

Forty years of uranium resources, production and demand in perspective

R. Price, F. Barthel, J.-R. Blaise, J. McMurray *

The NEA has been collecting and analysing data on uranium for forty years. The data and experience provide a number of answers to the questions being asked today, as many countries begin to look at nuclear energy with renewed interest. In terms of uranium resources, the lessons of the past give confidence that uranium supply will remain adequate to meet demand.

When the first “Red Book”¹ on *Uranium Resources, Production and Demand* was published in 1965, there were 40 reactors in operation worldwide with generating capacity totalling about 4.5 GWe. By 2005, 440 reactors were in operation with generating capacity totalling some 369 GWe. During this period, 20 Red Books were published, tracking the growth of nuclear power and providing comprehensive, official government data on uranium resources, exploration and production.

The history of the Red Book has paralleled the growth of nuclear energy, each influenced by world events such as the 1973 oil crisis that increased public awareness of the potential of nuclear energy,

the Three Mile Island and Chernobyl reactor accidents that slowed the growth of nuclear power, and the end of the Cold War in 1989 that led to the availability of new information and new sources of uranium as military inventories were made available to the commercial sector.

The Red Book Retrospective

*The Red Book Retrospective*² was undertaken to collect, analyse and publish all of the information collated over the 40 years of the Red Book’s existence. In addition to capturing information included in the Red Books published between 1965 and 2003, efforts were successfully made to fill gaps with new information to ensure that *The Red Book Retrospective* provides the most complete record possible of the commercial uranium industry publicly available since the birth of civilian nuclear energy up to the dawn of the 21st century. Detailed information about the history of the world’s uranium industry can be found along with a complete set of data tables.

The Red Book Retrospective provides information on reactor-related uranium requirements, installed nuclear capacity, natural and enriched uranium inventories, unconventional uranium resources, thorium resources, mine start-up and closure histories, and environmental aspects of uranium mining and processing. Analysis and histories of exploration, resources and production for the major uranium countries are also provided along with analyses of the data to reveal new information including discovery costs, accuracy of capacity and requirements projections, inventory to requirements ratios, production capacity to requirements ratios, and the evolution of the time to production

* Mr. Robert Rush Price (robert-rush.price@oecd.org) works in the NEA Nuclear Development Division. Mr. Fritz Barthel (fritz.barthel@t-online.de), former Chair of the Uranium Group, Mr. Jean-René Blaise (jrf.blaise@wanadoo.fr) and Dr. Jay McMurray (j.mcmurray@iaea.org), formerly of the IAEA Nuclear Fuel Cycle and Waste Technology Division, contributed to *The Red Book Retrospective* as NEA consultants.

after discovery for the different mining methods and many others.

In looking back at the information published in the Red Book, now supplemented with new data previously unavailable, fresh insights into the uranium sector have emerged.

Exploration

A total of 81 countries have reported exploration expenditures related to uranium with cumulative worldwide exploration expenditures between 1945 and 2003 of about USD 13 400 million. The world leaders in total uranium exploration expenditures during this time are listed in the following table.

Countries with highest exploration expenditures (1945-2003)¹

Country	USD million	% of world total
USSR ¹	3 692	27.6
USA	2 507	18.7
Germany ²	2 003	14.9
Canada	1 289	9.6
France	907	6.8
Others (total)	3 002	22.4
World total	13 400	100.0

1. Does not include expenditures by Kazakhstan, the Russian Federation, Ukraine and Uzbekistan since 1991.

2. Includes the German Democratic Republic.

Worldwide exploration expenditures have closely paralleled uranium market prices. The peak in exploration expenditures lagged behind the 1978 market price peak by only one year. The price of uranium reached its all-time peak in the late-1970s, driven by a combination of military requirements and concurrent growth in civilian nuclear power. After this peak, prices dropped

rapidly and then began a steady decline over the next 20 years, driven in large part by slower than expected growth in nuclear power, a result of the Three Mile Island accident and excess supply that resulted in the build-up of large inventories. The price of uranium hit a historic low in late 2000, but then began a rebound that has continued into 2006, reflecting a market adjustment to potential near to mid-term supply shortfalls (see Figure 1).

Resources

The 1965 Red Book reported resources in 16 countries totalling 3.21 million tonnes of uranium (tU); in 2003, 56 countries reported total resources in all confidence and cost categories of 14.38 million tU. The leading countries in uranium resources are listed in the following table.

Countries with the largest known resources recoverable at <USD 130/kgU (2003)¹

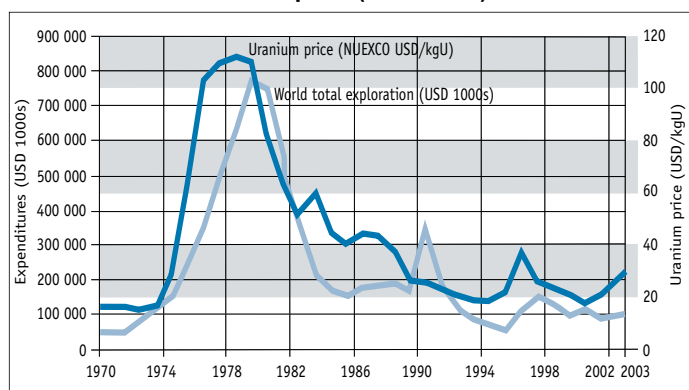
Country	tU	% of world
Australia	1 058 000	23.1
Kazakhstan	847 620	18.5
Canada	438 544	9.6
South Africa	395 670	8.6
United States ²	345 000	7.5
Others (total)	1 503 166	32.7
World total	4 588 000	100.0

1. Includes reasonably assured resources (RAR) and estimated additional resources I (EAR-I) at <USD 130/kgU.

2. The United States does not report resources in the EAR-I category.

Market price indirectly affects resources because it affects exploration expenditures in market-based economies. However, because of the time lag between exploration and reporting of directly related resources, that relationship is seldom readily apparent.

