The economics of uranium supply and demand

by Ph. Darmayan*

The uranium market is still a young one whose "laws" have yet to become entirely clear. This tends to disorient observers and decision-makers who are anxious to predict its development. It has a number of characteristics which are sharply differentiated from those of other minerals, including other energy commodities.

First, the *applications of uranium are very restricted,* being limited for all practical purposes to military technology and to civil nuclear power. Between 1942 and 1974, the world's military requirements accounted for over 200 000 tonnes of uranium, or nearly 50% of cumulative world output during that period. Such requirements no longer play a major role, and the production of electricity is now for all practical purposes the sole determinant of the economics of the uranium market. Only a very few other metals have such limited applications they include barium (used almost entirely as baryta in the drilling of oil wells), gallium (in the manufacture of diodes and superconductors), and titanium (in aircraft).

The second characteristic to be noted is that there are *no direct substitutes for uranium.* For a completed nuclear power plant uranium cannot be replaced by any other fuel. This near impossibility of substitution – other than by slow and expensive modifications to the power generation system – could well be unique for a metal. Even barium, gallium, and titanium can be replaced by other metals if their price becomes excessive. Most titanium parts, for example, can be manufactured if necessary from aluminium or special steels.

Thirdly, uranium also has *unusual economic characteristics* when compared to other energy-producing raw materials. Processing of the mineral accounts for a very large proportion – around 88% – of the cost of the final fuel assemblies put into nuclear reactors, compared with 42% and 33% respectively for coal- and oil-burning power plants. But the absolute levels of nuclear fuel costs are low which, despite high front-end costs (mainly for the enrichment plant and the costs of the power station itself), makes for predictability in the overall economics of an electricity generating station. One practical effect of these low fuel costs is that the uranium needed to supply a station during its operating life of up to 30 years can be considered as committed, almost independently of changes in the cost of natural uranium.

Fourthly, in terms of *transportation and storage costs* uranium has advantages over all other energy sources, including in particular oil and coal (see Table 1). This ease of storage, coupled with the need felt by operators of nuclear stations for long-term security of fuel supply, explains the large size of the currently existing stockpiles owned by the world's utilities (93 000 tonnes of U at the end of 1979).

Finally, the nuclear industry is one with unusually *long lead-times.* For both uranium miners and electrical utilities, it can take ten or more years between a decision to proceed with a project, and the point where a new mine or nuclear generating plant is brought into operation.

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Table 1. Annual fuel requirements of a 1000 MWe power plant [1]

	Coal-burning	Oil-burning	PWR nuclear
Fuel quantity	2.2 × 10^6 tonnes coal-equiv	1 5 × 10^6 tonnes oil-equiv.	150 tonnes natural uranium
Fuel storage	40ha (400 × 100m)	25ha (50 tanks at 30 000m^3)	<50m^2 (66 containers of 3 tonnes)
Fuel cost (French Francs, approx.)	450 million	600 million	60 million
Transport	22 bulk carriers of 100 000dwt – one every 16 days	1500 barges of 1000 tonnes – four every day	2 railwagons or seven road vehicles

Table 2. Forecasts of installed electrical capacity (GWe) for WOCA [2]

	DOE (low) 1980	NAC 1980	Uranium Inst. (low) 1980	NUKEM 1980	DOE (high) 1980	Uranium Inst (high) 1980	INFCE (low) 1979	NUEXCO 1980	NAC utility based 1980	INFCE (high) 1979
1985	209	208	227	227	242	227	245	264	264	274
1990	292	306	335	345	360	350	373	328	375	462
1995	388	395	356	—	493	494	550	—	—	770

Because of such long lead-times the upper limit for installed nuclear capacity, as well as enrichment plant capacity, is, for all practical purposes, already decided until the late 1980s. And, for a very similar reason, the maximum levels of uranium production capacity which will be available by then are also known with a high degree of certainty.

For all these reasons, the uranium market is strongly dependent on forecasts of nuclear electricity production, and on the market outlook for the main components of the nuclear fuel cycle, particularly enrichment. These linkages do not, however, entirely shield the uranium market from having to face uncertainties concerning the supply and demand balance in the 1980s and beyond. The substantial reductions in power plant programmes since 1976, over-capacity in the enrichment market, and lengthening delays in bringing new nuclear facilities into operation, plus the flexibility conferred by the ease of uranium storage, all warrant careful and continuing analysis of the uranium supply and demand equation.

