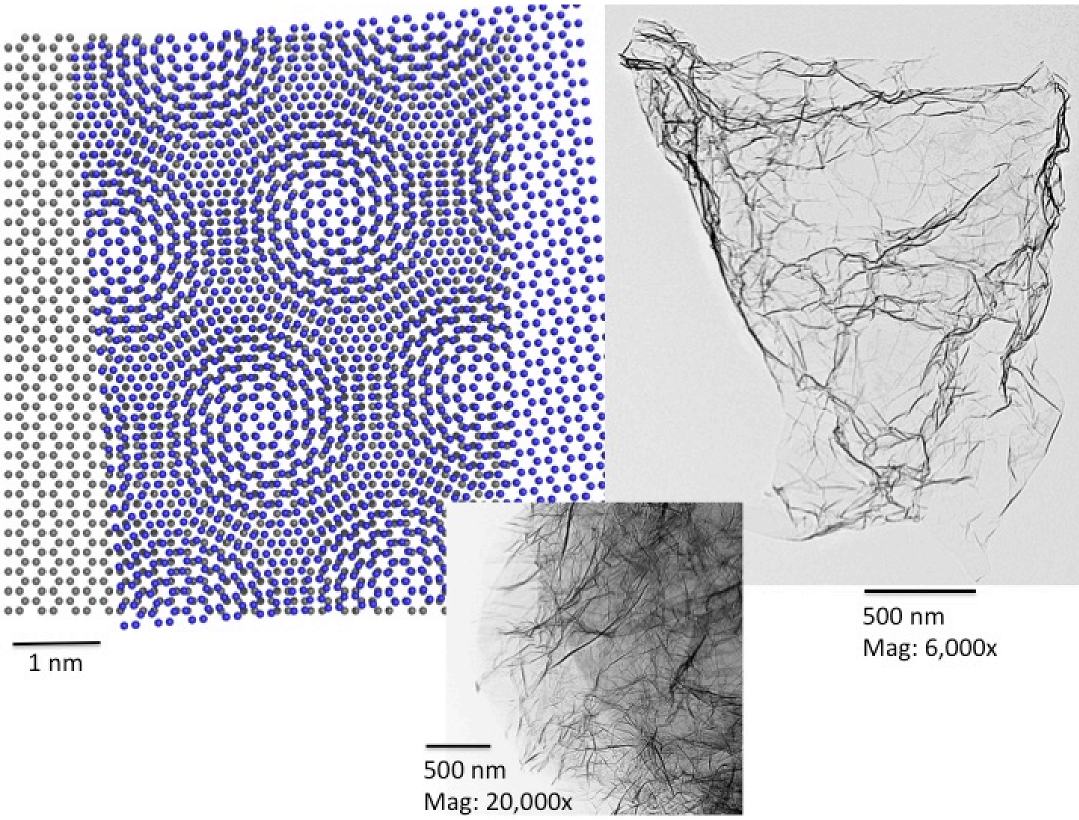


Figure 1 - The regular framework structure of carbon atoms in graphene sheets overlain upon each other show Moiré patterns, new larger periodic patterns. Image credits - NIST (National Institute of Standards and Technology) and Cabot Corporation (TEM images).

In the foreseeable future, their use will replace the need to harvest trees and to produce petroleum used currently to manufacture wood-based and plastic-based products such as furniture, utility poles, building-construction materials, and a host of other products. Coal and the other carbon-rich natural resources no longer need not be burned for the purpose of generating electricity but would be used as a feedstock to formulate carbon fiber and carbon (graphene) nanotubes that are presently used in reinforced plastics, heat-resistant composites, cell-phone components, fishing rods, golf club shafts, bicycle frames, sports car bodies, and many other products, including graphite rods used in nuclear reactors to control the rate of fission. Building fires and damage by high winds would also be minimized by using high-carbon materials formulated for such uses.

The production of these consumer products would maintain or increase employment in the current coal industry and associated new carbon-based industries. Even as we move off-world in the coming decades, carbon products of high density and strength will also be used in exploration to protect human habitation and electronics from radiation and various types of inherent stresses in orbit or on the surface of the Moon, asteroids, and even Mars.

Natural gas and nuclear power will continue to compete for the electricity generation market for decades to come, replacing coal on the basis of its environmental unsuitability and of the likely high cost of "clean-coal" technology. The need for nuclear fuel in the form of yellowcake produced by mines will rise for decades to come. Uranium exploration will continue on Earth in regions where new discoveries have been made on every continent, except Antarctica, and off-world until fusion becomes the principal source of power perhaps at least by the end of the 21st Century (Campbell and Wiley, 2011, and Campbell et al., 2013).

Introducing a major MIT report (MIT, 2013) on the future of natural gas in 2010, Moniz called this transition period "a bridge to a low-carbon future" of not burning fuels to produce electricity. "In the long term, natural gas would also likely be phased out in favor of zero-carbon options such as nuclear power," he said. But "for the next several decades, however, natural gas will continue to play a crucial role in enabling very substantial reductions in carbon emissions."

Nuclear power is considered a low-carbon source of energy that mitigates fossil-fuel emissions and the resulting health damage and deaths caused by air pollution from burning hydrocarbons and especially from coal. Jogalekar (2013) reported that Kharecha and Hansen (2013), (the latter of whom is a well-known proponent of climate change) estimated that as many as 1.8 million human lives would be saved by replacing fossil-fuel sources with nuclear power.

Kharecha and Hansen (2013) also estimate the saving of up to seven million lives in the next four decades, along with substantial reductions in carbon emissions, if nuclear power were to replace fossil fuel usage on a large scale. This includes coal and hydrocarbons. In addition, their study finds that the proposed expansion of natural gas would not be as effective in saving lives and preventing carbon emissions. In general, they provide optimistic reasons for the responsible and increased use of nuclear technologies in the near future.

They also emphasize the point that nuclear energy has prevented many more deaths than accidents related to production from other energy sources (coal, oil and gas, geothermal energy, wind, and solar), with the exception of hydropower. For an assessment of risks also see Campbell, (2005) for a review of human risks and attitudes toward nuclear power used to supply the U.S. electrical power grid.

U.S. Nuclear Power Industry

The designed age for nuclear reactors in the U.S. is 40 years. The average age of the 104 working plants is 32 years, according to the Energy Information Administration (EIA), a part of the U. S. Department of Energy (EIA, 2013a). With age is sure to come more maintenance and more outages. Other operators are likely to take the path chosen by the Kewaunee plant in Wisconsin and by the Crystal River Plant in Florida and begin the lengthy, complex, and expensive process of shutting down, cleaning up, and decommissioning (USNRC, 2013a).

Primarily a result of the Fukushima tsunami disaster in 2011, new nuclear plant safety requirements have been added to include emergency backup power and instrumentation to ensure spent-fuel pools operate adequately. All these reactors must also now have hardened vents for reactor containment structures to relieve pressure and discharge built-up hydrogen during a reactor vessel accident. The

Nuclear Regulatory Commission (NRC) is also contemplating requiring filters to capture vented radioactive material.

As retirements near for many of the U.S. nuclear reactors, NRC's oversight of the trust funds used to pay for decommissioning becomes paramount. Last year, a review by the Government Accountability Office (GAO), the investigative arm of Congress, challenged NRC's formula for determining the size of these funds (USGAO, 2012). The GAO report charges that the formula lacks detail and transparency, and in a sample of power plant savings programs, the report found NRC's formula may underestimate cleanup costs (USNRC, 2013b).

GAO investigated 12 reactors' trust funds, comparing company-prepared site-specific decommissioning cost estimates to NRC's formula. For nine reactors, NRC's formula resulted in funds below the companies' estimates. In one case, a company believed it needed $836 million, which was $362 million more than NRC's formula figure. GAO also noted NRC's funding formula was more than 30 years old, (Johnson, 2013).

The Vogtie Nuclear Plant in South Carolina has commenced construction of a new reactor, the second AP 1000 in America to start construction early 2013. World Nuclear News (WNN) also reported pouring of special basement concrete in South Carolina at the VC Summer Nuclear Plant. The site is the first reactor construction in 30 years. In addition, a second round of funding by the U.S. Government to encourage the development of Small Modular Reactors has begun, (WNN, 2013a).

