Uranium Resources and Supply

by James Cameron and Maurice V. Hansen*

Over the next decades the supply of uranium will be a vital factor in the fulfilment of the world's nuclear power programmes. Forecasts of nuclear power installation, which have only been marginally modified in the last two years, indicate spectacular increases over the next decades. The consequent demand for uranium will also increase proportionally during this period and the uranium producing industry is faced with considerable problems in discovering and developing sufficient resources to meet long term demand and in finding adequate production capacity in the short term.

The IAEA together with the Nuclear Energy Agency of OECD has been concerned with the problems of uranium supply and demand for a number of years and has produced, at roughly two-year intervals, a series of reports on these subjects so as to provide the Governments of Member States and the uranium and nuclear power industry with the best available information on these subjects.

The latest report in this series, compiled by the joint NEA/IAEA Working Party and entitled "Uranium Resources, Production and Demand" was published by NEA(OECD) in December 1975.

The report's main findings are summarised in the following paragraphs:

The question of adequacy of world uranium resources compared to world uranium demand has received increased attention in the past two years. The fossil fuel price increase has resulted in research into new forms of energy and has confirmed that apart from coal, uranium is likely to be the only energy source available in sufficient quantity to meet the increasing energy demand in the foreseeable future.

While it appears that the known uranium resources are adequate to support the planned and projected nuclear reactor programmes for the next ten to fifteen years, severe supply problems may arise in the longer term. It is therefore necessary to monitor continuously the development in nuclear power growth forecasts and to set them into relation to the known uranium resources and the production they can support. This report, like its forerunners, attempts to present a most recent overall picture in this respect. Its emphasis, as in previous reports, lies on the uranium resources side, being in its larger part compiled by a working party of uranium resources experts.

However it also covers, in lesser detail, the rest of the nuclear fuel cycle and future uranium demand.

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View of the Oklo uranium mine in Gabon. Photo: CEA ▶

