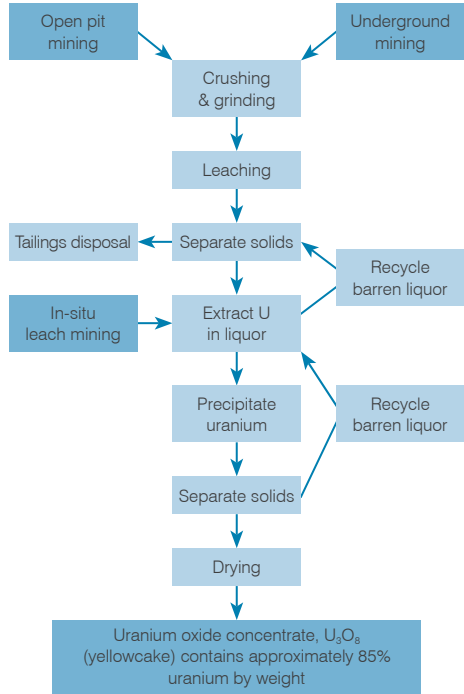


## Milling

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	2016 production (tU)	Uranium resources (tU)* <US\$130/kg
Australia	6315	1,174,000
Brazil	44	155,100
Canada	14,039	357,500
China	1616	120,000
Czech Republic	138	1300
India	385	Not available
Kazakhstan	24,575	285,600
Malawi	0	8200
Namibia	3507	248,200
Niger	3479	325,000
Pakistan	45	Not available
Romania	50	3100
Russia	3004	216,500
South Africa	490	175,300
Ukraine	1005	84,800
USA	1125	207,400
Uzbekistan	2404	59,400
Other	0	277,500
<b>Total</b>	<b>62,221</b>	<b>3,698,900</b>

\*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 11.5% 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.

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## Top uranium mines in 2015-2016

Mine	Country	Main owner	Mine type	Production (tU)		% of world production	
				2015	2016	2015	2016
McArthur River	Canada	Cameco	Conventional	7354	6945	12	11
Cigar Lake	Canada	Cameco	Conventional	4345	6666	7	11
Tortkuduk / Muyunkum	Kazakhstan	Areva	ISL	4109	4017	7	6
Olympic Dam	Australia	BHP Billiton	By-product (copper)	3179	3233	5	5
Inkai	Kazakhstan	Cameco	ISL	2234	2291	4	4
Somair	Niger	Areva	Conventional	2509	2164	4	4
Budenovskoye 2	Kazakhstan	Uranium One/Kazatomprom	ISL	2061	2081	3	3
South Inkai	Kazakhstan	Uranium One/Kazatomprom	ISL	2055	2056	3	3
Central Mynkuduk	Kazakhstan	Kazatomprom	ISL	1847	2010	3	3
Ranger	Australia	Rio Tinto/ERA	Conventional	1700	1994	3	3
<b>Total from top mines</b>				<b>31,760</b>	<b>33,457</b>	<b>51</b>	<b>54</b>

## 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), phosphates (USA and elsewhere) and copper (Australia).

## Uranium output by producer\*

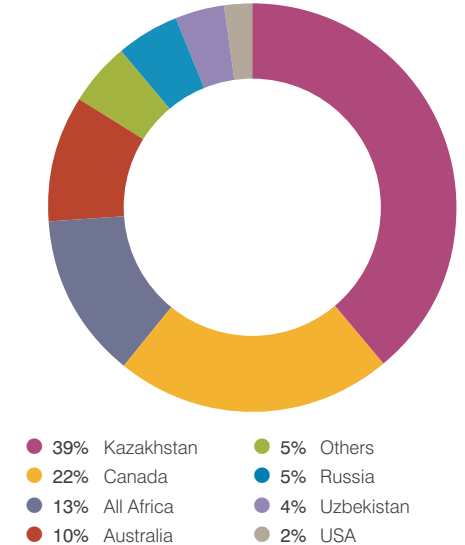
Company	2016 production	
	Actual (tU)	World share (%)
Kazatomprom	12,986	21
Cameco	10,438	17
Areva	8433	14
ARMZ-Uranium One	7913	13
BHP Billiton	3233	5
CNNC/CGN	2672	4
Rio Tinto Uranium	2440	4
Navoi Mining	2404	4
Energy Asia	2308	4
Sopamin	1200	2
Paladin Energy	1310	2
General Atomics/Quasar	1088	2
Sumitomo	1004	2
<b>Sub-total</b>	<b>57,428</b>	<b>92</b>
<b>World total</b>	<b>62,221</b>	<b>100</b>

\*based on ownership share

## 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.

## World uranium production, 2016



## Mining method, 2016

