Uranium Supply and Demand

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 periodically published reports on uranium resources, production and demand at roughly two-year intervals in order to provide to Governments of Member States and the mining and nuclear power industries the best available information on these subjects.

The latest report in this series, compiled by the joint NEA/IAEA Working Party is entitled "Uranium Resources, Production and Demand" and was published by NEA(OECD) in December 1977.

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

INTRODUCTION

The adequacy of world uranium resources compared to uranium demand has continued to receive considerable attention in the past two years. This attention has been accorded to uranium not only because it is one of the few energy sources likely to contribute to the needs of the foreseeable future, but also because it has the long-term potential, if properly utilized, to provide a virtually inexhaustible supply of energy.

Recently, international attention has been concentrated on the question of the alternative means for achieving this long-term potential in a manner which takes account of non-proliferation consideration. The adequacy of uranium resources to meet the fuel demands of the various alternatives is an important factor.

While estimated uranium resources are believed to be adequate to support the anticipated growth of nuclear power to the turn of the century, there is the possibility that difficult supply situations could occur within this period, due to possible limitations on the availability of uranium. In the longer-term, the emergence of advanced reactor systems could bring with it the more efficient utilization of uranium but until such systems can become essentially self-sustaining, substantial quantities of new uranium resources must be identified and exploited. It is therefore necessary to monitor continuously the growth patterns of nuclear power, and the uranium resources and production required to sustain this growth. The present report, like its forerunners, attempts to present the most recent overall picture, and prognosis for the future, in this respect. The emphasis again has been placed on uranium resources, as it has been compiled, in major part, by a working party of uranium resources experts. However, it also covers, in lesser detail, the future growth of nuclear power and consequent demand for uranium. Long-term supply and demand forecasts for other fuel cycle services are covered in a separate publication[1].

[1] "Nuclear Fuel Cycle Requirements and Supply Considerations, through the long-term", OECD, 1977

EXPLORATION ACTIVITIES

Reserves: More than 80% of the low-cost Reasonably Assured Resources ($<$ US \$80/kg U or $<$ US \$30/lb U_3O_8) (reserves) are in four countries (USA, South Africa, Australia and Canada) and this is probably because of the size and extent of the exploration efforts which have taken place in these countries in the past. Many of the unexplored areas of the world are in developing countries and provision of the necessary exploration expenditure, experience and technical skill will likely require collaboration between these countries and the industrialized nations.

Activity: World-wide exploration for uranium is currently at a record high level and in several countries more work was done in 1976 than ever before. The pace of work continues to increase, and it is likely that higher levels have been attained during 1977.

The surge in activity began about 1973 as consumers moved actively to acquire long-term uranium supplies. Prices reached new highs and many existing sales contracts were renegotiated upward. These changes in market conditions stimulated the search for new deposits.

The rate of increase of exploration activity of 1975 over 1974 and 1976 over 1975, was particularly high in Spain and in overseas exploration ventures by Japan. In only a few countries exploration declined. The most notable example, among nations with substantial resources, was Australia, where governmental decisions on uranium mining were awaited; a situation which tended to discourage further exploration efforts

Expenditures by each country for uranium exploration indicate a considerable increase in the tempo of exploration activity within the past two years, over 1975 levels. The largest exploration expenditures are in North America and other major programmes are underway in Australia, Brazil, France, Iran, Italy, South Africa and Spain. Major exploration programmes beyond domestic borders are financed from France, the Federal Republic of Germany, Japan and the USA.

CURRENT SITUATION IN URANIUM RESOURCES

Current Estimates: The world-wide uranium resource position on 1 January 1977 is summarized in Table 1 for Reasonably Assured Resources and in Table 2 for Estimated Additional Resources. The two resource cost categories have new cost brackets, i.e. $<$ \$80/kg U and \$80–\$130/kg U ($<$ \$30/lb U_3O_8 and \$30–\$50/lb U_3O_8). These replace the $<$ \$15/lb U_3O_8 and \$15–\$30/lb U_3O_8 of the last report in December 1975. Thus this report retains the "cost" concept adopted in the previous report but provides greater breadth to these categories in order to reflect the increased costs of developing resources. Nevertheless, the categories of this report, carefully used, do maintain a basis of comparison with those of previous reports.