The Uranium Institute, which was set up in 1975, is an international industrial association whose membership includes representatives of both uranium producers and electrical utilities. Over 50 major organizations from 14 countries take part in its work. One of the Institute's most important aims is to make use of the expertise available within its membership to contribute to a better understanding of the economics of the uranium market. This task has been approached mainly through the work of a Supply and Demand Committee, which has been in existence since 1978. Its task is to analyse the uranium supply and demand outlook, and to publish reports elucidating the factors governing the market. In addition, each year, in September, the Uranium Institute organizes a symposium where the economics of the uranium market are considered in detail by numerous organizations· producers, consumers, consultants, and government agencies.

The Institute's Supply and Demand Committee is currently updating its forecasts, and later this year will issue a further report. Meanwhile it is possible to foresee the likely trends with a fair degree of clarity by drawing on some of the features of the uranium market which have been detailed in papers presented at past Institute symposia.

Flexibilities in demand

The Uranium Institute's September 1980 forecast of the build-up of nuclear capacity over the period to 1995 is summarized in Table 2. According to these estimates*, which take account of all the reactors currently in operation, under construction or on firm order (as of September 1980), nuclear capacity in 1985 will be 227 GWe and 335 GWe in 1990. If all the reactors planned (in September 1980) are added to these figures, the estimates would become 350 GWe and 494 GWe for 1990 and 1995 respectively.

These forecasts take account of the status of each individual reactor under construction and of the situation with respect to the development of nuclear power prevailing in each country. Outside the United States, the Institute forecast assumes that construction lead-times will not exceed six years. Only about 20 stations, all of them still in the early stages of construction, are believed to be in difficulty and not available for commercial operation for a further 8 to 10 years. For the United States, a longer lead-time of ten years has been assumed; it is still too early to assess the future impact on lead-times of the recent signs of a more favourable attitude to nuclear power.

Apart from nuclear capacity projections, the main factors which influence uranium demand are the tails assays used at enrichment plants, and the possibility of recycling uranium and plutonium in PWR and FBR reactors after the reprocessing of spent fuel. Current enrichment techniques allow the tails assay to vary from 0.15% to 0.30%. Other methods, still at the experimental stage, might allow this to be reduced to as little as 0.10% or even 0.05%. Table 3 gives an indication of the extent to which uranium consumption might be reduced by varying the tails assay, with respect to a point of reference defined by a product concentration of 3.25% U-235, a tails assay of 0.20%, and no fuel recycling.

However, the flexibilities which theoretically exist in the demand pattern are not always available in practice to the utilities, since enrichment companies only allow their customers to choose tails assays between 0.20% and

* The corresponding estimates made by the International Fuel Cycle Evaluation form the subject of Mr Bennett's article on page 8 of this bulletin

Table 3. Possible reduction in uranium requirements following from certain changes in the fuel cycle [1]

Process change	U supply reduction (%)
tails assay cut to	
0.15%	7 3
0.10%	13.4
0.05%	18.6
reprocessing/recycling of	
uranium	19.0
uranium/plutonium	30.0
fast breeder reactor in full use·	99.0 approx

In the case of recycling these savings are only realized several years later Above reductions are relative to a standard case of tails 0 25%, product stream 3 25% U_{235}, no recycling

0.30%, and that provided 15 months to 4 years prior notice is given. The choice is strongly dependent on the prevailing price of natural uranium and of separative work (i.e. principally the enricher's electricity costs). Depending upon the tails assay chosen, demand can vary by as much as 20%, a factor of great importance in the overall balance of supply and demand.

Flexibilities in uranium supply

Until 1979, the question of whether the mining industry would be able to find enough uranium to avoid a shortage was a source of considerable concern to consumers, but 1980 saw a great change. It will probably be remembered as a year in which the spot price declined dramatically, mining projects were delayed or cancelled, and mills closed or operated at partial capacity only. These changes, were, of course, a direct consequence of the continuing delays in nuclear programmes. The net result has been an increase in the uncertainties surrounding future uranium production levels. The structure of supply capability for the period 1980 to 1995, viewed from today's perspective, is given in Figure 1.

The supply capability of currently operating mills amounts to some 40 000 tonnes per annum, half of which

Figure 1. Forecast of annual uranium production for selected years between 1980 and 1990 [2].

