Uranium FAQ

Frequently Asked Questions about Uranium and its Use and Waste Storage?

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Typical Questions:

What is Uranium and how was it formed ?

What is the origin and role of Uranium in planetary formation ?

How does Uranium get concentrated enough in the shallow subsurface to be mined as an economic commodity ?

Where in the world is Uranium found ?

How is Uranium recovered from the subsurface ?

What happens inside a nuclear reactor ?

What are fast reactors ?

What are the principal safety issues inherent in deploying nuclear power plants ?

What are small modular reactors (SMRS) ?

What is wrong with storing nuclear waste at the Yucca Mountain Nuclear Storage Site in Nevada ?

What is nuclear fusion ?

What other uses are there for Uranium ?

Often elements are associated with Uranium deposits, such as: Thorium (more) and Rare Earths (more).

For other questions (and links to the answers) for the major energy resources and use see (here).

Here are some answers:

What is Uranium?

- On a scale arranged according to the increasing mass of an element's nuclei, Uranium is one of the heaviest of all the naturally-occurring elements (Hydrogen is the lightest). Uranium is 18.7 times as dense as water.
- Uranium has a melting point of 1132°C. The chemical symbol for uranium is U.
  - Uranium was discovered in 1789 by Martin Klaproth, a German chemist, within in the mineral called pitchblende. It was named after the planet Uranus, which had been discovered eight years earlier.
  - For follow-up readings on the subject (more).

What is the origin and role of Uranium in planetary formation?

- Uranium was apparently formed in supernovas about 6.6 billion years ago. As planets were formed in the solar system, the heavy elements sank into the interior of the planets, perhaps creating such high heat that helium/hydrogen metals were created to form the cores of some or all planets of a certain minimum size, which by rotation created large magnetic fields so large that it has been protecting Earth by shielding it from out busts (aka coronal mass ejections (CME), which are unusually large releases of plasma and magnetic fields from the solar corona. They often follow solar flares and are normally present during a solar prominence eruption. The plasma is released into the solar wind) generated within the Sun or from gamma radiation originating from elsewhere in the galaxy.
- Uranium's slow radioactive decay provides the main source of heat inside the Earth lasting for billions of years after its formation. In the Earth, at least, driven by high heat and pressure causing deep convection and magma flow in turn causes continental drift of plates of cooled rock in the shallow subsurface and riding on the surface to move by faulting (rapid readjustment of rocks) and by creep (slow movement of large plates of rock). This process is referred to as plate tectonics.
- The cores of smaller planets may not have been large enough to initiate or maintain such heat and pressure and hence could not initiate or maintain the heat required to drive deep core rotation and associated plate tectonics.

At some point in time, planetary cores will cease to rotate, which will also eliminate the magnetic field and associated protective shield of the planet exposing the atmosphere and ground surface to CMEs and gamma radiation, which in turn would erode and finally eliminate the planets' atmospheres, killing off the remaining organic life.

- Like other elements, Uranium occurs in several slightly differing forms known as 'isotopes'. These isotopes differ from each other in the number of uncharged particles (neutrons) in the nucleus. Natural uranium as found in the Earth's crust, and likely in other similar planets that probably exist in other solar systems, is a mixture largely of two isotopes: uranium^{238} (U^{238}), accounting for 99.3% and uranium^{235} (U^{235}) about 0.7%.

- The isotope U^{235} is important because under certain conditions it can readily be split, yielding a lot of energy. It is therefore said to be 'fissile' and we use the expression 'nuclear fission'. Meanwhile, like all radioactive isotopes, they decay. U^{238} decays very slowly, its half-life being about the same as the age of the Earth (4.5 billion years). This means that it is barely radioactive, less so than many other isotopes in rocks and sediments. Nevertheless, it generates 0.1 watts/tonne as decay heat and this is enough to heat the Earth's core, etc.

- U^{235} decays slightly faster. The nucleus of the U^{235} atom comprises 92 protons and 143 neutrons ($92 + 143 = U^{235}$). When the nucleus of a U^{235} atom captures a moving neutron it splits in two (fissions) and releases some energy in the form of heat, also two or three additional neutrons are thrown off. If enough of these expelled neutrons cause the nuclei of other U^{235} atoms to split, releasing further neutrons, a fission 'chain reaction' can be achieved. When this happens over and over again, many millions of times, a very large amount of heat is produced from a relatively small amount of uranium. This characteristic is used to design nuclear bombs but also to boil water under controlled conditions to turn turbines generating electricity.

- For follow-up readings on the subject, see (more).