With respect to Estimated Additional Resources, significant effort in terms of manpower and exploration funds must be expended to upgrade these resources to the Reasonably Assured Resources category; indeed, some of the Estimated Additional Resources have yet to be discovered.

The low-cost Reasonably Assured Resources, defined as reserves for the purposes of this report ($<$ \$80/kg U or $<$ \$30/lb U_3O_8 in this report and $<$ \$15/lb U_3O_8 in the December

1975 report) have increased from 1.1 to 1 6 million tonnes uranium after production of 40 000 tonnes uranium. The following factors influenced the change in resource data for countries over the two-year period 1975 to 1976:

(a) Inclusion in reserves of resources from the former \$15 to \$30/lb U_3O_8 category.

(b) Exploration work leading to new discoveries and/or the transfer of resources from the Estimated Additional Resources category to the Reasonably Assured Resources category.

(c) Removal from reserves by production

(d) Exclusion of material because of cost increases.

It is interesting to note that the change of cost categories affects some countries more than others. For example, in the United States the factors affected its reserves estimate in the same order as the list above. For South Africa (a) was predominant, for Canada (a) and (b) influenced the results and for Australia (b) was the most significant factor in the changes.

Despite the change in the low-cost category it is the opinion of the working party that the addition of new uranium reserves attributable to the results of exploration over the last two-year period, is little more than the additions to reserves during the 1973 to 1974 period.

The total of all Reasonably Assured Resources is now 2.2 million tonnes which is only a modest increase over the previous of 1.8 million tonnes. The total of Estimated Additional Resources now stands at 2.1 million tonnes against a total of 1.68 million tonnes previously. Considering the increase in the cost bracket, this again reflects only a modest increase. The major additions in this area are provided by the United States and by Canada as a result of increased expectations for the discovery of additional resources in known uranium districts. The only major decrease in the table is provided by the deletion of the uranium from the lignite occurrences of Spain, which are not now available within these cost ranges.

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. The very large Elliot Lake deposits in Canada are one such example where there are limitations to expansion of production rates which means that the currently estimated reserves cannot 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 characterized by an economic production rate corresponding to the size and nature of the reserve.

In addition to these physical limitations, considerations of national energy autonomy and export policies in general can influence the availability of uranium outside the country of origin. In this context the new Canadian uranium export guidelines should be mentioned which have the objective of maintaining adequate reserves and production capacity for domestic consumption. Some countries and provincial authorities have required searching environmental and social impact enquiries to be made before a mine is developed or allowed to come into production. Finally, the United States, Canada and Australia will each seek to impose conditions on the export of uranium satisfactory to their respective safeguards concerns.

Table 1: **REASONABLY ASSURED RESOURCES** (1000 tonnes U)
Data available 1 January 1977

Cost range	< US $80/kg U (< US $30/lb U_3O_8) Reserves	US $80–130/kg U (US $30–50/lb U_3O_8)
Algeria	28	0
Argentina	17.8	24
Australia	289	7
Austria	1.8	0
Bolivia	0	0
Brazil	18.2	0
Canada[1]	167	15
Central African Empire[2]	8	0
Chile	0	0
Denmark (Greenland)	0	5.8
Finland	1.3	1.9
France	37	14.8
Gabón[2]	20	0
Germany, F.R.	1.5	0.5
India	29.8	0
Italy	1.2	0
Japan	7.7	0
Korea	0	3
Madagascar	0	0
Mexico[3]	4.7	0
Niger	160	0
Philippines	0.3	0
Portugal	6.8	1.5
Somalia[4]	0	6.2
South Africa	306	42
Spain	6.8	0
Sweden	1	300
Turkey	4.1	0
United Kingdom	0	0
United States	523	120
Yugoslavia	4.5	2.0
Zaire	1.8	0
Total (rounded)	1650	540

1 The material reported as "Reserves" is minable at prices up to $104/kg U and the other "Reasonably Assured Resources" are minable at prices between $104 and $156/kg U.
2 Source of data Uranium Resources, Production and Demand, Paris 1975.
3 Data refer to resources "in-situ", rather than recoverable.
4 Costs of recovery are not known so the resources are arbitrarily assigned to the higher-cost category.

