

Uranium Resources

Abstract

Uranium is a common element throughout the Earth's crust, soils, and oceans. Uranium resources are naturally occurring deposits that may have a sufficient concentration of uranium to support mining operations. Canada has about 8% of the world's unmined uranium resources, but accounts for some 25% of the global primary uranium production. Canada's uranium mines are located in the Athabasca Basin of northern Saskatchewan, which has ore grades as high as 21% uranium metal, an order of magnitude larger than any other deposits in the world. The nuclear industry provides about 15% of Canada's electrical power (50% of Ontario's). The map shows districts with potential for uranium development, small occurrences of uranium, locations of uranium mines and facilities, and locations of nuclear facilities that generate electrical power.

Uranium in Canada's History

Uranium was first recovered in Canada between 1931 and 1940 as a by-product of radium that was mined for medical use. It became a sought-after commodity in the 1940s when highly enriched uranium and specialized technology were used to develop weaponry to assist in the war effort. This led to the development of international security measures and nonproliferation agreements that safeguard against military threats. The potential of using uranium as an energy source for electric power generation was recognized at the same time, which led to Canadian research into uranium-fuelled reactors. Since the opening of Canada's first nuclear power plant at Rolphton, Ontario in 1962, and the subsequent construction of such power plants in Canada and worldwide, the main use of uranium has been to generate electricity.

Uranium Mining in Canada

Uranium was initially mined from vein deposits of the Port Radium, Northwest Territories and Beaverlodge, Saskatchewan districts, and granite pegmatite-related deposits around Bancroft, Ontario. These mines were closed by the mid-1980s. The next major mines developed in the ancient placer deposits at Elliot Lake, Ontario. Mining at Elliot Lake continued until 1996 when it ceased to be profitable, largely because new large, very high-grade uranium deposits had been discovered within and beneath the Proterozoic sedimentary Athabasca Basin. Uranium mining remains strong in the Athabasca district (of northern Saskatchewan) and new discoveries are made annually.

Most known uranium districts were recently re-explored because world uranium prices and the forecast for long-term demand became much higher than in the past. Districts associated with flat-lying Proterozoic sedimentary basins retain the highest potential for future development, followed by deposits in the Central Mineral Belt of Labrador within highly deformed, ancient volcanic rocks. As this map shows, other small occurrences of uranium are numerous and widespread because uranium is a common element at the Earth's surface. The general term 'occurrence' used on the map embraces all local uranium concentrations that are above background levels. Only rare occurrences may be developed after years of exploration into deposits of sufficient size, concentration, and composition to be mined in a safe, environmentally benign, and economical manner.

Uranium can be extracted from the rocks by underground, or open-pit mining, or by solution (in situ leach) methods. Currently in northern Saskatchewan, the ore from the underground McArthur River mine is crushed underground, and transported as slurry in shielded containers to a processing mill at Key Lake mine. Ore from the underground Eagle Point mine is crushed at surface before shipping to the nearby mill at Rabbit Lake mine. At McClean Lake mine ore is mined by open pit and transported to the nearby JEB mill. At the mills, the crushed ore is ground and further processed using various chemical techniques to isolate the uranium.

Uranium Processing

Yellowcake is the uranium oxide concentrate obtained from the processing of uranium ore at the mills. It requires further processing before it can be used as fuel for nuclear reactors. The yellowcake is transported in ring-sealed steel drums from the mills to a refinery in Blind River, Ontario where the concentrates are further cleaned of their impurities and then chemically converted to uranium trioxide (UO₃). The UO₃ is transported by truck to Port Hope, Ontario where it is converted into either uranium dioxide ('natural uranium') for use in Canada, or into uranium hexafluoride for export to the United States, United Kingdom, and France, which produce 'enriched uranium' (enhanced in the ²³⁵U isotope) for use in their power generation facilities.

