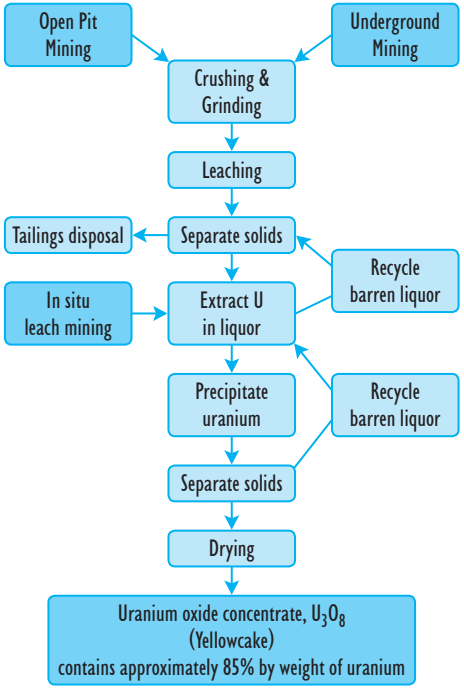
Milling

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 or area	2010 production (tU)	Capacity (tU) at 31.12.10	Uranium resources (tU)* <US$80/kg
Australia	5900	9550	1,163,000
Brazil	148	400	157,700
Canada	9783	11,810	336,800
China †	827	1000	100,900
Czech Republic	254	440	400
India †	400	500	0
Kazakhstan	17,803	20,000	233,900
Namibia	4496	5000	2000
Niger	4198	4500	42,500
Pakistan †	45	50	0
Romania †	77	100	0
Russia	3562	3750	100,400
South Africa	583	2000	142,000
Ukraine †	850	1000	38,780
USA	1660	2000	39,880
Uzbekistan	2400	2500	55,200
Other	677	n/a	102,640
Total	**53,663**	**64,600**	**2,516,100**

Sources: WNA, OECD/NEA

* OECD/NEA Reasonably Assured Resources Category
† WNA estimate

NB Many other countries also have known uranium resources

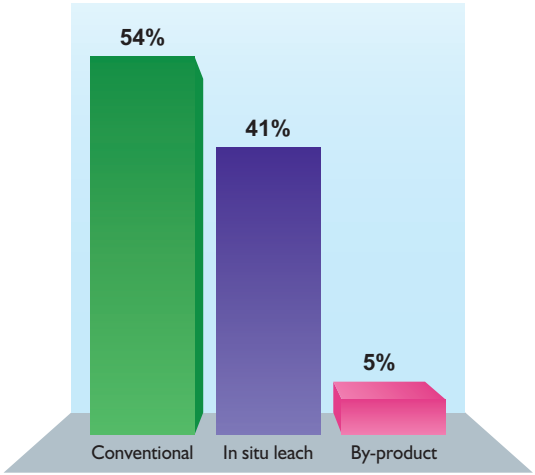
Uranium history

- In 1789 Martin Klaproth, a German chemist, isolated an oxide of uranium while analysing pitchblende samples from the Joachimsthal 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, 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 simply dumped 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. The first nuclear explosion in 1945 demonstrated the enormous power potential of nuclear fission.
- From a small beginning in 1951, when four lightbulbs were lit with nuclear electricity, the nuclear power industry now supplies some 14% of world electricity.