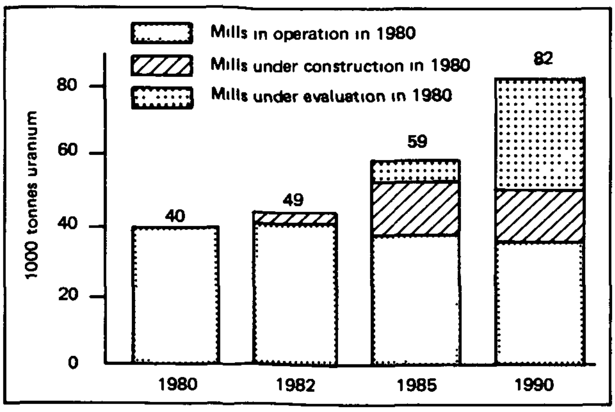


Table 4. Concentration of uranium in relatively few deposits [3]

	Cumulative		
Number of deposits	Number of deposits	Reserves (1000 tons)	% of total
9	9	982 0	49 5
17	26	1336 3	67 3
60	86	1811 0	91 2
48	134	1985 3	100.0

is accounted for by the United States. In 1985 uranium supply, as forecast by the Institute, could rise to about 60 000 tonnes if no existing mills were closed or run at reduced capacity. Of this total production, 65% would come from currently operating mills, and 24% from projects under construction, only 10% would come from mills which are currently at the evaluation stage.

By 1990 many more projects could be brought into production. A potential total of at least 82 000 tonnes could be produced by that date. In this case 45% of the supply would come from existing mills, 17% from mills under construction, and the remaining 38% from projects currently under evaluation. It must, however, be remembered that it has yet to be shown that many of these projects are technically and economically feasible.

The structure of this uranium supply is highly concentrated. Tables 4 and 5 show that 17 deposits account for 67% of the reserves (i.e. reasonably assured deposits economically workable at a forward cost of less than US \$30/lb U_3O_8) and that four countries own 81% of these reserves. This concentration, which is rather

Table 5. Summary of uranium deposits by country (short tons U_3O_8) [3]

Country	Number of deposits	Reserves (1000 tons)	Reserves per deposit (1000 tons)
Algeria	1	34 0	34 0
Australia	14	491 7	35 1
Brazil	2	4 0	2 0
Central African Republic	1	10 5	10 5
Canada	45	527 3	11 7
France	3	156 2	52 1
Gabon	5	46 5	9 3
Greenland	1	0 1	0 1
Niger	6	273 5	45 6
Namibia	2	125 0	62 5
USA	52	315 4	6.0
Germany, Fed Rep of	2	1 1	0 5
Total	134	1985 3	14 8

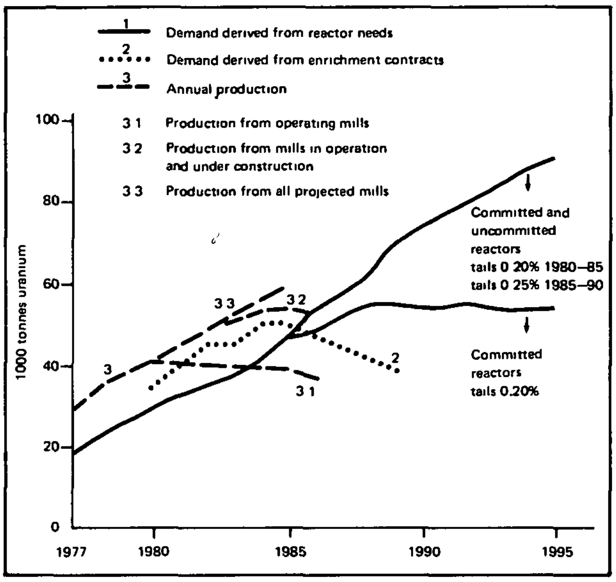


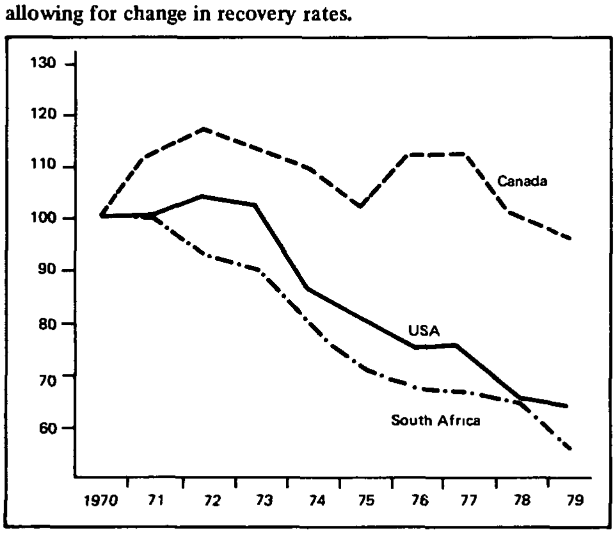
Figure 2. Uranium supply and demand estimates [2]. (Annual, 1980–95, 1000 tonnes uranium.)

surprising in view of the fact that uranium is widely distributed in the earth's crust, constitutes one of the major possible sources of supply disruption faced by the uranium market.