How does Uranium get concentrated enough in the shallow subsurface to be mined as an economic commodity?

- Uranium gets distributed in most rocks in concentrations of 2 to 4 parts per million as a result of the redistribution of elements via plate tectonics and is now, except for when an excess uranium occurs when uranium minerals are formed.as common in the Earth's crust as tin, tungsten and molybdenum.

- Uranium gets concentrated in sediments via biogeochemical processes (as in so- called “roll fronts” in Tertiary sediments located in Texas, Wyoming, Colorado, Kazakhstan, etc.) and in old rocks deposited under similar conditions but with overprinting metamorphic processes as well (as in so-called “unconformity deposits” with Precambrian metamorphosed sediments and igneous/metaphoric rocks located in the Athabasca Basin of Canada, in the Northern Territory of Australia).

- Uranium occurs in seawater, and one day can be recovered from the oceans, making it a sustainable energy resource, like the wind (when it blows) and like the sun (when it shines). Although the cost of uranium fuel is extremely low within the framework of the cost of the electricity produced, uranium prices would have to be in the range or $200 to $300 / pound U_3O_8 before it would be profitable to remove the uranium present in seawater.

- Over 2005 and 2006 exploration efforts resulted in the world’s known uranium resources increasing by 15% in that two years. However, in 2013, companies exploring for uranium in Canada discovered extremely high-grade and high tonnage uranium deposits in the Athabasca Basin.

- Considering all current activities, the Canadian discoveries have likely tripled the world uranium reserves just over the past few years.

- The future uranium price dictates when and how much uranium companies mine and conduct exploration to develop need reserves.

- For follow-up readings on the subject, see (more).

Where in the world is Uranium found?

- Almost 90% of the Uranium used to fuel U.S. nuclear power plants comes from outside the U.S. However, the U.S. still has known undeveloped Uranium resources of considerable size, and it has potential undiscovered deposits. For example, the State of Virginia contains a world-class undeveloped Uranium deposit in igneous/metamorphic rocks, the development of which has been opposed by exaggerated concerns of groundwater contamination.

- At least 10 states have viable Uranium deposits in the U.S., including Texas, Colorado, Utah, Arizona, Nebraska, North Dakota, South Dakota, Wyoming, Washington, and Alaska. Those deposits occurring in Tertiary sedimentary deposits are developed by in situ recovery methods, while others are mined by open pit or underground methods in older deposits with structural controls in igneous and metamorphic rocks.

- The costs to mine in combination with low uranium prices have limited Uranium production in the U.S. This condition has worsened since the incident at Fukushima, Japan, which drove uranium fuel prices to new lows.

- Mining is currently under way in Wyoming, Nebraska, and Texas, with about 20 other projects in various stages of development or remediation. Of those currently not operating, they are waiting for the predicted Uranium price rises to begin in late 2016 and accelerating in 2017 and afterward.

- International uranium deposits are currently being mined in Kazakhstan, Canada, Australia, Niger, Russia, Namibia, Uzbekistan, China and 10 other countries, in order of total yearly production.

- For follow-up readings on the subject, see (U.S. more), International (current: more; and for 2015 (more)).

How is Uranium recovered from the subsurface?

- Uranium is recovered by conventional mining, *i.e.,* by either open-pit (if the uranium deposit is shallow) or by underground mining (if the deposit is greater than 300 feet bgs.). The ore is outlined, exposed by removing the overburden, blasted to break-up the rock and trucked to the processing plant, where it is crushed and processed with fluids that oxidize the ore liberating uranium and any molybdenum or selenium that may also be associated with or around the uranium mineralization of the deposit.

- Yellowcake is produced and dried, and then stored in 55-gallon drums for shipment to other plants that use the yellowcake to make enriched uranium pellets that fit into fuel-rod racks of nuclear reactors.

- Uranium is also recovered by in-situ mining, where holes are drilled from above the deposit and water that has been enriched with oxygen and carbon dioxide is injected, which oxidizes the mineralization and solubilizes the uranium, and any molybdenum or selenium that may also be associated with or around the uranium mineralization of the deposit.

- The so-called "pregnant" fluids produced are pumped to the surface and piped (or trucked) to the uranium processing plant where yellowcake is produced and dried, and then stored in 55-gallon drums for shipment to other plants that use the yellowcake to make enriched uranium pellets that fit into fuel-rod racks of nuclear reactors.

- The most common uranium product from mines after processing is U_3O_8 which contains about 85% uranium (U^{235} plus U^{238}). Some production figures are presented as pure uranium (U)/pound but may be expressed in terms of U_30_8 /pound by multiplying by 1.1793.