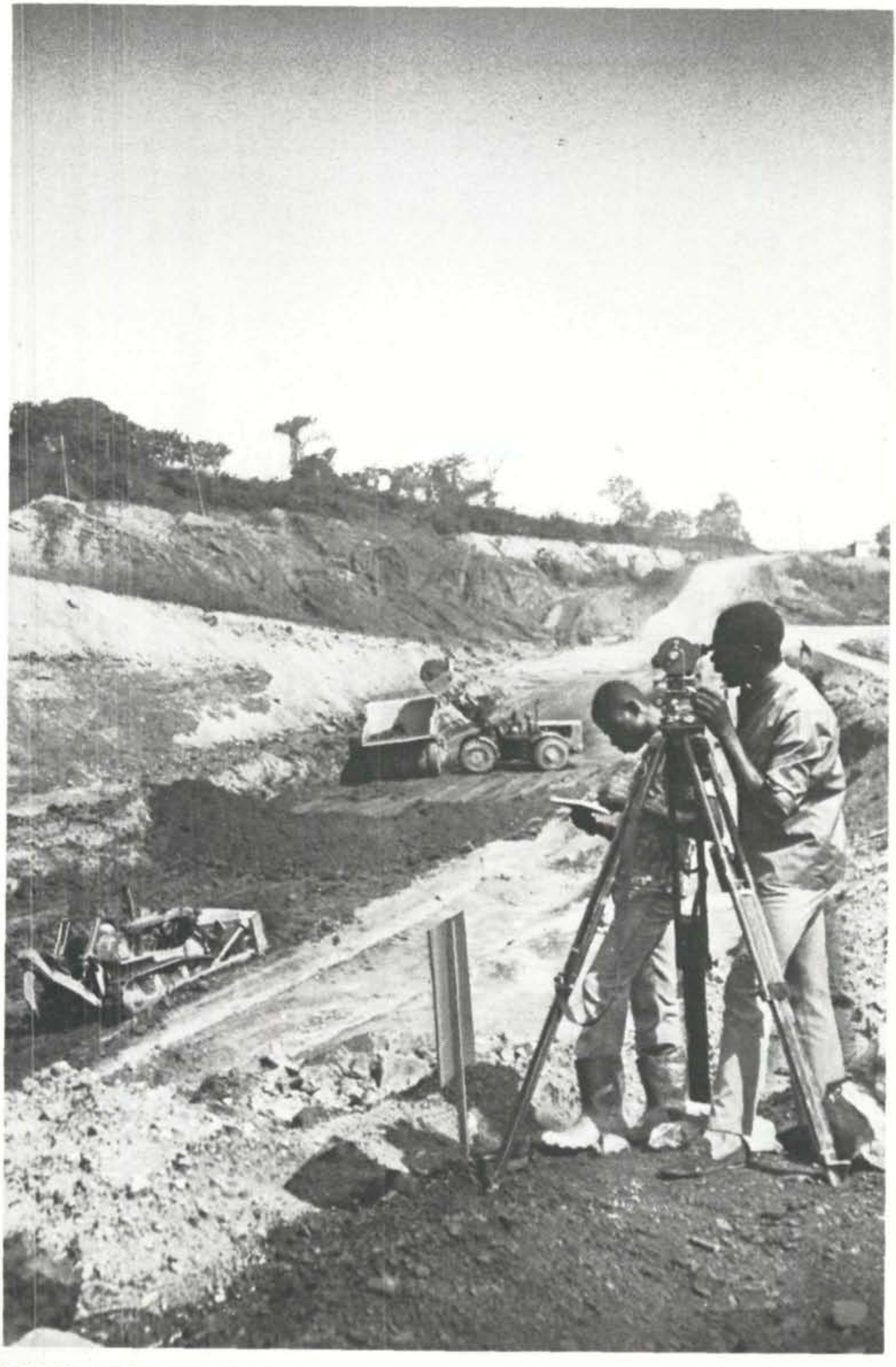

TABLE 1
ESTIMATED WORLD RESOURCES OF URANIUM
Data available 1st January 1975

Cost Range	Reasonably Assured Resources (1000 tonnes U)		Estimated Additional Resources (1000 tonnes U)	
	< 15$/lb U_3O_8 Reserves	15–30$/lb U_3O_8	< 15$/lb U_3O_8	15–30$/lb U_3O_8
Algeria	28	–	–	–
Argentina	9.3	11.3	15	24
Australia	243	–[a]	80	–[a]
Brazil	9.7	(0.7)	8.8	–
Canada[b]	144	22[c]	324	95[c]
Central African Republic	(8)	(–)	8	–
Denmark (Greenland)	–	6	–	10
Finland	–	1.9	–	–
France	37	18	25	15
Gabon	(20)	(–)	(5)	(5)
Germany, Fed.Rep.of	0.5	0.5	1	3
India	3.4	25.8	0.8	22.5
Italy	–	1.2	–	1
Japan	1.1	6.6	–	–
Korea	–	2.4	–	–
Mexico	5	1	–	–
Niger	40	10	20	10
Portugal	6.9	–	–	–
South Africa	186	90	6	68
Spain[e]	10	93.5	8.8	98
Sweden	–	300	–	–
Turkey	2.6	0.5	0.4	–
United Kingdom	–	1,8	–	4
USA[d]	320	134	500	312
Yugoslavia	4.2	2.3	–	15.2
Zaire	(1.8)	(–)	(1.7)	(–)
Total (rounded)	1080	730	1000	680

( ) Figures taken from Uranium Report 1973 because no new data available.

a) Estimates of resources in this range have not been made and are therefore unknown. Exploration to date has concentrated on proving high grade resources.

b) Categories are by reference to price.

c) Estimates in this price range are preliminary, restricted only to principal deposits, and thus very conservative.

d) Does not include 54,000 tonnes U as by-product from phosphates or 15,000 tonnes U as by-product from copper production which might be recovered in the period to the year 2000.

e) Includes some 80,800 tonnes U reasonably assured resources and 63,800 tonnes U estimated additional resources in lignites in the cost range $15–30/lb U_3O_8 for which the availability is uncertain.

THE CURRENT SITUATION IN URANIUM RESOURCES

The worldwide uranium resources position as of 1st January 1975 is displayed in **Table 1.** The most important change compared to previous reports concerns the production costs categories. The choice of the new cost ranges reflects three factors: the effect of inflation, the general rise of energy prices in absolute terms and the increased competitiveness of nuclear power combined with its lower sensitivity to higher fuel costs. The new cost ranges have been chosen with the aim of maintaining a basis for comparison for a longer period of time.

The Working Party decided to abandon the notion "price categories" in favour of "cost categories" in order to maintain a degree of stability in the resource categories employed and to become independent of possible significant price changes in the future.