Table 2: ESTIMATED ADDITIONAL RESOURCES (1000 tonnes U)
Data available 1 January 1977

Cost range	< US \$80/kg U (< US \$30/lb U_3O_8)	US \$80–130/kg U (US \$30–50/lb U_3O_8)
Algeria	50	0
Argentina	0	0
Australia	44	5
Austria	0	0
Bolivia	0	0.5
Brazil	8.2	0
Canada[1]	392	264
Central African Empire[2]	8	0
Chile	5.1	0
Denmark	0	8.7
Finland	0	0
France	24.1	20.0
Gabon[2]	5	5
Germany, F.R.	3	0.5
India	23.7	0
Italy	1	0
Japan	0	0
Korea	0	0
Madagascar	0	2.0
Mexico[3]	2.4	0
Niger	53	0
Philippines	0	0
Portugal	0.9	0
Somalia[4]	0	3.4
South Africa	34	38
Spain	8 5	0
Sweden	3	0
Turkey	0	0
United Kingdom	0	7.4
United States	838	215
Yugoslavia	5.0	15.5
Zaire	1.7	0
Total (rounded)	1510	590

[1,2,3,4]. As in footnotes to Table 1.

NB: A number of occurrences of uranium are not well enough defined to be included in these tables.

All these considerations are relevant in estimating uranium availability in relation to world demand. For the purpose of estimating the supply and demand situation in this report, political limitations are left aside and a comparison is made between annual uranium requirements and the projected attainable uranium production capacities, which are determined largely on the basis of known low-cost resources. In practise, however, political limitations will be very important in determining what is actually available.

RECENT COST AND PRICE TRENDS

Most countries have experienced significant increases in the cost of producing uranium. Within the period 1973 to 1976 total labour costs for uranium mines have increased by more than 50% in North America. Fuel and electricity costs have almost tripled in the same period and costs of major chemicals and reagents have more than doubled. In addition to these direct operating costs, exploration and drilling costs have increased sharply. The United States mining industry spent about $2 in exploration for every pound of uranium produced from 1966 to 1974, but is now spending about $6. Uranium mill construction costs increased by a factor of 3 from 1973 to 1977 and finally tax and royalty regimes have been revised upward in many areas.

World prices for uranium for near-term delivery have responded to marketing factors and cost increases by rising from about $39/kg U ($15/lb U_3O_8) in 1974 to $54/kg U ($20/lb U_3O_8) by mid-1975, and finally stabilized near $104/kg U ($40/lb U_3O_8) by 1977.

It should be noted that many of the existing contracts were negotiated in the late 1960s and early 1970s, when uranium prices were lower. Thus, the average price for all 1976 deliveries in the United States, for example, was $41.86/kg U ($16.10/lb U_3O_8).

It is difficult to make price projections for uranium, and there is a variety of opinion on the matter. One opinion is that the supply of uranium for many years will come from identified resources, and that present price levels adjusted for inflation will therefore be sufficient to provide the required incentive to permit industry to meet future requirements through new discoveries. Therefore, these sources suggest that future price increases will follow normal inflationary trends. On the other hand, another school of thought holds that the costs of exploration, mining and milling will mount more rapidly than the anticipated rate of inflation, as lower-grade resources must be identified and exploited. Thus, they cite the probability of even higher uranium prices. Clearly, there can be a number of price projections, depending on the underlying assumptions.

URANIUM PRODUCTION AND PROJECTED CAPACITIES

Production Statistics: World uranium production remained fairly constant in the range of 19 000–20 000 tonnes annually between 1972 and 1975. However, as shown on Table 3, after a small increase in 1976, it is expected that almost 30 000 tonnes will be produced in 1977. The latter is due largely to substantial increases in production in Canada, the United States and South Africa.