- For follow-up readings on the subject (more).

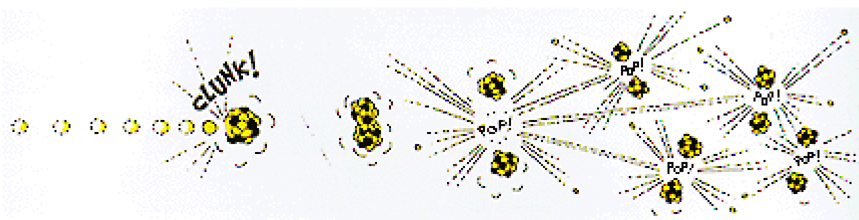
What happens inside a nuclear reactor?

- Neutrons in motion are the starting point for everything that happens in a nuclear reactor. When a neutron passes near a nucleus, for example, uranium^{235}, the neutron may be captured by the nucleus and this may or may not be followed by fission. Capture involves the addition of the neutron to the uranium nucleus to form a new isotope. A simple example is:

$$U^{238} + \text{neutron} \Longrightarrow U^{239} - \beta \text{ (electron)} \Longrightarrow Np^{239}$$

- The new nucleus may decay into a different nuclide. In this example, U^{239} becomes Np-239 after emission of a beta particle (electron). But in certain cases the initial capture is rapidly followed by the fission of the new isotope. Whether fission takes place, and indeed whether capture occurs at all, depends on the velocity of the passing neutron and on the particular isotope involved.

- Fission may take place in any of the isotopes after capture of a neutron. However, low-energy (slow, or thermal) neutrons are able to cause fission only in those isotopes of uranium and plutonium whose nuclei contain odd numbers of neutrons (*e.g.* U^{233}, U^{235}, and Pu^{239}).
- Thermal fission may also occur in some other transuranic elements whose nuclei contain odd numbers of neutrons. For nuclei containing an even number of neutrons, fission can only occur if the incident neutrons have energy above about one million electron volts (MeV). (Newly-created fission neutrons are in this category and move at about 7% of the speed of light, while moderated neutrons move a lot slower, at about eight times the speed of sound.)
- It is this process, in effect "burning" uranium, which occurs in a nuclear reactor. The heat is used to make steam to produce electricity.



- Nuclear power stations and fossil-fueled power stations of similar capacity have many features in common. Both require heat to produce steam to drive turbines and generators. In a nuclear power station, however, the fissioning of uranium atoms replaces the burning of coal or natural gas.
- In a nuclear reactor the uranium fuel is assembled in such a way that a controlled fission chain reaction can be achieved. The heat created by splitting the U-235 atoms is then used to make steam which spins a turbine to drive a generator, producing electricity.
- The chain reaction that takes place in the core of a nuclear reactor is controlled by rods which absorb neutrons and which can be inserted or withdrawn to set the reactor at the required power level.
- The fuel elements are surrounded by a substance called a moderator to slow the speed of the emitted neutrons and thus enable the chain reaction to continue. Water, graphite and heavy water are used as moderators in different types of reactors.

For additional readings: (more[1]) and (more[2])

What are fast reactors?

- Today, there is renewed interest in fast neutron reactors for three reasons.
  - First, is their potential roles in burning long-lived actinides recovered from light-water reactor used fuel,
  - Second, a short-term role in the disposal of ex-military plutonium, and
  - Third, enabling much fuller use of the world's uranium resources (even though these are apparently more abundant than previously assumed).
- In all respects, this technology is important to reinforce the long-term considerations of nuclear power as a principal sustainable source of world energy as well as to reduce the handling and volume of nuclear waste.
- India, Russia, China, and the U.S. are moving toward the new type of "Fast Reactors" and some may go into operation in the next few years, or less, as predicted, for the purpose of providing the grid with reliable power.
- For follow-up readings on the subject, see (more).

What are the principal safety issues inherent in deploying nuclear power plants?

- There are two major kinds of risk associated with nuclear power: A serious accident at a nuclear power plant could release large amounts of dangerous radiation, with disastrous consequences for the environment and an increased risk of cancer for those exposed to the radiation.
- There has been only one serious accident in over 16,000 cumulative reactor-years of commercial nuclear power operation in 33 countries. The evidence over six decades shows that nuclear power is a safe means of generating electricity. The risk of accidents in nuclear power plants is low and declining.
- The Chernobyl disaster was caused by poor reactor design, inept management, and poor technology during the Soviet Union's competition with the U.S. during the "Cold War."
- There are no inherent safety issues in deploying nuclear power plants, the claims of such have been found to be false, misguided, and memed by agenda-driven anti-nuclear groups.

