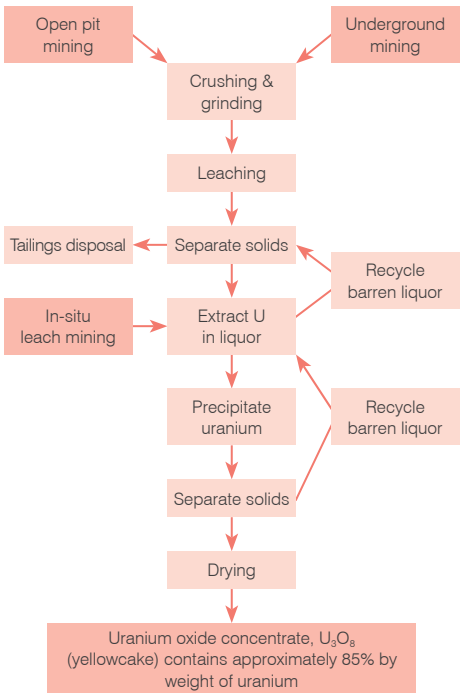
Milling

Simplified flow chart of uranium ore processing from mining to the production of concentrate. These processes are commonly known as milling and the product – uranium oxide concentrate – is the raw material for making nuclear fuel.



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Uranium production and resources

Country	2014 production (tU)	Uranium resources (tU)* <US$130/kg
Australia	5001	1,174,000
Brazil	231	155,100
Canada	9134	357,500
China	1500	120,000
Czech Republic	193	1300
India	385	Not available
Kazakhstan	23,127	285,600
Malawi	369	8200
Namibia	3255	248,200
Niger	4057	325,000
Pakistan	45	Not available
Romania	77	3100
Russia	2990	216,500
South Africa	573	175,300
Ukraine	962	84,800
USA	1919	207,400
Uzbekistan	2400	59,400
Other	36	277,500
Total	**56,252**	**3,698,900**

*OECD/NEA Reasonably Assured Resources category

Sources: World Nuclear Association & OECD/NEA

Uranium history

- In 1789 Martin Klaproth, a German chemist, isolated an oxide of uranium while analyzing pitchblende samples from silver mines in Bohemia.
- For over 100 years uranium was mainly used as a colorant for ceramic glazes and for tinting in early photography. Uranium was produced in Bohemia, Cornwall (UK), Portugal and Colorado and total production amounted to about 300-400 tonnes.
- The discovery of radium in 1898 by Marie Curie led to the construction of a number of radium extraction plants processing uranium ore (radium is a decay product of uranium).
- Prized for its use in cancer therapy, radium reached a price of 750,000 gold francs per gram in 1906 (US$10 million). It is estimated that 754 grams were produced worldwide between 1898 and 1928. Uranium itself was treated simply as a waste material.
- With the discovery of nuclear fission in 1939, the uranium industry entered a new era. On 2 December 1942, the first controlled nuclear chain reaction was achieved in Chicago. Although nuclear fission was first used for military purposes, the emergence of civil nuclear power reactors in the 1950s demonstrated the enormous potential of nuclear fission for supplying electricity.
- From a small beginning in 1951, when four lightbulbs were lit with nuclear electricity, the nuclear power industry now supplies about 11% of world electricity.
- Between the mid-1940s and the late-1980s, uranium supply exceeded reactor requirements. However, the gap between requirements and production since 1990 has been filled by secondary supplies, mostly from stockpiles including military inventory. Going forward, the gap will increasingly be filled by higher primary production, as secondary supplies diminish.