STATUS OF U.S. URANIUM INDUSTRY

1st QUARTER 2013 STATISTICS

U.S. EIA (2013b) reported that U.S. production of uranium in the first quarter 2013 was 1,147,031 pounds U_3O_8, up 20 percent from the previous quarter and up 6 percent from the first quarter 2012. During the first quarter 2013, U.S. uranium was produced at six U.S. uranium facilities.

U.S. Uranium Mill in Production (State)

1. White Mesa Mill (Utah)

U.S. Uranium In-Situ-Leach Plants in Production (State)

1. Alta Mesa Project (Texas)
2. Crow Butte Operation (Nebraska)
3. Hobson ISR Plant/La Palangana (Texas)
4. Smith Ranch-Highland Operation (Wyoming)
5. Willow Creek Project (Wyoming)

Total U.S. uranium concentrate production in 2012 totaled 4,145,647 pounds. This amount is 4 percent higher than the 3,990,767 pounds produced in 2011. Historical production is shown in Figure 2.

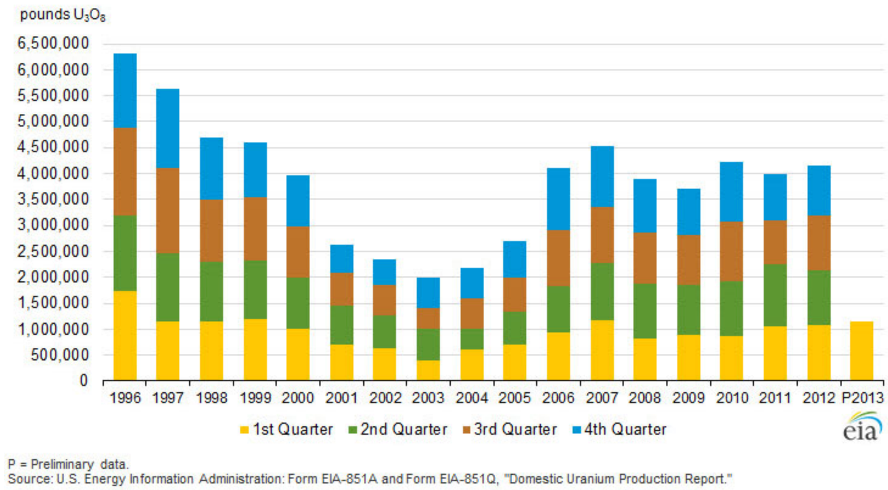


Figure 2 – Uranium Concentrate Production in the U.S. – 1996 through 1st Quarter, 2013
(from EIA , 2013b)

The Mestena Uranium's processing plant of the Alta Mesa Project in south Texas is shown in Figure 3. This illustrates the basic design of a currently producing in situ processing plant in Texas, plant that has been in operation for almost 10 years. It is also currently receiving produced resin from nearby in-situ production fields and by tanker from a distant producing field.

Figure 3 – Mestena Uranium's Alta Mesa Project – Texas
From Goranson (2008).

Table 1 – Uranium In-Situ Recovery Plants (By Owner, Location, Capacity, and Operating Status)

(From EIA (2013b))

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 2012	Operating Status at End of 1st Quarter 2013
Cameco	Crow Butte Operation	Dawes, Nebraska	1,000,000	Operating	Operating
Hydro Resources, Inc.	Church Rock	*McKinley, New Mexico*	1,000,000	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
Lost Creek ISR, LLC	Lost Creek Project	Sweetwater, Wyoming	2,000,000	Under Construction	Under Construction
Mestena Uranium LLC	Alta Mesa Project	Brooks, Texas	1,500,000	Producing	Producing
Power Resources, Inc. dba Cameco Resources	Smith Ranch-Highland Operation	Converse, Wyoming	5,500,000	Operating	Operating
Powertech Uranium Corp	Dewey Burdock Project	*Fall River and Custer, South Dakota*	1,000,000	Developing	Developing
South Texas Mining Venture	Hobson ISR Plant	Karnes, Texas	1,000,000	Operating	Operating
South Texas Mining Venture	La Palangana	Duval, Texas	1,000,000	Operating	Operating
Strata Energy Inc	Ross	*Crook, Wyoming*	3,000,000	Partially Permitted And Licensed	Partially Permitted And Licensed
URI, Inc.	Kingsville Dome	Kleberg, Texas	1,000,000	Standby	Standby
URI, Inc.	Rosita	Duval, Texas	1,000,000	Standby	Standby
URI, Inc.	Vasquez	Duval, Texas	800,000	Restoration	Restoration
Uranerz Energy Corporation	Nichols Ranch ISR Project	Johnson and Campbell, Wyoming	2,000,000	Under Construction	Under Construction
Uranium Energy Corp.	Goliad ISR Uranium Project	*Goliad, Texas*	1,000,000	Permitted And Licensed	Permitted And Licensed
Uranium One Americas, Inc.	Jab and Antelope	*Sweetwater, Wyoming*	2,000,000	Developing	Developing
Uranium One Americas, Inc.	Moore Ranch	*Campbell, Wyoming*	500,000	Permitted And Licensed	Permitted And Licensed
Uranium One USA, Inc.	Willow Creek Project (Christensen Ranch and Irigaray)	Campbell and Johnson, Wyoming	1,300,000	Producing	Producing
Total Production Capacity:			**27,600,000**		

Notes: Production capacity for 1st Quarter 2013. 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.

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

Table 2 – U.S. Uranium Mills (By Owner, Location, Capacity, and Operating Status)

From EIA (2013b)

Owner	Mill and *Heap Leach*[1] *Facility* Name	County, State (existing and *planned* locations)	Capacity (short tons of ore per day)	Operating Status at End of 2012	1st Quarter 2013
EFR White Mesa LLC	White Mesa Mill	San Juan, Utah	2,000	Operating	Operating
Energy Fuels Resources Corporation	Piñon Ridge Mill	*Montrose, Colorado*	500	Partially Permitted And Licensed	Partially Permitted And Licensed
Energy Fuels Wyoming Inc	*Sheep Mountain*	*Fremont, Wyoming*	725	-	Undeveloped
Kennecott Uranium Company/Wyoming Coal Resource Company	Sweetwater Uranium Project	Sweetwater, Wyoming	3,000	Standby	Standby
Strathmore Resources (US) Ltd.	*Gas Hills*	*Fremont, Wyoming*	2,200	-	Developing
Strathmore Resources (US) Ltd.	Pena Ranch	*McKinley, New Mexico*	2,000	-	Developing
Uranium One Americas, Inc.	Shootaring Canyon Uranium Mill	Garfield, Utah	750	Standby	Standby
Total Capacity:			**11,175**		

- = No data reported.

[1] Heap leach solutions: The separation, or dissolving-out from mined rock, of the soluble uranium constituents by the natural action of percolating a prepared chemical solution through mounded (heaped) rock material. The mounded material usually contains low grade mineralized material and/or waste rock produced from open pit or underground mines. The solutions are collected after percolation is completed and processed to recover the valued components.

Notes: Capacity for 1st Quarter 2013. An operating status of "Operating" indicates the mill was producing uranium concentrate at the end of the period.

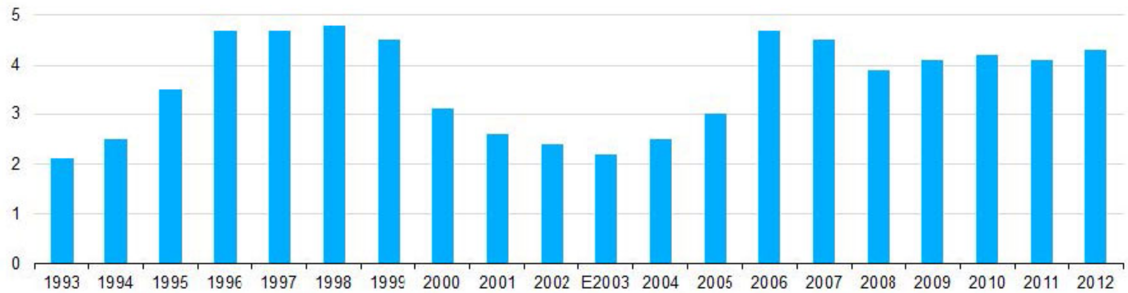
Source: U.S. Energy Information Administration: Form EIA-851A and Form EIA-851Q, "Domestic Uranium Production Report."