The new low-cost category up to 15$/lb corresponds essentially to the old price category below 10$/lb, i.e. to **uranium reserves** in the mining sense. It is therefore still possible to make some prudent comparisons of the new figures with the corresponding data given in the previous report. The new reserves amount to about 1,080,000 tonnes uranium compared to 865,000 tonnes uranium in 1973. A net increase of 215,000 tonnes uranium. The most significant changes in reserves were in Australia, the United States and Algeria.

AVAILABILITY OF URANIUM RESERVES

In evaluating the uranium reserves position, it is important to consider whether all this material could be made available at a rate corresponding to the increasing demand. There are several reasons why this is not necessarily the case. The physical nature of an ore body can be one limiting factor. Thus the very large Elliot Lake deposits with limited opportunity for easy access can only be worked at certain production rates which mean that they will not be depleted until well into the next century. In other cases, uranium is a by-product (e.g. of gold production in South Africa) and hence its production rates depend on the output of the main product.

Moreover, all mines are characterised by an economic production rate corresponding to the size and nature of the deposit. In addition to these physical limitations, consideration of national energy autonomy and export policies in general can influence the availability of uranium outside of its country of origin. New Canadian uranium export guidelines have the objective of maintaining adequate reserves and production capacity for domestic consumption. A further example is the Australian Government's present reassessment of its policy of development of Australia's uranium resources, which will determine future production rates.

All these considerations as well as market conditions, are relevant in estimating uranium availability in relation to cumulative world demand.

RECENT PRICE TRENDS IN THE URANIUM MARKET

During the early period of uranium exploration, discovery rates were stimulated by attractive prices. Indeed, during the 1950s, when the nucleus of world uranium reserves was developed, prices were in the order or \$10 to \$11/lb U_3O_8. Demand for uranium for commercial purposes did not develop until the mid-1960s at which time prices were re-established in the range \$6 to \$8/lb U_3O_8. Although the commercial demand for uranium became more and more evident toward the end of the 1960s, consumers were generally slow to recognize the need to contract for their long-term requirements. Moreover, by the early 1970s many producers, in addition to having excess production capacity, had built up sizeable inventories of unsold uranium and as a result of this over-supply situation, prices were below $5/lb U_3O_8 by 1972, thus providing little incentive to the mining industry to develop the huge exploration programmes that would be required to meet the demand of the 1980's. It was not until the oil crisis of the winter of 1973–74, that many consumers moved to acquire their longer term uranium supplies. Prices adjusted quickly to levels of $12–$13/lb U_3O_8 and then gradually rose to about $20/lb by mid-1975 as surplus inventories and excess capacities became fully committed. This trend has continued and prices are currently above that level. It is to be hoped that the present increase will provide the necessary stimulation for the major exploration effort that will be necessary, but there is also considerable danger of instability if prices rise too high too fast.

URANIUM PRODUCTION AND INVENTORIES

World uranium production has remained stable for the past two years, being 20,000 tonnes uranium in 1973 and 19,000 tonnes in 1974. Estimated production figures for 1975 indicate an increase of some 3,000 tonnes mainly due to higher production in Canada and the United States.

World uranium production capacity is expected to be some 30,000 tonnes in 1975 increasing to about 44,000 tonnes in 1978. Possible further developments could raise world annual production capability to over 60,000 tonnes in 1980 and the production capability attainable by 1985 on the basis of presently known reserves is estimated at almost 100,000 tonnes uranium. This level could probably be maintained for a few years, after which it would decline due to depletion of some deposits and the need to mine lower grade material. In order to maintain or increase this capacity beyond the 1980s, substantial additional reserves would have to be identified.

EXPLORATION ACTIVITIES

A renewed effort in uranium prospecting has been initiated by market forces, i.e. the substantial increase in uranium prices during the past two years. However, market forces alone will probably not be sufficient to stimulate adequate exploration efforts on a world-wide scale. A glance at Table 1 shows that of the present low cost resources, more than 80% are in four countries (USA, South Africa, Canada and Australia), which have undertaken great exploration efforts in the past. It may be concluded that a comparable effort in other geologically favourable areas would give similar results. However, as exploration expenditure is heavy and considerable experience and technical skill is needed for location and development of new deposits, close collaboration is required between the industrialized nations and developing countries where most of these unexplored areas are situated. Increased international co-operation in the field of uranium exploration could have a very stimulating effect on uranium discoveries in the longer term.