Figure 1. World exploration expenditures and uranium market price (1970-2003)



Production

Uranium production in 1945 is estimated to have totalled 507 tU that year. In 1965, when the first Red Book was published, production totalled 31 630 tU. Production peaked in 1980 at 69 683 tU from 22 countries. In 2003, uranium production was reported by 19 countries with output totalling 35 600 tU. Cumulative worldwide uranium production between 1945 and 2003 totalled 2.2 million tU, with production having been reported or estimated from 35 different countries since 1945. The leading countries in

cumulative uranium production from 1945-2003 are listed in the table below.

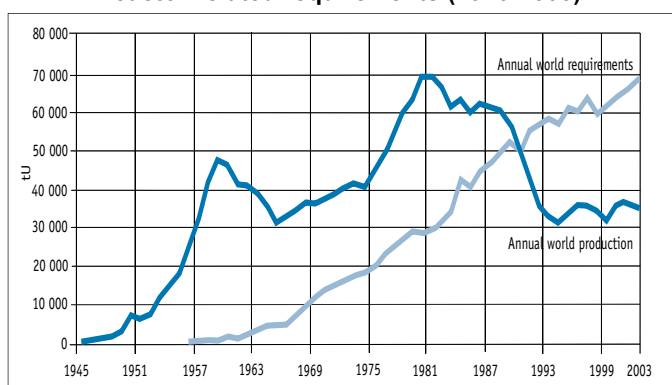
Leading uranium producer countries based on cumulative production (1945-2003)

Country	tU	% of world total
USSR ¹	377 613	17.1
Canada	374 548	17.0
United States	366 846	16.6
Germany ²	219 239	9.9
South Africa	157 618	7.1
Others (total)	708 848	32.3
World total	2 204 712	100.0

1. Only includes production until 1991.
2. Includes production of the German Democratic Republic (1946-1989) and the Federal Republic of Germany (1961-2003).

Primary supply exceeded reactor-related uranium requirements until 1991, when that relationship was reversed (see Figure 2). Since 1991, the gap between primary supply and uranium requirements has been filled by secondary supply, such as uranium excess to military requirements, reprocessed uranium and mixed-oxide fuel. Requirements in 2003 were met in almost equal proportions by primary and secondary supply.

Figure 2. Annual uranium production and reactor-related requirements (1945-2003)

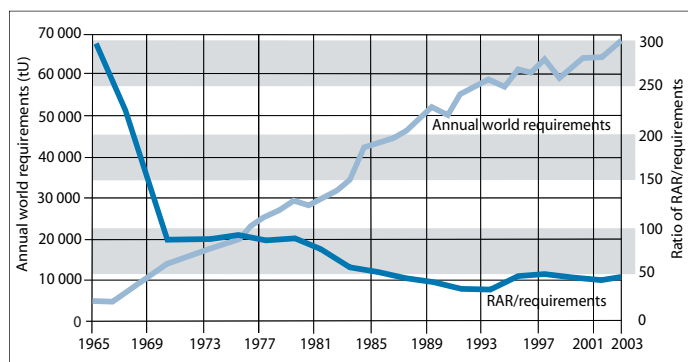


Two key messages

While there are many lessons to be drawn from the facts presented in the text and tables, two key messages deserve highlighting as the world considers whether to expand the use of nuclear energy in a manner not seen since the 1970s. First,

past exploration for uranium has resulted in the discovery of uranium deposits and ultimately led to reported resources. A period of low exploration expenditures ended in late 2000, having lasted for over 20 years. Since 2001, exploration expenditures have steadily increased as they follow the market price upward from historic lows. It can be expected that this new period of exploration will result in the discovery of new sources of uranium and an increased resource base. Second, despite these low levels of exploration and the cumulative production of over 2.2 million tU since 1945, reported uranium resources have steadily increased since the mid-1980s. The analysis of annual reactor-related requirements to reported resources shows a forward-looking reserves ratio that has steadily averaged about 45 over the past twenty years, despite steadily increasing requirements (see Figure 3).

Figure 3. Ratio of annual reactor-related requirements and reasonably assured resources (<USD 130/kgU)



Taken together, the lessons of the past provide confidence that uranium resources will remain adequate to meet demand. ■

Notes

1. Called as such due to its red cover.
2. *Forty Years of Uranium Resources, Production and Demand in Perspective: "The Red Book Retrospective"* will be available for purchase online at www.oecdbookshop.org. Purchasing details are available from neapub@nea.fr.