EIA has added new information in Table 1 and Table 2 that now include County and State location of existing and planned mills and in-situ-leach (ISL) plants.

U.S. uranium mines produced 4.3 million pounds U_3O_8 in 2012, 5 percent more than in 2011. Six underground mines produced uranium ore during 2012, one more than during 2011. Uranium ore from underground mines is stockpiled and shipped to a mill, to be processed into uranium concentrate (a yellow or brown powder, otherwise known as yellowcake). Additionally, five ISL mining operations produced solutions containing uranium in 2012 that was processed into uranium concentrate at ISL plants. Overall, there were 11 mines that operated during part or all of 2012.

Figure 4 illustrates the historical total production of U.S. uranium concentrate from 1993 through 2012. In 2012, 4.3 million pounds U_3O_8 were produced, 4 percent more than in 2011, from six facilities: one mill in Utah (White Mesa Mill) and five ISL plants (Alta Mesa Project, Crow Butte Operation, Hobson ISR Plant/La Palangana, Smith Ranch-Highland Operation, and Willow Creek Project). Nebraska, Texas and Wyoming produced uranium concentrate at the five ISL plants in 2012.

Total shipments of uranium concentrate from U.S. mills and ISL plants were 3.9 million pounds U_3O_8 in 2012, 2 percent less than in 2011. U.S. producers sold 3.6 million pounds U_3O_8 of uranium concentrate in 2012 at a weighted-average price of $49.63 per pound U_3O_8.



E = Estimated data.
Sources: U.S. Energy Information Administration: 1993-2002-Uranium Industry Annual 2002 (May 2003), Table H1 and Table 2. 2003-2012-Form EIA-851A, "Domestic Uranium Production Report" (2003-2012).

Figure 4 - U.S. Mine Production of Uranium, 1993-2012 (From EIA (2013b))

At the end of 2012, the White Mesa mill in Utah was operating with a capacity of 2,000 short tons of ore per day. Shootaring Canyon Uranium Mill in Utah and Sweetwater Uranium Project in Wyoming were on standby with a total capacity of 3,750 short tons of ore per day. There is one mill (Piñon Ridge Mill) planned for Colorado.

Five U.S. uranium ISL plants were operating at the end of 2012, with a combined capacity of 10.8 million pounds U_3O_8 per year (Crow Butte Operation in Nebraska; Alta Mesa Project, Hobson ISR Plant/La Palangana in Texas; Smith Ranch-Highland Operation and Willow Creek Project in Wyoming). Kingsville Dome and Rosita ISL plants in Texas were on standby with a total capacity of 2.0 million pounds U_3O_8 per year. Lost Creek Project (Figure 5) and Nichols Ranch ISR Project (Figure 6) were under construction in Wyoming. There are seven ISL plants planned in New Mexico, South Dakota, Texas, and Wyoming (EIA, 2013b).

Figure 5 - UR-Energy's Lost Creek Plant Building 2012-13. Wyoming.
(from Robert Odell)

Figure 6 - Uranerz Energy's Nichols Ranch Aerial View as of September, 2012. Wyoming
(from Robert Odell)

Drilling Statistics in Uranium Exploration

U.S. EIA (2013a) reports that U.S. uranium exploration drilling was 5,112 holes covering 3.4 million feet in 2012. Development drilling was 5,970 holes and 3.7 million feet. Combined, total uranium drilling was 11,082 holes covering 7.2 million feet, 5 percent more holes than in 2011. Development Drilling at Mestena Uranium's Alta Mesa Project in south Texas is shown in Figure 7 This photo illustrates close-spaced drilling in preparation for in situ production of uranium in solution from uranium roll-fronts that occur along a mineralized trend from depths of 600 to 1,200 feet below ground and to be piped or trucked to the processing plant shown in Figure 2.

Figure 7 – Development Drilling at Mestena Uranium's Alta Mesa Project Texas
(Campbell, *et al*., 2009)

Exploration has been brisk in the U.S. until recently when some exploration companies began to cut expenditures because of the uncertain future of yellowcake prices. Texas has remained active with exploration permits increasing over the past few years (see Table 3). Campbell, *et al*., (2007 and 2009; and Campbell and Wise, 2010) discuss the fundamentals of uranium exploration, assessment and yellowcake production.

The IAEA has published a new report providing a description of geophysical methods in uranium exploration. It presents several relevant advances in geophysics and provides some evidence of advances in airborne and ground geophysics for uranium exploration through selected examples from industry and government entities (IAEA, 2013).

Table 3 – Texas Uranium Exploration Permits
(By Permit Number, Company Name, and County)

Permit No.	Permittee	Texas County
118	URI, Inc.	Duval
121A	URI, Inc.	Kleberg
122A	URI, Inc.	Duval
123A	UEC	Goliad
124B-1	S.TX Mining Venture	Duval
125A-1	Mestena	Brooks & Jim Hogg
126A	UEC	Karnes
127	UEC	Goliad
128	UEC	Zavala
129	UEC	Goliad
131	URI, Inc.	Jim Wells & Duval
132	URI, Inc.	Duval & McMullen
133	URI, Inc.	Jim Wells & Neuces
134	Signal Equities LLC	Atascosa
135-1	Signal Equities LLC	Live Oak
136	UEC	Briscoe
Pending	Signal Equities LLC	Bee
Pending	S. TX Mining Venture	Brooks, Starr & Hidalgo
Pending	Manti Operating Co	Karnes
Pending	URI, Inc.	Duval

Employment in the Uranium Industry

The historical total employment in the U.S. uranium production industry for the period 1993 through 2012 is illustrated in Figure 8. For 2012 employment, EIA, (2013a) reports 1,196 person-years, an increase of less than one percent from the 2011 total. Exploration employment was 161 person-years, a 23 percent decrease compared with 2011. Milling and processing employment was 394 person-years in 2012, a 6 percent decrease from 2011.

Uranium mining employment was 462 person-years, the same as in 2011, while reclamation employment increased 75 percent to 179 person-years from 2011 to 2012. Uranium production industry employment for 2012 was in 11 States: Arizona, Colorado, Nebraska, New Mexico, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

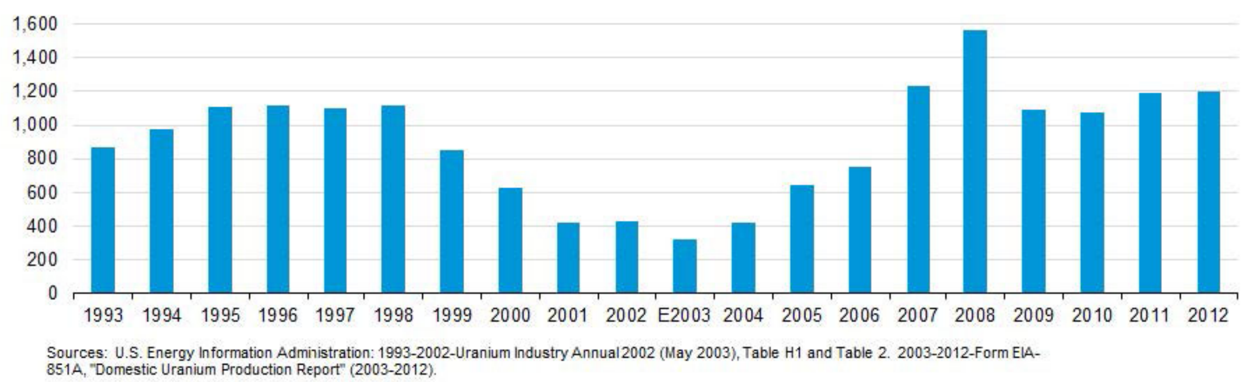


Figure 8 - Employment in the U.S. Production Industry, 1993-2012 (EIA, 2013b)

Expenditures in the Uranium Industry

Total expenditures for land, exploration, drilling, production, and reclamation were $353 million in 2012, 11 percent more than in 2011. Expenditures for U.S. uranium production, including facility expenses, were the largest category of expenditures at $187 million in 2012 and were up by 11 percent from the 2011 level. Uranium exploration expenditures were $33 million and decreased 23 percent from 2011 to 2012. Expenditures for land were $17 million in 2012, a 14-percent decrease compared with 2011. Reclamation expenditures were $49 million, a 46-percent increase compared with 2011. U.S. Department of interior's Budget Appropriations Bill of November, 2012 recommended reforming Hardrock Mining on Federal Lands to a leasing program, including gold, silver, lead, zinc, copper, uranium and molybdenum. Annual claim rental fees and a royalty not less than 5% of gross proceeds were recommended to generate Treasury fees of $80 million over ten years (EIA, 2013b).