WORLD NUCLEAR ASSOCIATION

2015/16
Pocket Guide

Uranium, From Mine to Mill

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Top uranium mines in 2013-2014

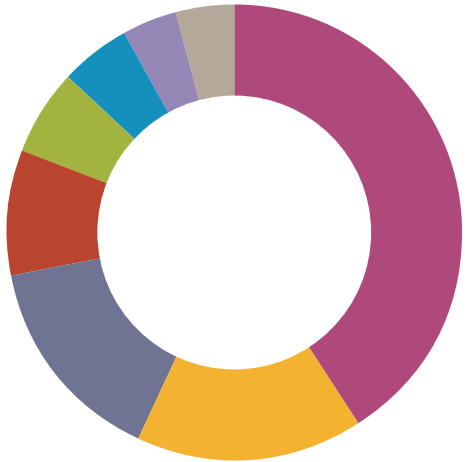
Mine	Country	Main owner	Mine type	Production (tU)		% of world production	
				2013	2014	2013	2014
McArthur River	Canada	Cameco	Conventional	7744	7356	13	13
Katco (Tortkuduk/Muyunku)	Kazakhstan	Areva	ISL	2563	4322	4	8
Olympic Dam	Australia	BHP Billiton	By-product (copper)	3399	3351	6	6
Arlit (Somair)	Niger	Areva	Conventional	2730	2331	5	4
Karatau (Budenovskoye 2)	Kazakhstan	Uranium One/Kazatomprom	ISL	2115	2084	4	4
South Inkai	Kazakhstan	Uranium One/Kazatomprom	ISL	2030	2002	4	4
Priargunsky	Russia	ARMZ	Conventional	2133	1970	4	4
Langer Heinrich	Namibia	Paladin	Conventional	2098	1947	4	3
Inkai	Kazakhstan	Cameco	ISL	2047	1922	3	3
Total from top mines				26,859	27,285	47	49

Leading uranium mining companies*

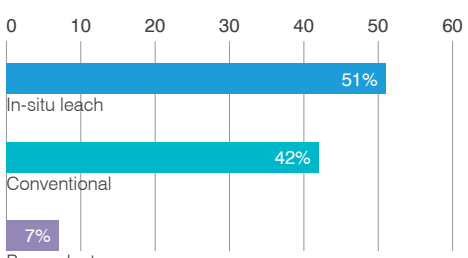
Company	2014 production	
	Actual (tU)	World share (%)
Kazatomprom	12,563	22
Cameco	8999	16
ARMZ-Uranium One	7845	14
Areva	6496	12
BHP Billiton	3351	6
CNNC/CGN	2610	5
Navoi	2400	4
Paladin	1829	3
Rio Tinto	1573	3
Sub-total	**49,044**	**85**
World total	**56,253**	**100**

**based on ownership share*

World uranium production, 2014



Mining method, 2014



Mineralogy and ore grade

- Uraninite is the most common primary uranium mineral; others of economic interest include coffinite and brannerite. The most common form of uraninite is pitchblende, which is sometimes associated with colourful secondary uranium minerals derived from weathering.
- The average abundance of uranium in the Earth's crust is 2.7 parts per million, making it more common than tin.
- The concentration of uranium needed to form an economic mineral deposit varies widely depending on its geological setting and physical location. Average ore grades at operating uranium mines range from 0.03% U to as high as 24% U, but are most frequently less than 1% U. Lower uranium grades are viable as by-product.

Mining methods

- **Open pit:** used to mine relatively shallow deposits. Economics depend on the ratio of ore to waste, higher grade ores having lower ratios.
- **Underground:** used to mine deposits too deep for open pit mining. For mining to be viable, these deposits must be comparatively high grade.
- **In-situ leach:** this method is applicable only to sandstone-hosted uranium deposits located below the water table in a confined aquifer. The uranium is dissolved in acid or alkali injected into and recovered from the aquifer by means of wells. The geology remains undisturbed.
- **By-product:** uranium often occurs in association with other minerals such as gold (South Africa), phosphate (USA and elsewhere) and copper (Australia).

Processing and extraction

- **Crushing and grinding:** breaks down the ore to fine particles.
- **Leaching:** acid or alkali dissolves the uranium, and the uranium-bearing solution is separated from the leached solids.
- **Extraction:** ion exchange or solvent extraction methods are used to separate the dissolved uranium.
- **Precipitation and drying:** uranium is precipitated from solution using one of several chemicals. Dewatering, filtration and drying complete the process. The final product is sometimes known as yellowcake, although it is typically khaki in colour.