To make fuel bundles for the Canadian-invented CANDU nuclear reactors, the uranium dioxide is packaged in steel drums and shipped to one of two fuel fabricators, Cameco Fuel Manufacturing Inc. located in Port Hope, Ontario, or General Electric Hitachi Nuclear Energy Canada Inc. (GE-Hitachi), which has operations in Toronto and Peterborough, Ontario.

Uranium as an Energy Source

The fuel requirements for the worldwide nuclear reactor fleet are the major driver of worldwide uranium demand. Currently there are 439 nuclear power reactors worldwide with an additional 41 reactors under construction. Nuclear energy supplies

about 2.6 billion megawatts of electricity, which is about 16% of the world's base-load supply of electricity (Nuclear Energy Agency, Nuclear Energy Outlook, 2008, p. 49). Five nuclear power stations comprising a total of 22 CANDU reactors supply about 15% of Canada's electricity: 50% of Ontario's, 30% of New Brunswick's, and 3% of Quebec's electricity. Spent nuclear fuel is stored in water-filled pools or dry storage concrete canisters at the reactor sites. Reactors are periodically shut down for scheduled maintenance or refurbishment.

Table 1. CANDU Reactors in Canada

Reactor	Province	Number of Reactors (status of May 2009)	Gross Capacity (megawatts)
Point Lepreau	New Brunswick	1 (bring refurbished)	680 MW
Pickering A	Ontario	2 (2 shutdown)	542 MW
Bruce A	Ontario	2 (2 shutdown)	542 MW
Pickering B	Ontario	4 (operating)	540 MW
Bruce B	Ontario	4 (operating)	872 MW
Darlington	Ontario	4 (operating)	935 MW
Gentilly-2	Quebec	1 (operating)	675 MW

Source : Canadian Nuclear Safety Commission

Uranium for CANDU reactors is formed into pellets and arranged into rods that are fabricated into fuel bundles. Inside a CANDU reactor core, the fuel bundles are placed into pressure tubes that contain heavy water as a moderator. Atoms of uranium-235 (a small proportion of the natural uranium fuel) are easily split in two by a moving neutron to simultaneously release two or three additional new neutrons that split other atoms in a 'fission chain reaction'. This controlled chain reaction occurs millions of times over in a process that heats the enclosing heavy-water moderator, which is pressurized to prevent it from boiling. Control rods made of material that absorbs neutrons moderate the rate of fission and thus the rate of heat production. A separate set of shut-down rods is used to end the fission chain reaction.

In addition to heat energy, the fission chain reaction also produces radioactive by-products. Accordingly, the reactor core is surrounded by a containment structure and other safety measures that prevent leakage and unsafe exposure levels. The heated heavy water passes through a heat exchanger that heats a separate normal water cycle that produces steam. The steam drives large turbines that are connected to electromagnetic coils that produce the electric current fed into the electric power grid. After driving the turbines, the steam condenses and the waste heat is transferred to a separate water cooling cycle. Because heat energy is generated without the combustion of fuel such as coal or gas-fired plants, nuclear power plants produce low carbon emissions.

Atomic Energy of Canada Limited (AECL) is a Crown corporation that develops, sells, markets, and builds CANDU power reactors. Their nuclear research laboratories are located at Chalk River and at Sheridan Park, Ontario.

Uranium's Role in Nuclear Medicine

Uranium can be used to produce radioactive substances called medical isotopes that can be safely administered to patients for the diagnosis and treatment of illnesses. Medical isotopes are produced (along with other radioisotopes) when uranium is bombarded with neutrons inside the core of a nuclear research reactor. In the branch of medicine called nuclear medicine, medical isotopes are administered to patients in the form of radiopharmaceuticals. When ingested by patients, they emit energy that can be captured on film for diagnostic imaging. They can also be applied to tumours or used to arrest cancerous growth. According to Health Canada, approximately 300 therapeutic doses of medical isotopes and 30 000 diagnostic tests are administered to Canadians each week. Canada's National Research Universal (NRU) reactor located in Chalk River supplies up to 50% of the world's medical isotopes that help over 76 000 people every day and 27 million people every year, in more than 80 countries.