Supply and demand balance

Figure 2 compares uranium consumption and supply capability as derived from the Institute's estimates given above. Up to 1985 it is clear that, in spite of several enrichment contract cancellations, the demand resulting from enrichment contracts will remain higher than that derived from reactor needs. But it can also be seen that, from 1980 to 1985, uranium production from mills currently in operation and under construction will in all probability exceed uranium demand, however it is derived.

Figure 3. Trends in average delivered grades of uranium mined, 1970–79 [4]. (Index numbers 1970 = 100, annual averages.) US figures refer to the head-grade of mill-feed before allowing for changes in recovery rates, whereas the Canadian figures are after allowing for change in recovery rates.



After 1990, the balance of supply and demand will very much depend on current nuclear policies. Figure 2 also shows the upper and lower limits of reactor requirements based on the Institute's nuclear estimates and tails assay flexibilities. So far as supply is concerned, decisions to build new mills are likely to be very strongly influenced by decisions regarding the reactivation of nuclear programmes.

Uranium price analysis

Attempts are often made to study the uranium market without trying to analyse the influence of price trends on the supply and demand balance. It has already been seen that demand is relatively insensitive to changes in price, so much so that the concept of break-even cost has very little meaning for the production of energy from uranium. This cost would presumably relate to the price which a producer of electricity would have to pay for his uranium in order to arrive at the same cost for nuclear generated electricity as for the next least-expensive means of generating electricity (usually coal). In practice, of course – owing to the long lead-times required for the construction of nuclear plants – such a concept is more useful in assessing the economic advantages of nuclear power against coal than in helping the industry and the market to balance uranium supply and demand.

As far as supply is concerned, a distinction must be made between potential producers and existing producers. The latter have only a limited capability of responding to changes in the economic environment. The main parameters that can be subjected to management decisions are: mine cut-off grades, mill utilization, and uranium recovery efficiency. None of these offer great flexibility, and if used for too long a period could even have adverse consequences on future production. Nevertheless, it is significant that in the past there has been a general tendency for average grades to rise during a recession, and to fall during periods of economic recovery.

The Canadian curve of Figure 3 is a good example of the way in which the market price has an influence on the grades of ore processed. The Elliot Lake mines exploited high-grade ore during the recession of the early 1970s. Subsequently the prospect of improved margins and rising demand encouraged mine expansion and the development of lower-grade ores. Except for the start-up of the relatively rich Rabbit Lake deposit in late 1975, this downward trend in average Canadian recovered grades continued until 1979.

The influence of price is even more significant for uranium exploration. As shown in Figure 4, exploration has tended to follow the broad pattern of reactor orders in the United States. The chart shows the history of 20 years' experience of exploration and development drilling in the USA, in terms of the number of holes drilled from the surface each year. It clearly reflects the

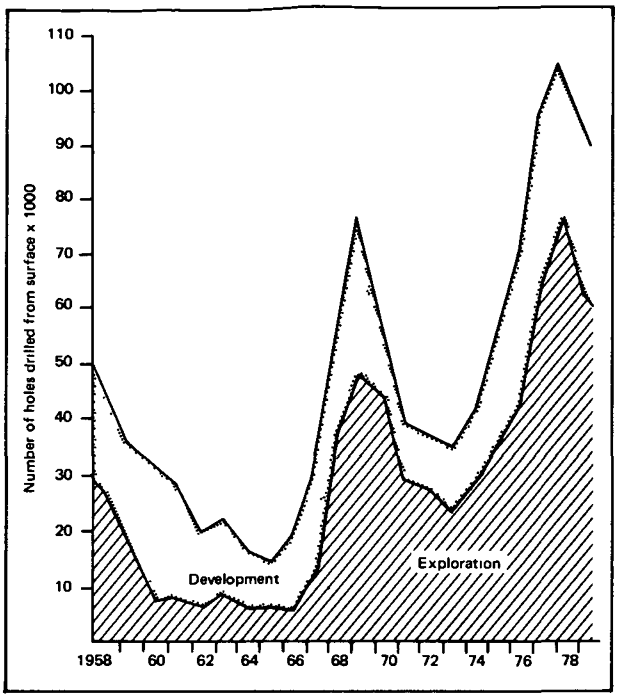


Figure 4. US uranium exploration statistics [4].

recessions in the industry of the early 1960s and early 1970s, and shows the possible beginning of another in 1979.

Ore grades and exploration expenditure are two examples of the historical close linkage between uranium price trends and both actual and potential uranium production. While price changes can have only a limited impact on existing production facilities they can discourage mining companies – which often have other interests besides uranium – from continuing to invest in uranium exploration. Continuation of such a trend over time could lead to a return of the very low exploration levels of the early 1970s, with all that this could mean later on for production and for the long-term security of fuel supply for existing nuclear power stations throughout the world.

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An open-pit uranium mine in the Vendée region of France.