THE LONG TERM URANIUM RESOURCES SITUATION

The information made available has enabled presently known uranium reserves and resources to be quantified under two categories, "Reasonably Assured Resources" and

"Estimated Additional Resources" and to subdivide these in two cost ranges, i.e. less than 15\$/lb U_3O_8 and between 15 and 30\$/lb U_3O_8.

In general, however, only the "Reasonably Assured Resources" can be considered for specific planning and forecasting in the short and medium term and even the availability of much of these resources is constrained. If it were assumed that the present "Estimated Additional Resources" could be confirmed and developed, the total of the two categories would still be inadequate to meet the long term uranium requirement which has been estimated at up to four million tonnes by the year 2000 and might reach 10 million tonnes uranium by the year 2025.

There is therefore an obligation to comment on the world uranium potential and the problems involved in the future discovery of adequate uranium to meet requirements.

The three principal constraint factors are:

(1) Physical: i.e. the existence of deposits.
(2) Economic: i.e. the availability of adequate exploration, development and capital investment funds (this includes funds for research and development of new methods and techniques).
(3) Political: i.e. the availability of search areas and production and export facilities.

The future potential may be considered under two categories; i.e. under 30\$/lb U_3O_8 and lower grade uranium with a cost above 30\$/lb U_3O_8.

With regard to potential uranium resources in the under 30\$/lb U_3O_8 cost category the principal factors which should be taken into account by Governments of both advanced and developing countries when defining their future policies in respect to uranium are:

(1) Present uranium **reserves** are approximately one million tonnes uranium only.

(2) There will be a requirement of up to four million tonnes by the year 2000 and of the order of 10 million by the year 2025.

(3) The commercial importance of uranium may be limited to the next 40–60 years and the requirement thereafter may decrease sharply.

(4) The lead time between initial exploration in a new area (particularly in a developing country) and initial production may be as much as 15 years.

(5) The scale of the finance required for major exploration and developing programmes is likely to be available only from commercial or national organisations of the advanced countries or through international development funds.

(6) The price structure and rewards over the next decades are likely to be attractive.

Turning to **lower grade uranium ores** with a cost above 30\$/lb U_3O_8 it is considered that for the rest of this century, conventional type uranium resources at cost levels of the order of 30\$/lb or less may be identified in quantities sufficient to provide for forecast requirements. However, there is certainly no guarantee for this. Moreover, due to the rise in oil prices, uranium of a much higher price level could be competitive for nuclear power generation and thus it would seem prudent to examine higher cost uranium resources more closely. Up to the present, relatively little has been done to quantify higher cost uranium resources.

Past exploration has generally been directed to deposits with average grades greater than 0.1% U_3O_8 and at the other extreme, a good deal is known about the characteristics and problems involved in recovery from very high cost material such as shales, granites, phosphates etc. There is, however, a considerable gap in knowledge about uranium between these two extremes and much future exploratory effort will need to be directed towards sources of uranium in the range 0.1–0.01% U_3O_8.

To be able to select the economically most favourable material in grades greater than 100 ppm and to produce from it, it will be necessary to fund a major research and development programme on exploration, mining and milling techniques and with improvements in technology and higher prices, some contribution from higher cost material of this type might be expected in the medium and long term future.

It is unlikely that very low grade material, that is, under 100 ppm U_3O_8, can provide any substantial part of the presently envisaged requirement. This is principally due to the environmental problems that the development of such material would cause and also because the time scale required for the development of techniques to exploit such deposits is so great that the uranium requirement may be diminishing before substantial tonnages can be produced.

Quoting at Random

NUCLEAR ENERGY WITH LOW ACCIDENT POTENTIALITY

The number of annual fatalities and injuries expected among the 15 million people living within 25 miles of present and planned US reactor sites are compared to other type accidents in a Reactor Safety Study: An Assessment of Accident Risks in US Commercial Nuclear Power Plants, by the US Nuclear Regulatory Commission in October 1975:

Comparative Accident Potentialities

Accident Type	Fatalities	Injuries
Automobile	4 200	375 000
Falls	1 500	75 000
Fire	560	22 000
Electrocution	90	0
Lightning	8	0
Reactors (100 plants)	2	20