Uranium and Nonproliferation

Canada is committed to the peaceful uses of nuclear energy. As a party to the Nuclear Non-Proliferation Treaty (NPT), Canada and many other countries have implemented security safeguards and procedures that control uranium enrichment and prevent specialized technologies from being diverted to military uses. Canada has no uranium-enrichment facilities.

Canadian Nuclear Safety Commission

The Canadian Nuclear Safety Commission (CNSC) is charged with regulating the development and production of nuclear energy and nuclear substances in Canada. The CNSC regulates the use of nuclear energy and materials to prevent unreasonable risks to the health, safety, and security of Canadians and to the environment, and to respect Canada's international commitments on the peaceful use of nuclear energy. The commission reports to Parliament through the Minister of Natural Resources.

Through licensing and compliance programs, CNSC staff monitor nuclear operations to ensure compliance with safety and security regulations. The CNSC conducts environmental assessments under the Canadian Environmental Assessment Act (CEAA), and develops safety and security standards in conjunction with the International Atomic Energy Agency (IAEA) and other member countries.

Definitions of underlined terms

Background level: The abundance of an element, or any chemical property of a naturally occurring material in an area of a certain rock type that is within the range expected for the average un-mineralized rock of that type, i.e. not anomalously low or high. The background level of uranium has a wide range from one rock type to another, being much higher for a rhyolite (felsic volcanic rock) than for a sandstone.

Granitic pegmatite-related deposits: Granitic pegmatite-related deposits occur within and around the walls of sheets, pods, and veins of exceptionally coarsely crystalline granite, referred to by geologists as pegmatite. Geologists use the term granite (a noun) and the descriptor granitic (adjective) for crystalline rock composed mainly of light coloured, white, pink, and buff, relatively hard silicate minerals: quartz (SiO₂), feldspar (a family of minerals composed of Silicon (Si), Aluminum (Al), and Oxygen (O) with varying proportions of Sodium (Na), Calcium (Ca), and Potassium (K) and minor dark coloured minerals.

High grade uranium deposits: High grade is a relative term depending on the deposit type and how the uranium is extracted. For example, in traditional mining methods that involve drilling and blasting, 20% is super high grade by any standard, 2% is high grade, 0.2% may be moderate grade, and 0.02% may be low grade, although some deposits are economic with grades of 250 ppm (0.0025%). For in-situ solvent extraction or heap leach operations, 0.2 to 1 % may be high grade. Uranium may also be a by-product of a multi-element deposit whose aggregate metal value is high whereas the uranium by itself is a low-grade component.

Placer deposits: A placer deposit is a surficial or unconsolidated mineral deposit formed by mechanical concentration of heavy mineral particles from weathered debris transported by water in a stream or beach environment. Such heavy minerals include gold, cassiterite (tin oxide), rutile (titanium oxide) and uraninite (UO₂). Geologists apply the term paleoplacer to very ancient placer deposits that have been buried and solidified within the earth's crust. Under modern atmosphere-hydrosphere conditions uraninite is dissolved (except where it is very cold), however, under the reducing atmospheric conditions that existed before 2.3 billion years ago it was stable enough to form placer deposits.

Proterozoic: A period of time that began approximately 2500 million years ago and ended approximately 542 million years ago.

Sedimentary basins: Sedimentary basin refers to a volume of sedimentary rock that filled an area which subsided and created space for sand, or evaporites, or carbonate material to be deposited. The initial sediments were unconsolidated but with increasing burial and time they were subjected to increasing pressure and fluid flow that compacted and cemented them into rock. In geology, subsidence is the

motion of the Earth's surface as it shifts downward relative to the surrounding area and/or to a reference elevation such as sea-level.

Vein deposits: A mineral deposit consisting of mineral filling of faults and/or fractures in a host rock, in tabular or sheet-like form. The deposit is precipitated from warm to hot fluids that circulated through the fault/fracture spaces, often with associated replacement of the host rock in proximity to the veins. The veins may pinch and swell, and have well-defined walls.

Map Sources

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International Government

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<http://aua.org.au/>