Uranium Reserves

The EIA in 2010 began collecting annual reserve estimates on the survey Form EIA-851A, "Domestic Uranium Production Report." To date, these annual reserve estimates span data years 2009 through

2012. There are no plans to publish data prior to 2012 due to reporting inconsistencies and data accuracy concerns.

EIA (2013b) indicates that the 2012 uranium reserves are estimated quantities of uranium in known mineral deposits of such size, grade, and configuration that the uranium could be recovered at or below a specified production cost (forward cost) with currently proven mining and processing technology and under current laws and regulations. This information is collected from the entities that otherwise report on the Form EIA-851A; i.e. companies that conduct uranium drilling, exploration, mining, and reclamation.

Beginning with this report, and for the data year 2012, a new table includes uranium reserve estimates for mines and properties by status, mining method, and State. Sixteen respondents reported reserve estimates on 71 mines and properties. Estimated uranium reserves were 52 million pounds U_3O_8 at a maximum forward cost of up to $30 per pound. At up to $100 per pound, estimated reserves were 304 million pounds U_3O_8. At the end of 2012, estimated uranium reserves for mines in production were 21 million pounds U_3O_8 at a maximum forward cost of up to $50 per pound (EIA, 2013b).

The uranium reserve estimates presented cannot be compared with the much larger historical data set of uranium reserves published in the July EIA 2010 report *U.S. Uranium Reserves Estimates*. Those reserve estimates were made by EIA based on data collected by EIA and data developed by the National Uranium Resource Evaluation (NURE) program, operated out of Grand Junction, Colorado, by the U.S. Department of Energy (DOE) and predecessor organizations. The EIA data covered approximately 200 uranium properties with reserve estimates, collected from 1984 through 2002. The NURE data covered approximately 800 uranium properties with reserve estimates, developed from 1974 through 1983. Although the 2012 data collected by the Form EIA-851A survey covers a much smaller set of properties than the earlier EIA data and NURE data, EIA believes that within its scope the EIA-851A data provides more reliable estimates of the uranium recoverable at the specified forward cost than estimates derived from 1974 through 2003. In particular, this is because the NURE data has not been comprehensively updated in many years and is no longer a current data source. However, because much of the data gathered are proprietary and cannot be released by EIA, this makes these new reports of limited value.

In any event, potential uranium resources are likely to increase substantially over this decade as discoveries are made in frontier areas of the U.S., (see Campbell and Biddle, 1977), and in trend areas, (see Dickinson and Duval, 1977). The known areas in Texas that are favorable for uranium occurrence are suggested in Figure 9 below. Extensions to these areas of mineralization are likely, both along trend and at greater depths. Discoveries outside the U.S. have been made in South America, Africa, and in Australia and Canada. Greenland has confirmed a substantial, new rare earth and uranium discovery along the northern area of the Ilímaussaq Complex, which offers the potential to produce both a light and heavy rare-earth product, uranium, and other products (see discussion by Campbell, et al., 2013, p 206). Overseas uranium resources were reviewed in the 2011 review in this journal (Campbell and Wiley, 2011, pp. 311-323, and which will again be reassessed and published in this journal during late 2015.

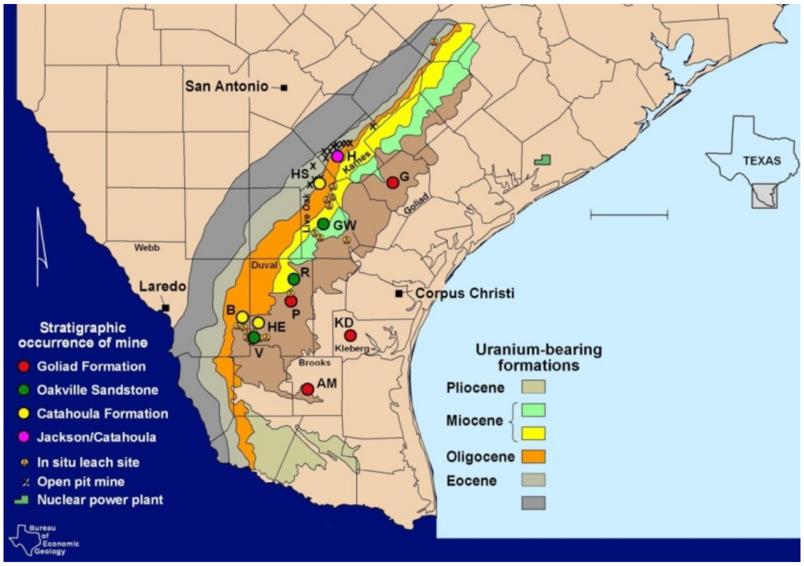


Figure 9 - Uranium Trends in South Texas
(From Ambrose, 2007)

Uranium Prices

Industry consultant *TradeTech's* Weekly U_3O_8 Spot Price Indicator dropped to U.S.$39.75/lb. by later June, 2013. US$40 has been tested time and time again, but now the price level has finally been penetrated (see Figure 10). *TradeTech* (2013) reports that current spot demand remains small and the only way to conclude sales at the moment is to drop prices. One non-U.S. utility has recently considered offers for over 500 thousand pounds of U_3O_8, with a supplier to be named, and the price from this transaction will likely remain around the U.S.$40.00 mark and lower. However, these prices are expected to rise over the next few months.

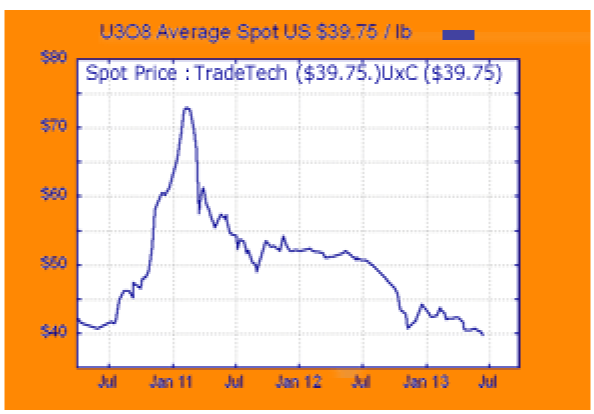


Figure 10 – Yellowcake Spot Price (TradeTech)

According to global industry resource experts at *Money Morning* (2013), four factors could come into play to cause a major increase in the current price of uranium in the next few months. They are summarized and expanded in the following:

Factor 1: Increasing Demand in Developing Markets

The growth in nuclear power is centered on the emerging markets, especially China. Last summer, the Chinese cabinet reconfirmed the country's commitment to its nuclear program, saying it would begin issuing new reactor licenses again after temporarily suspending them post-Fukushima. China's renewed pledge to nuclear power means they could be adding as many as 100 nuclear reactors over the next two decades, considering that China currently operates only 15 reactors. Its capacity is likely to climb to 40 million kilowatts from nuclear by 2015, compared to 12.54 million at the close of 2011. Clearly, China will need to acquire substantial uranium fuel, which they have apparently been doing in the spot market recently.