- The safety record of U.S. nuclear power plants has been outstanding, exceeding all forms of energy production such as coal and natural gas. Aside from an early accident with a research reactor in Idaho in the 1950s that killed 2 workers (under suspicious conditions), no person has died in a nuclear power plant accident in the U.S., including the Three-Mile Island incident.

- The incident at Three-Mile Island was revealed to be a minor problem and only caused first-degree burns to two maintenance people. The media hyped the intrinsic fears of people concerning nuclear radiation (which were based on the residual fears of radiation of the nuclear weapons used to end WWII and of the prevailing fears of the “cold war” of the 1950 and 1960s that set back the U.S. nuclear power plant expansion program by more than 30 years.
- The disaster at Chernobyl, Ukraine was caused by the poor Soviet Union design of the nuclear reactors and poor judgment when designing a test for the power plant. They were designed to serve the duel role of producing plutonium for military purposes (nuclear bombs) and of electrical generation for the power grid of the region.
- The disaster killed more than 20 brave, dedicated firemen and workers, mostly by radiation burns and radiation sickness. Over the years following, about 4,000 children contracted thyroid cancer, but about 99% were treated and recovered.
- Fukushima Daiichi nuclear plant incident was caused by tsunamis that struck the plant site located on the coast damaging two nuclear reactors that exposed the core. In the building housing the exposed spent fuel, hydrogen was formed by the boil off of the cooling water. The hydrogen was ignited by a spark source and the building exploded in dramatic fashion and spread some radioactive material in the immediate vicinity.
- No one was killed or irradiated, but the media once again hyped the danger and created fear in the local population far from the plant site. In response, the government shuttered most, if not all, nuclear power plants in Japan out concern for public safety and potential vulnerability of the plants to future earthquakes and tsunamis. This impacted the world view of nuclear power over the following years causing the uranium price to fall by some 60% and a few countries to re-evaluate their own nuclear power programs, such as Germany, and a few others.
- Over the years since the Fukushima incident, most of the countries have completed their safety evaluations and have determined that nuclear power plants can withstand significant earthquakes without the loss of a single human

life resulting from radiation as in many industrial accidents where safety is of primary concern.

- After considerable sociological study in Japan, the biggest impact of the tsunami, aside from the physical damage at the one plant, was determined to be the psyche of the local inhabitants and their imagined fear of radiation, which no doubt remains from memories of the end of WWII.
- Some anti-nuclear public views have been inherited from many years ago, but have been shown to be false, their views perpetuated by numerous commercial environmental companies paid to function as anti-nuclear adversaries, funded by membership and donations from likeminded companies and individuals.
- Recently, anti-nuclear views have even become politically-motivated as support for renewable energy have overtaken sound economics and have encouraged the use of natural gas to the clear detriment of climate concerns, especially in California.
- For follow-up readings on the subject, see (more[1]) and (more[2])

What are small modular reactors (SMRS)?

- Over the past 10 years, interest has developed in expanding the use of small nuclear reactors for use in supplying electricity to the local inhabitants in small towns/cities or within large cities in multiple installations.
- The original SMRs were built in a few laboratories for university research and in numbers for the U.S. Navy for the Nautilus Class of submarines in the early 1950s.
- The basis for interest in SMRs is the lower cost (compared to the typical size of nuclear reactors rated 250 MW to 500 MW) and transportability of such units (the units are small enough to be transported by highway-rated trucks or by railway cars, which means that they can be used in remote areas and as back-up power in case of emergencies.
- Called “nuclear batteries” by some, they typically are designed to produce about 25 MW to serve a population of about 25,000 and because of their simple design requires less governmental regulation. This is because the reactor is located underground on a property the size of a typical utility transformer site and requiring little or no special security provisions because the small core would be

out of reach of any tampering. It is constructed in an assembly that is self-contained and is to be replaced every 5 to 7 years with little radioactive waste produced requiring extra special handling as in the typical grid-size nuclear reactor designs and cooling requirements.

- More than 25 companies in the U.S. alone are working to develop various designs of SMRs to the market with many indicating approved versions will be ready for operation in the early 2020s. But China, Russia, France, UK, and others are showing an interest in SMRs because of their obvious advantages of lower cost (than the current large plants), the rapid installation (streamlined permitting) and low maintenance, and expandable in cities to grow in numbers as the population electricity demand increases.
- For additional reading (more[1]) and (more[2]).