Projected Capacities: Estimates of the projected attainable capacities for uranium production throughout the world are shown on Table 4. It can be observed that there is a projected uranium production capability of 92 000 tonnes per year by 1985. However,

Table 3. Uranium Production (tonnes U)

Country	Pre-1972	1972	1973	1974	1975	1976	1977 Estimated
Argentina	188	25	24	30	23	50	130
Australia	7,080	0	0	0	0	360	400
Canada	92,540	4,000	3,710	3,420	3,510	4,850	6,100
France	16,600	1,545	1,616	1,673	1,742	2,063	2,200
Gabon	4,400	210	402	436	800	n.a.	n.a.
Germany, FR	150	0	0	26	57	38	n.a.
Japan	8	8	10	7	3	2	2
Mexico	42	0	0	0	0	0	0
Niger	410	867	948	1,117	1,306	1,460	1,609
Portugal	1,483	73	73	92	115	88	85
South Africa	61,433	3,197	2,735	2,711	2,488	3,412	6,700
Spain	166	55	55	60	136	170	191
United States	346,000	9,900	10,200	8,900	8,900	9,800	11,200
Zaire*	25,600	0	0	0	0	0	0
Total	372,100	19,880	19,773	18,472	19,080	22,293	28,617

n a.: not available
* Estimated by the Steering Group of the Joint NEA/IAEA Working Party on Uranium Resources.
Sweden total cumulative production to 1976 was 200 tonnes U.

Table 4: ATTAINABLE PRODUCTION CAPABILITIES (tonnes U)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1990
Argentina	130	280	360	360	310	310	390	600	600	600
Australia	400	500	500	500	1,800	4,600	8,300	10,600	11,800	20,000
Brazil	n.a.	n.a.	385	385	385	385	385	385	385	385
Canada	6,100	6,450	6,950	7,950	9,750	10,200	11,150	12,500	12,500	11,250
Central African Empire	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000
France	2,200	2,850	2,850	2,850	3,350	3,600	3,600	3,600	3,700	4,000
Gabon	800*	(1,200)	1,200*	(1,200)	1,200*	1,200*	1,200*	1,200*	(1,200)	1,200*
Germany, F.R.	100	100	100	100	150	150	200	200	200	200
India	200*	200*	200*	200*	200*	200*	200*	200*	200*	200*
Italy	0	0	0	120	120	120	120	120	120	120
Japan	30	30	30	30	30	30	30	30	30	30
Mexico	0	20	90	170	550	550*	550*	550*	550*	550*
Niger	1,609	2,400	3,850	4,100	4,300	9,000	9,000	9,000	9,000	9,000
Philippines	0	0	38	38	76	76	76	38	0	0
Portugal	85	86	90	95	100	270	270	270	270	270
South Africa	6,700	8,800	9,700	11,700	11,700	12,900	12,800	12,600	12,500	12,000
Spain	191	191	339	678	678	678	678	678	1,272	1,272
Turkey	0	0	0	100	100	100	100	100	100	100
United States	14,700	19,300	20,300	22,600	26,300	31,200	32,300	34,300	36,000	47,000
Yugoslavia	0	0	0	0	120	120	120	180	180	440
Total (rounded)	33,000	42,000	47,000	53,000	61,000	77,000	82,000	88,000	92,000	110,000

n a not available
( ) numbers taken from the 1975 Uranium Report
* Estimated by the Steering Group of the Joint NEA/IAEA Working Party on Uranium Resources

the conditions necessary to the attainment of such a level of production must be emphasized. Clearly, the growth of nuclear power must become more predictable in order to provide the incentive and sufficient lead time for the establishment of the necessary mining and milling facilities. Evidence of the nuclear industry's stability would also provide the stimulus for the exploration effort required to increase resources to levels required to sustain such production rates, as well as provide the confidence needed to obtain the necessary financing. Aside from factors of a planning, economic and geological nature, possible political constraints on production must be considered. Each of these possibly limiting factors will be considered shortly in the section on constraints on expansion of uranium production.

ESTIMATION OF URANIUM REQUIREMENTS

Because of a variety of pressures, nuclear power growth forecasts have again been revised downward despite the continuing competitive advantages of nuclear power. For example, the previous world nuclear power forecast of 479–530 GWe for 1985 is now 277–368 GWe, while for the year 2000, the revision is from 2005–2480 GWe down to 1000–1890 GWe. Furthermore, the lower limits of these new forecasts are considered to represent the more likely future growth conditions for nuclear power, as they are based on present trends in energy utilization.