For instance, earlier this month Russia's state owned *Atomredmetzoloto* and its *Effective Energy N.V.* affiliate, otherwise known together as *ARMZ*, announced they would buy the remaining 48.6% of *Uranium One,* which they didn't already own at a premium. This effectively solidifies them as the world's fourth largest uranium producer, concentrating uranium production even further into Russian control.

And it's not just China and Russia that are re-committing to nuclear power. Other nations such as the United Kingdom, India, South Korea, and the United Arab Emirates (UAE) are contemplating new nuclear power plants as well, adding to the 435 nuclear reactors already providing base-load power worldwide. Today, 65 nuclear power plants are under construction in the world, another 160 new reactors are currently in the planning stages and 340 more have been proposed. Given this activity, the demand for uranium will increase but there is currently a uranium-supply (yellowcake) deficit and this alone should result in increasing prices for yellowcake and hence increased activity in exploration and plant start-ups.

Factor 2: Growing Supply Deficit

Because of the post-Fukushima fallout, and the severely depressed yellowcake prices that followed, many uranium explorers and producers were forced to shelve development and expansion projects. This has led to a sizeable supply deficit. According to the World Nuclear Association, total consumption of uranium was 176.7 million pounds in 2011 and growing, while the 2012 total uranium output was 135 million pounds. That's an annual deficit of roughly 40 million pounds. Altogether, by 2020, the world demand would be short by 400 million pounds. Of course, as discussed in a previous paper (Campbell and Wiley, 2011, especially pp. 317-323), resource estimates typically rise as frontier exploration discovers new ore bodies. Such activities require time to unfold and production from a new ore body may require up to 10 years before the first yellowcake can be produced for further processing into nuclear fuel pellets and rods. However, in-situ development projects often require less time to go on-line than open-pit operations. In the interim, yellowcake prices are likely to rise and fuel alternatives, such as thorium, will emerge.

Factor 3: Japan Reverses Course

As a result of considerably higher energy costs, Japan is now shifting its stance on nuclear power. Japan's current power grid, without nuclear power, has been experiencing rolling blackouts. Natural gas imports have risen 17%, and even coal imports are up 21%. According to *Japan Today*, newly elected Prime

Minister Shinzo Abe indicates that he is willing to build new nuclear reactors, which is a dramatic shift from the previous government's pledge to phase out all of the country's 50 working reactors by 2040. This reality is likely to spread to Germany and other countries that panicked after the tsunami in Japan a few years ago. But when Japan announced that it was shutting down its 54 nuclear power plants, they erased 20 million pounds of U_3O_8 demand, and exacerbated the pricing situation by simultaneously selling 15 million pounds U_3O_8 into the market, primarily to China.

Factor 4: Megatons to Megawatts

With the end of a program called **Megatons to Megawatts** this year**,** the fuel-supply deficit will increase. The program was created in the wake of the cold war, the **Megatons to Megawatts** program is an agreement between the U.S. and Russia to convert highly-enriched uranium (HEU) taken from dismantled Russian nuclear weapons into low-enriched-uranium (LEU) for nuclear fuel. The existence of this program alone covers a large portion of the worldwide annual deficit, with 24 million pounds of uranium going to American utilities. In years past, up to 10% of the electricity produced in the United States has been generated by fuel fabricated using LEU from the Megatons to Megawatts program. The program will expire toward the end of 2013, if the Russians decide not to renew the agreement - and that's the general expectation worldwide - the impact would be substantial but can be offset.

A Look into the Future

In 2012, world consumption of uranium was 165 million pounds versus 152 million pounds of mined uranium production. Globally there are 434 nuclear reactors operable, 67 reactors are under construction, 159 are on order or planned and 318 are proposed. However, just counting the reactors currently under construction, it's expected that uranium demand will increase by 13%, pushing up annual consumption to 200 million pounds, and that’s not accounting for any reactors in the planning stages. The problem is that some experts think we may only see as much as 180 million pounds of annual uranium output by 2020; and it's estimated that spot prices need to reach and remain around \$70 - \$80/ pound U_3O_8 before mining companies will be prepared to bring on new projects to reach that 180 million pound level.

Campbell and Wise (2010) made some preliminary calculations on the likely development of production within the U.S. over the next 15 years and considered the impact of fuel additives, such as BeO and thorium to improve fuel-burn efficiency on yellowcake production levels and the arrival of fast-breeder reactors by 2030. These projections may be pushed into the future some 15 to 20 years, although volatility in the spot and long-term price may return, which will push prices up over an extended period of time stimulating the start-up of those mines currently poised to initiate production in the U.S. and overseas including Canada, Australia, and Kazakhstan. There are plans for 13 new reactors in the U.S., three reactor units are under construction, and as many as six may come online in the next decade so uranium exploration and development of mines in the U.S. will need to be increased to supply these new reactors over this decade and beyond.

UNITED STATES URANIUM ACTIVITIES

Exploration and mine development in the U.S., although slow at the moment, both are posed to ramp up as soon as the yellowcake price begins to rise. Although Canada, Australia, and Kazakhstan can produce during low prices, the U.S. mines must have higher prices to meet stockholders expectations. The following provide a brief summary of the more active companies in the U.S. by State:

ARIZONA

Energy Fuels has shifted focus to mining low-cost, high grade breccia pipes. At White Mesa, milling of uranium and vanadium ores continues from stockpiles.

COLORADO

Energy Fuels reported that the Pinion Ridge uranium mill has won the approval of the Colorado Department of Health and Environment. *Cotter Corporation* at the Schwartzwalder Mine area will attempt a molasses and alcohol mix in Ralston Creek above the mine in a bioremediation exercise to treat a 24,000 ppb heavy metal contamination level. *ASARCO* is also conducting similar tests at its smelter in Denver, according to an Associated Press release to the *Casper Star Tribune*, March 4, 2013.

NEBRASKA

Cameco continued exploration drilling at Crow Butte with two drills.

NEW MEXICO

Strathmore Minerals announced in March (2013) that the three-year Roca Honda Mine area study by *Mangi Environmental Group*'s Draft Environmental Statement (DEIS) managed by the U.S Forestry Service has been published. *Uranium Resources Inc*.'s feasibility studies at its Section 8 property in the Grants Mineral Belt reported 6.5 million pounds of 0.11% U_3O_8 with a 67% recovery of the deposit. Direct production costs have been estimated at US$20 to $23 per pound U_3O_8.

SOUTH DAKOTA

POWERTECH URANIUM has its final Safety Evaluation Report for the DEWEY-BURDOCK project, signaling the end of NRC's technical reviews and requiring only the Supplemental Environmental Impact Statement and NRC review. The 6.7 million pound indicated U_3O_8 deposit covers 17,800 acres located on the southwest flank of the Black Hills, SD. Another 4.5 million pounds U_3O_8 are inferred in two additional deposits.

TEXAS

URANIUM ENERGY CORP (UEC) announced on February 28, 2013 receipt of a NI 43-101 resource estimate for 2.9 million pounds grading 0.047% U_3O_8 at its BURKE HOLLOW project exploration site, Drilling has located two lower Goliad sub-roll fronts at a depth of between 700 and 860 feet.

VIRGINIA

VIRGINIA ENERGY (VE) shares will be acquired by ENERGY FUELS to help develop the COLES HILL deposit in south central Virginia. That deposit, the largest in the U.S., totals some 133 million pounds grading 0.056% U_3O_8. VE indicates that progress is being made by the Virginia Legislature in considering lifting the State's ban on uranium mining.

WYOMING

BAYSWATER URANIUM announced it will receive investment funding of $2.5 million from PACIFIC ROAD RESOURCES FUNDS, the first of a $7.5 million investment in the AUC LLC PROJECT, where commercial production is planned for 2016. *CAMECO* reported that 16 production drills are active in 2013 at the Christensen Ranch project in Powder River Basin. *ENERGY FUELS* this year continues base-line environmental monitoring of properties acquired from TITAN in the Great Divide Basin Sheep Mountain area. The LOST CREEK Project is having some legal issues regarding permitting. In the meantime, 10 development drills were active mid-March, 2013.