What is wrong with storing nuclear waste at the Yucca Mountain Nuclear Storage Site in Nevada ?

- Billions of dollars have been spent on site feasibility studies over the years and those knowledgeable geoscientists involved say that the site is a safe place to store nuclear waste. This is storage, not disposal. We may be able to use the “waste” in the future.
- The project attracted political attention over the years and became a lightning rod for anti-nuclear opposition, assuming that if the storage site is blocked, that will adversely impact the expansion of nuclear power contradiction activities around the U.S.
- All County Supervisors were in favor of initiating operations when completed.
- A senior senator from Nevada took on the opposition of Yucca Mountain opening by spending a career leading the fight against opening the storage site. He is retiring soon, so such opposition may be decreasing soon, although Liberal opposition remains apparent on the subject in Nevada.
- For follow-up readings on the subject, see (more).

What is nuclear fusion?

- While not strictly related to the fission process involved in uranium, a great deal of research is being undertaken to harness nuclear fusion power, as occurs in the Sun. This involves fusing deuterium (H^2) with tritium (H^3) to H^4 plus a huge amount of energy as a result, as opposed to splitting uranium to release energy (heat).

- A number of reactions are possible, but the one which is within reach technologically is the deuterium-tritium reaction. This has proven possible in a small reactor – the Joint European Torus (JET), where 16 MW was achieved briefly, and 5 MW was sustained in 1997. This work is now being scaled up internationally with ITER, being built in France (ITER Project).

  The reaction is:

  $H^2 + H^3$ ===> He^4 + neutron + Energy (17.6 MeV)

  Tritium can be bred from lithium^6 in a blanket around the torus (high-temperature plasma), using neutrons from the reaction:

  Li^6 + neutron ==⇒ $He^4 + H^3$ (tritium) + Energy (4.8 MeV)

  Deuterium is relatively abundant in seawater.

- There are other reactions that may be possible by fusing H^2 and He^3 producing a proton and helium^4 (He^4). The products weigh less than the initial components, and the missing mass produces a huge energy output:

  $H^2 + He^3$ ===> He^4 + proton + Energy (Huge)

- He^3 is scarce on Earth but is present in the Lunar regolith in significant quantities and likely on other planets and asteroids that have been bathed in He^3 by the solar wind over billions of years (more).

- Capturing this energy at a useful scale is being investigated by many countries on Earth, including the U.S., China, India, Russia, Japan, and others.

- For follow-up readings on the subject, see (more).

What other uses are there for Uranium metal?

- The high density of uranium means that it also finds uses in the keels of yachts, as jackets of bullets and military shells, as counterweights for aircraft control surfaces, as well as for radiation shielding and other uses.
- Apart from its use in energy production and military devices, antitank ammunition is often made from depleted uranium because of its high density

and its ability to transfer impact energy to modern armor.

- Uranium is also used in the construction of aircraft gyroscopes.

- Uranium has chemical properties that make it valuable to several industries. In the 19th century, oxidized uranium was used as an additive in the manufacture of colored glass. Uranium has been detected in glass that dates to the early Roman Empire, where it was used to impart a golden yellow hue to high-quality glass. The use of uranium in glassware largely came to an end after it was discovered that uranium glass emits alpha radiation.

- For follow-up readings on the subject, see (more).

For focused search results from the I2MWeb Portal on various aspects of uranium and its use, see (more).

For more details on Uranium from the Uranium (Nuclear and REE) Committee of the Energy Minerals Division, AAPG., see: (more).

Other FAQs:

FAQ from U.S. Geological Survey: on Approach to Assess Baseline Chemical and Radiological Conditions Prior to Uranium Mining near Grand Canyon National Park (more).

FAQ from the Texas Groundwater Protection Committee: In Situ Uranium Mining (more).

FAQ from the Environmental Science Division of Argonne National Laboratory for the U.S. Department of Energy (DOE), Office of Environmental Management (more[1]) and (more[2]).

FAQ from the Federal Institute for Risk Assessment Department Risk Communication, Berlin (more).

FAQ from the U.S. Department of Health and Human Services, Department of Health and Human Services (more).

FAQ from Stanford University Professor on Nuclear Energy (more).

FAQ from Natural Resources of Canada on Nuclear Waste Management (more).

FAQ from Nuclear Energy Institute on Nuclear Energy (more).

FAQ from the Beifer Center for Science and International Affairs, John F. Kennedy School of Government on: Nuclear Terrorism (more).

FAQ from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) on Ionizing Radiation in Consumer Products (more).

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