Although these downward revisions tend to increase the adequacy of existing uranium reserves, the longer-term increases in the energy needs of mankind, and the general recognition of the major role to be played by nuclear power, make it no less urgent that substantial additional uranium reserves be identified.

Uranium Demand Forecasts: The 1977 world requirement for natural uranium of about 23 000 tonnes could increase to the following levels.

YEAR	ANNUAL DEMAND (tonnes uranium)
1985	71 000– 88 000
1990	102 000–156 000
1995	134 000–234 000
2000	178 000–338 000

These levels of demand, and particularly the more likely lower limits, are considerably less than those stated in the previous edition of this report. A major reason for the reduction in demand estimates, has been the corresponding reduction in the estimated growth rate of nuclear power. However, one factor that has tended to sustain demand estimates is the general recognition that there will probably be little recycling of spent fuel to light-water reactors before the 1990s. Nevertheless, the new demand estimates for uranium will pose a formidable challenge to the uranium industry, as well as to its consumers. The industry must continue not only to provide sufficient additions to reserves to sustain required production rates, but also to overcome physical obstacles to expansion of production itself. In doing so, it will have to cope with political and economic problems that could constrain the availability of search areas, and the freedom to develop, produce, and export from identified deposits.

The rapidly mounting requirements for uranium suggests another challenge of equal significance in improving reactor technology. Clearly, thermal converters must in time be replaced by more advanced reactor systems that will conserve the uranium resources if nuclear power is to play a major role in supplying world energy needs in the longer-term.

THE LONG-TERM URANIUM RESOURCES SITUATION

Uranium Resource Studies: The long-range planning of the nuclear industry requires a knowledge of its potential source of fuel. Recognizing this need, Canada and the United States have begun assessments of the uranium potential within their borders. The programmes of both countries will provide high-quality reconnaissance data to the uranium mining industry and are designed to ultimately result in a quantitative estimate of the potential uranium resources of each country. The Canadian Uranium Reconnaissance Programme and the United States National Uranium Resource Evaluation programme involve substantial expenditures and will continue for several years. In the United States, the programme also includes a very substantial research programme in many diversified subjects related to uranium exploration, mining and processing.

From the national reports included in this volume, it can be seen that several countries have mounted large-scale exploration programmes directed not so much toward assessment of potential uranium resources scale exploration programmes directed not so much toward assessment of potential uranium resources within their borders, as toward actual discovery and delineation of uranium ore. In addition, the Commission of the European Communities is now supporting (to between 30 and 70% of cost) a number of exploration programmes within the Community. This programme is additional to what is being done nationally in the Member States of the Community.

In recognition of the need for a world-wide assessment of potential uranium resources the NEA (OECD) and IAEA have begun a joint programme involving international co-operation to evaluate the uranium potential of the world, a task which is extremely difficult because of the lack of provenor standardized methodology. It becomes even more difficult or impossible for some areas of the world because of the lack of an adequate data base.

URANIUM RESOURCE STUDIES

Higher-Cost Uranium: There is considerable uncertainty about the extent of $130/kg uranium resources and their adequacy to meet projected long-term demands. However, due to the rise in fossil fuel prices, uranium at higher-cost levels could be of economic interest for nuclear power generation. Therefore, some consideration must be given to the extent and availability of higher cost, generally lower-grade resources.

Exploration to date has essentially been directed toward deposits with average grades greater than 0.1% uranium, and consequently there is a considerable lack of knowledge about deposits having average grades in the 0,01% to 0,10% range. In recent years, however, lower-grade deposits have received attention, and it is anticipated that much future exploration and evaluation effort will be directed toward them. Many of these deposits will probably be of conventional types previously explored for higher grades, and, in fact, may be associated with higher-grade deposits, but many others are expected to be in new unconventional environments not previously explored for uranium. It is also quite likely that many of the 0,01% to 0.05% deposits will be producible at a cost of $130/kg U ($50/lb U_3O_8) or less.

At this stage it is not considered feasible to quantify uranium resources in a category above $130/kg U but governments should consider future studies to identify, quantify and evaluate uranium resources which might be produced in the medium- or long-term future in the cost category range of $130 to $260/kg U.