PENINSULA ENERGY Ltd has upgraded its east Wyoming LANCE resource estimates to 17.2 million pounds, measured and indicated uranium resources. Total resources are now at 53.7 million pounds U_3O_8. PENINSULA completed an Optimization Study showing gross revenue of $187 million with a long-term contract price of US$62.33 per pound U_3O_8. Metallurgical recoveries of 64% were calculated for the associated ROSS, KENDRICK, and BARBER production units.

STRATHMORE late in 2012 indicated *CROSSHAIR ENERGY* had returned all claims to the JUNIPER RIDGE uranium property in south central Wyoming, which is within shipping distance of STRATHMORE's Gas Hills proposed uranium mill, citing "continued deterioration of existing market conditions". CROSSHAIR drilled 549 drill holes and identified a new uranium trend and an NI 43-101 resource estimate of 5.2 million pounds U_3O_8.

STAKEHOLDER and *URANIUM ONE* continue uranium reserves development in Wyoming. Reserves are estimated to be 4.14 million pounds with an average grade of 0.063% U_3O_8.

CANADIAN URANIUM ACTIVITIES

Canada was the world's largest uranium producer for many years, accounting for about 22% of world output, but in 2009 was overtaken by Kazakhstan. Production in Canada comes mainly from the McArthur River mine in northern Saskatchewan province, which is the largest in the world (Canadian Nuclear Safety Commission, 2013). A more detailed summary of activities in Canada is provided in Campbell (2013b).

Production is expected to increase significantly in 2013 as the renovated Cigar Lake mine returns to operation. With known uranium resources of 572,000 tons of U_3O_8 (or 485,000 tU), as well as continuing exploration, Canada will have a significant role in meeting future world demand. The country has a very vigorous research program underway at the federal, provincial, and university levels, with considerable funding provided by industry.

Exploration and mine development in Canada are also posed to ramp up as soon as the yellowcake price begins to rise. Canada can produce at some mines during low prices. The following provide a brief summary of the more active companies in Canada:

ASHBURTON VENTURES has acquired two uranium properties in Saskatchewan's PATTERSON LAKE SOUTH (ALPHA MINERALS/FISSION ENERGY discovery area).

*CAMECO r*educed long-term uranium plans due to the weak global economy. CAMECO will concentrate on projects presently in an advanced stage and anticipates production of 36 million pounds U_3O_8 annually by 2018. CIGAR LAKE production will commence in 2013, with expansion of the KEY LAKE MILL and extension of RABBIT LAKE and ISL facilities.

DENISON reported WHEELER RIVER drilling involves two drill rigs on a 24-hole program, with 18 holes already completed in the Athabasca Basin. At the PHOENIX A deposit, four infill drill holes returned one occurrence of 3.5 meters grading 36.3% U_3O_8 and three lesser occurrences grading from 13.5% to 24.1% U_3O_8, 2.6 to 3.0 meters thick. MOORE LAKE exploration continues to encourage further drilling.

SKYHARBOR RESOURCES has picked up six uranium exploration properties in the Athabasca Basin totaling 209,000 acres in the Patterson Lake area. Uranium mineralization is associated with granitic plutons, stocks and felsic gneiss.

INNUIT government sources in NUNAVUT were indicated in www.wise-uranium.org to be changing earlier mining policy to encourage mining by reducing the current 12% royalties on all minerals, including gold and uranium.

BRITISH COLUMBIA has banned uranium and thorium exploration, for now.

ONTARIO's MINISTRY of NORTHERN DEVELOPMENT has modernized their Mining Act (April, 2013), allowing no staking on private lands and requiring private companies to consult with aboriginal groups.

SASKATCHEWAN will cut royalty rates, as of March 22, 2013. No details or rates were mentioned by WISE via www.wise-uranium.org. AREVA was reported to have won a royalty-calculating methodology law suit against the provisional government, which must repay AREVA millions of dollars in overage charges.

AUSTRALIAN URANIUM ACTIVITIES

Australia has the world's largest Reasonably Assured Resources (RAR) of uranium and currently is the world's third largest producer of uranium after Kazakhstan and Canada. There are three operating uranium mines, at Olympic Dam and Beverley in South Australia and Ranger in the Northern Territory, plus three additional operations are scheduled to begin production in the near future. Australia's uranium production is forecast to more than double by 2030. Australia is a dominant supplier to the world and has been so for the past 30 years (WNA, 2012). The country has a vigorous research program underway at the federal, state, and university levels. A more detailed summary of activities in Australia is provided in Campbell (2013b).

The Queensland Government has recently lifted the 10-year ban on uranium mining and as a result uranium exploration has resumed in earnest. Western Australia will also initiate uranium mining in the near future after many years of opposition. The Australian uranium industry will be highlighted in a future EMD Review sometime in late 2015.

OVERSEAS ACTIVITIES OF PARTICULAR NOTE

GREENLAND MINERALS and ENERGY will evaluate potential for an “offsite refinery” for its KVANEFJELD uranium/rare earths project projected to offer a potential production rate of three million tons per year. The firm claims inferred uranium reserves of 512 million pounds U_3O_8. The reserves of rare earth and other metals have not been announced but are considered to be substantial.

ENVIRONMENTAL ISSUES

Uranium and other nuclear minerals are critical energy resources that are necessary for generating electricity, and the nuclear industry has an outstanding safety record when all the information is considered. The Three-Mile Island incident and the Japanese earthquake that caused severe damage to the Fukushima Daiichi Power Plant have served to make the nuclear industry even stronger than before. No lives were lost at either power plant. The Chernobyl disaster does not count against the U.S. nuclear industry's safety record because the Soviet Union's nuclear industry made seriously flawed design decisions that led to the meltdown and explosion at the facility; and because the Chernobyl plant was a dual-use weapons reactor, designed to produce plutonium for weapons as well as energy, so the Chernobyl disaster does not fit in the same discussion with power-reactor accidents.

According to the IAEA (2005), this catastrophe resulted in the deaths of a number of managers and firemen, and approximately 4,000 children and adolescents contracted thyroid cancer some years later but almost all of these recovered with a treatment-success rate of about 99%. Few realize that these design decisions had been severely criticized by the West as the reactors were being built many years ago. They ignored the West's comments because of the competitive pressures of the "Cold War".

Community Cooperation

Campbell (2013a) has developed a program of commenting on selected media articles to alert the general public to the vagaries of the local news media and news media in general around the U.S. Those offering this program encourage the general public to take notice of how some local public servants, activists, and news media are sowing the seeds of misinformation, creating unnecessary controversy and mistrust around the U.S. This includes the dissemination of blatantly biased articles related specifically to inhibiting the expansion of nuclear power and associated uranium exploration and recovery.

Effects of Radiation

WHO (2013) reports that “Clear cases of health damage from radiation generally occur only following exposure of greater than 1,000 mSv” – which is far more radiation than the reported Fukushima doses of 10 to 50 mSv. Radiation is also discussed in Campbell, *et al*., pp. 171-177 (2013), which focuses on both off-world and on-Earth exposure issues. They indicate that:

> *"A fairly strong relationship exists between dose and cancer occurrence at high doses, but the relationship disappears below 10 rem. These observations, taken together with the fact that there has not been a single death in more than 20 years in the civilian nuclear industry in the United States, suggest that the risk associated with chronic low doses of radiation less than 10 rem/yr (0.1 Sv/yr) appear to be small with respect to any other risk associated with normal living and working activities…"*

Further, Conca (2013b) indicates that radiation doses less than about 10 rem (0.1 Sv) are not significant. The linear no-threshold dose hypothesis (LNT) does not apply to doses less than 10 rem (0.1 Sv), which is the range encompassing background levels around the world, and is the region of most importance to nuclear energy, most medical procedures, and most areas affected by accidents like Fukushima.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2012) reports that among other things, uncertainties at low doses are such that UNSCEAR "*does not recommend multiplying low doses by large numbers of individuals to estimate numbers of radiation-induced health effects within a population exposed to incremental doses at levels equivalent to or below natural background levels*." (WNN, 2013b; UN, 2012).

Nuclear Wastes in the U.S.