McArthur River – world's top producing uranium mine in 2010

World Nuclear Association

URANIUM, FROM MINE TO MILL



World uranium production by mining method, 2010

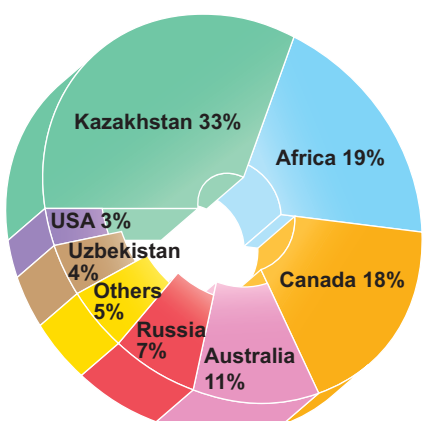
Top ten uranium mines in 2009 - 2010

Mine	Country	Main owner	Mine type	Production (tU)		% of world production		Rank	
				2009	2010	2009	2010	2009	2010
McArthur River	Canada	Cameco	Conventional	7339	7654	15	14	1	1
Ranger	Australia	ERA (Rio Tinto 68%)	Conventional	4444	3216	9	6	2	2
Rössing	Namibia	Rio Tinto (69%)	Conventional	3520	3077	7	6	3	3
Priargunsky	Russia	ARMZ	Conventional	3004	2920	6	5	4	4
Arlit	Niger	Areva	Conventional	1808	2650	4	5	7	5
Tortkuduk	Kazakhstan	Katco JV	ISL	2272	2439	4	5	6	6
Olympic Dam	Australia	BHP Billiton	By-product (copper)	2955	2330	6	4	5	7
Budenovskoye 2	Kazakhstan	Karatau JV	ISL	1415	1708	3	3	10	8
South Inkai	Kazakhstan	Betpak Dala JV	ISL	831	1701	2	3	18	9
Inkai	Kazakhstan	Cameco	ISL	715	1642	1	3	19	10
World total from top ten mines				**28,303**	**29,337**	**56**	**55**		

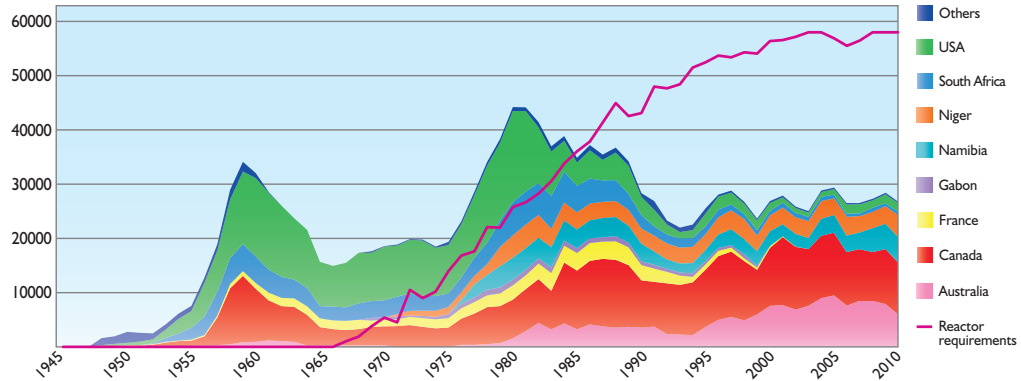
Leading uranium mining companies

Company	2010 production	
	Actual (tU)	World share (%)
Cameco	8758	16
Areva	8319	16
KazAtomProm	8116	15
Rio Tinto	6293	12
ARMZ	4311	8
Uranium One	2855	5
Navoi	2400	4
BHP Billiton	2330	4
Paladin	2089	4
Sopamin	1450	3
Sub total	46,921	87
World total	**53,663**	**100**

World uranium production, 2010



Western world historic uranium production



The gap between reactor requirements and production since 1985 has been filled by secondary supplies (e.g. from weapons material and inventories). In future, the gap will increasingly be filled by higher primary production, as secondary supplies diminish.

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**.
- 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. These figures do not apply to by-product operations.

Mining methods

- **Open pit:** used to mine relatively shallow deposits. Economics depend on the ratio of ore to waste.
- **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 a mildly alkaline or acidic solution that is 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, phosphate and copper.

Processing and extraction

- **Crushing and grinding:** breaks down the ore to sand/silt sized particles, thereby freeing the uranium minerals.
- **Leaching:** acid or alkali dissolves the freed uranium, allowing the uranium-bearing solution to be separated from the leached solids.
- **Extraction:** ion exchange or solvent extraction methods are used to separate the dissolved uranium from the aqueous solution.
- **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.