There are four general categories of nuclear waste in the U.S. (see Figure 11 below): commercial spent nuclear fuel (SNF), high-level nuclear waste (HLW) from making weapons, transuranic waste (TRU) also from making weapons, and low-level radioactive waste (LLW) from many things like the mining, medical and energy industries. A minor amount of other radioactive wastes are distributed among these categories. This nuclear and radioactive waste comes in four different types that are treated and disposed of in different ways and at different costs. However, most of the high-level waste (HLW) is no longer waste with high levels of radiation.

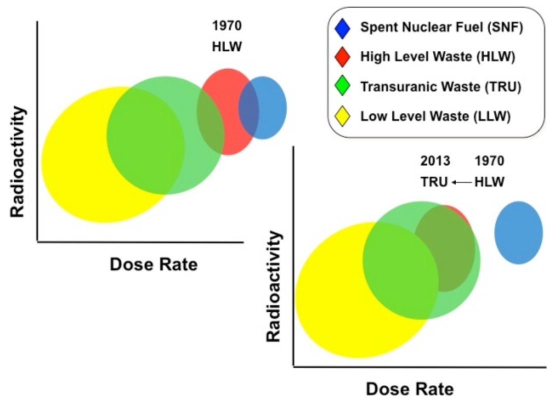


Figure 11 - Types of Nuclear Waste (from Conca, 2013c)

Conca also suggests that changing laws, regulations, and agreements are very difficult in today's political climate, but it is still a better strategy and cheaper than treating HLW that no longer exhibits high-level radiation. The cost of physically and chemically treating transuranic waste as though it is HLW is very expensive and unnecessary. He concludes that the difference is about $200 billion, suggesting that this is a significant amount to spend on a legal technicality.

Conca (2013c) indicates that the SNF is the waste with the highest radiation, consisting of two isotopes, Cs-137 and Sr-90, both with approximately 30-year half-lives, making the waste exhibit high-level radiation for less than 200 years. Similarly for HLW – it's the Cs-137 and Sr-90 that contribute the high radiation, although not as much as SNF. LLW is not very radioactive at all. TRU waste spans the gamut from low-level to high-level radiation, and is primarily determined by the amount of plutonium, while the level of radiation is again determined by the amount of Cs-137 and Sr-90.

There are a myriad of laws and regulatory controls on all of the wastes, but this may have changed recently. The U.S. Congress took the first step in adopting a rational and achievable nuclear waste disposal plan that would reverse the catatonic state of our existing nuclear program. The Nuclear Waste Administration (NWA) would be formed as a new and independent agency to manage nuclear waste, construct an interim storage facility(s) and site a permanent waste repository through a consent-based process. All of this is to be funded by on-going fees collected from nuclear power ratepayers which have been accumulating in the Nuclear Waste Fund for decades, see Conca, (2013d).

UNIVERSITY URANIUM RESEARCH IN U. S., CANADA, AND AUSTRALIA

The Uranium (Nuclear and Rare Earth Minerals) Committee of the EMD is pleased to remind readers of the Jay M. McMurray Memorial Grant which is awarded annually to a deserving student whose research involves uranium or nuclear fuel energy. This grant is made available through the AAPG Grants-In-Aid Program, and is endowed by the AAPG Foundation with contributions from his wife, Katherine McMurray, and several colleagues and friends. For further information, see AAPG Foundation (2013).

Research in the U.S.

Uranium-related research activities at the major American universities were limited in scope in 2012. Funding was primarily from private sources, usually uranium mining companies. The Society of Economic Geologists (SEG) provided two student grants related to uranium ore deposits. One of the uranium related grants was for study of uranium/rare-earth elements (REE) in mid-crustal systems and their links to iron oxide copper gold [IOCG] deposits while the other grant was for a study of a deposit in British Guyana. In contrast, a total of four SEG grants were for the study of REE.

In the U.S., uranium-related research at government agencies in 2012 was mostly limited to the U.S. Geological Survey and the Wyoming State Geological Survey (WSGS) in cooperation with the University of Wyoming Department of Geology and Geophysics (UW-GG). The U.S. Geological Survey continues its research into the uranium ore forming processes and the geology and geochemical changes that take place during extraction and processing and into the occurrence of rare earth elements in the U.S., especially as reported in Wyoming. For additional information on these programs, see Campbell (2013b)

Research in Canada

In Canada, uranium-related research is driven by a prosperous uranium industry and robust funding by the Canadian Government and by the Provinces involved in uranium exploration and mining. This funding supports numerous programs at the Geological Survey of Canada, the Saskatchewan Geological Survey, the Canadian Mining Innovation Council, and at numerous universities, i.e., Nancy Université, Queen's University, University of Regina, University of Saskatchewan, and University of Windsor. Funding is principally provided by AREVA, Cameco Corporation, CanAlaska Uranium, JNR Resources, and Uravan Minerals among others. A more detailed summary of activities in Canada is provided in Campbell (2013b).

Research in Australia

In Australia, uranium-related research is also driven by an active uranium industry and by funding from the Australian Government via the Commonwealth Scientific and Industrial Research Organization (CSIRO), and the Australian National University, and by the States involved in uranium exploration and mining, such as Macquarie University and the University of Sydney; The University of Queensland; James Cook University; University of Adelaide, and the University of New South Wales. A more detailed summary of activities in Australia is provided in Campbell (2013b).

STATUS OF THE THORIUM INDUSTRY

Most of the world's nuclear power reactors currently run on uranium fuel. However, other designs exist that may offer more desirable characteristics. Some such designs utilize thorium as the fuel, which is considered to be a more sustainable energy source. These designs are drawing increasing interest. Research is being conducted in the UK to study the viability of these designs (Sorensen, 2012). Oslo based Thor Energy is pairing up with the Norwegian government and U.S.-based (but Toshiba owned) Westinghouse to begin a four-year test that they hope will dispel doubts and make thorium a viable fuel for nuclear power (Thor Energy, 2013). China is also using Canadian and American research to pursue a safe reactor based on thorium (Xuqi Min, 2011).

Moreover, pilot thorium-based reactors have been built and are being evaluated. The Molten Salt Reactor (MSR), built in the Oak Ridge National Laboratory in Tennessee, ran for four years and helped to prove the basic concepts of a Liquid Fluoride Thorium Reactor (Sorensen, 2012). The CANDU reactor in Canada also has had a long history of outstanding operation.

Thorium Resources

Geochemically, thorium is four times more abundant than uranium in the crust of the Earth and economic concentrations of thorium are found in a number of countries. Geologically, thorium deposits are found in various geological environments, such as alkaline complexes, pegmatites, carbonatites and heavy mineral sands with wide geographic distribution. For vein-related thorium occurrences in the U.S., see Armbrustmacher (1995).

Worldwide, current thorium resources are estimated to total about six million tons. Major resources of thorium are present in Australia, Brazil, Canada, India, Norway, South Africa and the U.S. Thorium exploration is presently ongoing in some countries, such as India and U.S. The present production of thorium is mainly as a by-product of processing of heavy mineral sand deposits for titanium, zirconium, tin and REEs. Thorium is widely available in Australia from sands containing monazite in heavy-mineral beach sand deposits (see Mernagh and Miezitis, 2008). Thorium (and REEs) have also been tentatively identified on the Moon, see summary Campbell and Ambrose, (2010).

STATUS OF THE RARE EARTH INDUSTRY

The EMD Mid-Year Report for 2011 offers the uninitiated an introduction to the rare earth commodities. That report covers the list of 17 REEs, their geological origins and distribution, production, prices, and explores some of the geopolitical issues involved, with a brief description of the REEs on the Moon. That report also contains extensive introductory discussions and references on REEs and associated deposits (Campbell, 2011).

Light Rare Earth Elements

Binnemans, *et. al.*, 2013, report that the balance between the demand by the economic markets and the natural abundance of the REEs in ores is a major problem for the marketing of these elements. At present, the light rare earth elements (LREE) market is driven by the demand for neodymium for use in the manufacture of neodymium-iron-boron (NdFeB) magnets. For example, only about 25,000 tons of neodymium were required for the production of magnets in 2011. This means that significant quantities of REE ores had to be mined to produce 25,000 tons of neodymium metal. Because the natural abundance of neodymium is relatively low in the LREE ores (say 0.10% Nd for example), then only about 300 thousand tons of ore would needed to be mined and processed to produce 25,000 tons of Nd metal (making certain assumptions about metal recovery during mining, processing, and separating the concentrates into Nd metal), with cerium, praseodymium, and samarium often produced from the same ore but processed separately to produce marketable concentrates or metals.

At present the demand is not large, and although this is expected to rise as magnet demand rises, especially for samarium, the LREEs are available in various parts of the world but China is currently controlling the prices to a significant extent. For additional information on REEs occurring off-world (especially samarium, see Campbell, *et al.*, 2013, pages 194-195).

The lanthanum market is in balance, i.e., production = sales, for use in nickel metal hydride batteries and optical glasses. Praseodymium can be used as an admixture in NdFeB magnets but not samarium. More samarium-cobalt magnets could be produced, but the high price of cobalt is an issue. To bring the LREE market into balance, new high-volume applications using samarium, praseodymium, and especially cerium, are required.

Heavy Rare Earth Elements

Binnemans, *et. al.*, 2013 also report that the heavy rare earth elements (HREEs) are produced in much smaller quantities than the LREEs. Currently, the HREE market is driven by the demand for dysprosium, which is used to increase the temperature resistance of NdFeB magnets. About 1,600 tons of dysprosium were consumed in 2011. The supply equals the demand for europium, yttrium, and erbium. However, there is a shortage of terbium, but this problem can still be relieved by the use of stockpiles. Gadolinium, holmium, thulium, ytterbium, and lutetium are produced in excess and are stockpiled at most production sites around the world. New large volume applications are needed that use the heaviest rare earths (Ho through Lu on the element periodic chart). Apparently, no large-scale separation of these elements is being performed by industry.

Although production levels of the REEs are relatively small, Tanton, (2012) estimates that the U.S. must import 96% of the rare earths consumed (and 92% of uranium consumed), while $40 billion in increased economic development are lost and nearly 9,000 jobs are not filled due to bureaucratic and political demands impacting mine permitting in the U.S. He recommends trade missions to Australia and Canada where mine permitting is often completed in one quarter of the time while meeting all appropriate environmental and mine-safety concerns, which minimizes mining project opponents from delaying or denying mining projects through litigation.

Status of Selected Rare Earth Projects

Although the first quarter of 2013 was challenging for the rare-earth sector as a whole because of depressed markets for development funding, there have been some notable developments, especially with a few junior REE mining companies. China continues to acquire properties and companies in various parts of the world. Currie (2013) provides a summary of current REE activities. The following are selected highlights:

GREENLAND MINERALS AND ENERGY conducted studies that show that the costs and risks associated with its Kvanefjeld project can be lowered and its financial returns increased if it establishes the refinery for the project outside of Greenland. The company had originally considered establishing the refinery for uranium and heavy and light REEs in Southern Greenland, in proximity to the mine and concentrator.

SEARCH MINERALS announced a revised preliminary economic assessment (PEA) for its Foxtrot REE project, which is located in Labrador, Canada. Highlights include a reduction in capital costs from $469 million to $221 million, with a 3.8-year payback period. Further, net revenue for the project has increased by $110 per metric tonne (MT) milled and operating expenditures have increased by $38 per MT. The revised project will now focus on higher-grade REE material of “0.89% total REE … on average, which compares to the 0.58% TREE on average for the original bulk open pit concept,” according to a press release.

PEAK RESOURCES announced further improvements to beneficiation process for its Ngualla rare earth project in Tanzania. It confirmed that the ability to concentrate mineralization at an early stage prior to acid-leach recovery is likely to have a “significant impact” on costs. One improvement is that the optimization of the beneficiation process reduces by 43% the mass of feed to be treated by the acid-leach recovery process. The latest test work also indicates that conventional magnetic separation and flotation techniques will reduce the mass of the feed mineralization by 78% through the rejection of relatively mineralized barite and iron oxides. The cost reductions will be quantified in a revision of the scoping study, and an economic assessment is scheduled for completion in the second quarter of 2013.

LYNAS CORPORATION, the major Australian REE miner, plans to implement a price schedule for its rare earth concentrates on July 1, 2013. The company said recent spot prices for rare earths of $16 to $20 per kilogram are 25% below the price that producers need for sustainable operations. Prices had been $100 per kilogram less than three years ago.

RARE ELEMENT RESOURCES announced a 65% increase to its total measured and indicated (M&I) REE resource estimate for the Bear Lodge project. The increase saw a rise from 571 to 944 million pounds of

Rare Earth Oxides (REO). The updated NI 43-101 compliant resource estimate includes the first indicated resource at the heavy rare earth element (HREE)-enriched Whitetail Ridge deposit and high grades of critical rare earth oxides (CREOs) in all deposits. CREOs are rare earth oxides that have the highest values and the strongest projected future growth.

GREAT WESTERN MINERALS GROUP released a PEA for its Steenkampskraal REE project that indicates strong potential for its integrated business model. Project highlights include a $555-million after-tax net present value when applying a 10% discount rate, a 28% South African corporate tax rate and a 66% after-tax internal rate of return. On an after-tax basis, the project has a 4.3-year estimated payback period from the start of underground mining production. It also has an 11-year potential mine life.

TASMAN METALS announced the first NI 43-101 compliant independent resource estimate for its 100%-owned Olserum HREE project in Sweden. Its press release notes that highlights include a 0.4% total rare earth oxide (TREO) cut off, an indicated resource of 4.5 million MT at 0.60% TREO and an inferred resource of 3.3 million MT at 0.63% TREO. It adds that "higher value" HREEs comprise 34% of the total REE content at Olserum, with the five critical REEs (dysprosium, terbium, europium, neodymium and yttrium) comprising approximately 40% of the REE content.

UCORE RARE METALS confirmed that United States senators Lisa Murkowski and Mark Begich jointly introduced a bill in Washington, DC to authorize construction of a road to the Niblack and Bokan Mountain projects on Prince of Wales Island. Ucore also highlighted the introduction of Senate Joint Resolution No. 8 in the Legislature of the State of Alaska by senators Lesil McGuire, Berta Gardner and Johnny Ellis. The resolution supports the continued and increased exploration, extraction, processing and production of REEs in the state. It is positive news for the project as it supports a number of initiatives and urges state agencies that administer the permits required for the development of REE projects in Alaska to expedite the consideration and issuance of permits for the development of REE deposits.

QUEST RARE MINERALS provided an update on the preparation of a Preliminary Feasibility Study (PFS) for the B-Zone deposit at its Strange Lake Heavy REE (HREE) deposit, located in Quebec. It confirmed that significant development work demonstrates that Strange Lake is a "very large rare earth project" with high concentrations of HREEs, as well as by-products such as zirconium and niobium.

Further Research on Availability of Rare Earth Elements

On other developments, the U.S. Geological Survey has built a website offering information on mineral deposits containing REE and yttrium in the U.S. and from around the world with geographical locations, grade, tonnage, and mineralogy, where available (USGS, 2013).

Many publications on the various aspects of rare earth elements, uranium exploration and mining, thorium development, and nuclear power development are included as URLs or PDFs in the interactive I2M Web Portal. At present, the data base contains almost 3,000 URLs of technical papers and news items related to the subjects covered in this paper and many other subjects of interest to the geoscientist and general public, see I2M Associates, LLC., (2013).

EMD URANIUM COMMITTEE PUBLICATION JUST RELEASED

The *AAPG-EMD Memoir 101: The History and Path Forward of the Human Species into the Future: Energy Minerals in the Solar System* has just been released in book form. The EMD's Uranium Committee's 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*. Because the 2012 updates to Chapter 9 were omitted during final editing, these updates have been included in a PDF version of the chapter. Chapter 9 is included as a PDF in the References list below, followed by author biographies, the Memoir 101's Press Release, Table of Contents, ordering information, book preface, and a copy of the front book cover, see Campbell, *et al*., (2013) below. *Forbes.com* has highlighted Memoir 101 in a recent article emphasizing the coverage of Chapters 8 and 9 (see Conca, 2013a).

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