Estimates of Future Demand for Uranium and Nuclear Fuel Cycle Services

by Rurik Krymm and Georg Woite

As a review of forecasts made over the last few years amply demonstrates, projections of nuclear power capacity on a country, regional or world basis are subject to uncertainties. Table 1, which summarizes the evolution of estimates made in the recent past, should provide a sobering reminder of the advisability of relying on ranges rather than on single figures.

But these basic uncertainties are only a beginning when it comes to estimating future demands for uranium and nuclear-fuel-cycle services. General estimates of total nuclear capacity are no longer sufficient. They must be supplemented by detailed breakdowns by reactor types extending over the whole time horizon covered by the study. For each category future operational characteristics must be known or assumed. Alternative hypotheses must be made on fuel management policies in such crucially important areas as, for instance, reprocessing, recycling of uranium and plutonium, and waste assays from enrichment plants. Under these conditions, the "tree of possible events" soon grows so many branches as to make its description difficult and its interpretation confusing. If, for example, three reasonable alternative assumptions are made on each of five major parameters (total nuclear capacity, reactor mix, recycling, waste assay and load factor), no less than 243 sets of demand curves would have to be produced and interpreted.

For the purpose of this short review, alternative assumptions have been kept to a minimum and limited to two major areas: total nuclear capacity and recycling. The other relevant parameters were assumed fixed at levels felt to be reasonable under present circumstances, and the sensitivity of the results to their possible variation is briefly touched upon in the concluding section.

While the alternative assumptions on recycling are explained below, a few words should be said about the assumptions on total nuclear capacity which appear in Table 2. These estimates may strike the reader as highly conservative in comparison with those contained in such recent publications as the joint IAEA/NEA/OECD report on uranium resources production and demand, published at the end of 1975. Indeed, they may prove too conservative for the last decade of the 20th century. Nevertheless, they incorporate the latest downward revisions which a variety of factors brought about in the programmes of several major industrial countries and the stringent constraints which financing and skilled manpower bottlenecks are likely to impose on the penetration of nuclear power in the electricity supply systems of developing nations. Sufficient reference has been made to the variability of forecasts to make it clear that they are subject to permanent revisions.

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ASSUMPTIONS

In order to estimate the demand for uranium and nuclear-fuel-cycle services, it was assumed that the nuclear power plants will consist of light water reactors (LWR), heavy water reactors (HWR) and fast breeder reactors (FBR). It was further assumed that LWR's would contribute 93%, HWR's would contribute 5%, and FBR and other reactor types 2% of the installed nuclear capacity in 1990. For the year 2000, it was assumed that the FBR portion would go up to 5%, and the LWR portion down to 90%.

Table 1: Evolution of Estimates of World Nuclear Power Growth (Not Including Countries with Centrally Planned Economies)

Estimate For	Date of Estimate				
	1969	1970	1973	1975	1976 (preliminary)
	Installed Capacity at Year End in GWe				
1970	25.6	18	14	–	–
1975	101–125	118	94	71	69
1980	235–330	300	264	179–192	178
1985	–	610	567	475–525	350–400
1990	–	–	1070	875–1000	550–750
2000	–	–	–	2000–2500	1500–1800

OECD/NEA-IAEA estimates based on information supplied by member governments.

Table 2: Regional Breakdown of Nuclear Power Estimates Made in 1976 for Countries with Markes Economies (Installed Capacity at Year End in GWe)

	1975	1980	1985	1990	2000
North America	43	88	150–170	230–310	650–750
Western Europe	18	68	150–170	220–290	600–700
Japan, Australia, New Zealand, South Africa	7	16	30–40	60–80	130–160
Developing countries	1	5	20–25	50–60	150–200
Total[1]	69	178	350–400	550–750	1500–1800

[1] In view of the large margins of uncertainty, totals were rounded off.

Table 3: Power reactor characteristics[1]

	PWR	BWR	HWR	FBR
1. Initial loading				
Uranium (t/GWe)	79	114	143	50
Average initial enrichment (w/o ^{235}U)	2.38	2.03	0.711	depleted
Natural uranium required (t/GWe)	372	444	145	—
Separative work required (1000 SWU/GWe)	209	227	—	—
Fissile Plutonium required (t Pu/GWe)	—	—	—	2.5
2. Replacement loadings				
Uranium (t/GWe · yr)	33.8	39.4	168	20
Fresh fuel enrichment (w/o ^{235}U)	3.2	2.7	0.711	depleted
Natural uranium required (t/GWe · yr)	221	211	170	—
Separative work required (1000 SWU/GWe · yr)	145	129	—	—
Fissile Plutonium required (t Pu/GWe · yr)	—	—	—	1.2
3. Irradiated fuel				
Burn-up (MWd/kg)	32.5	27.5	7.5	2–66[2]
Uranium (t/GWe · yr)	32.8	38.4	166	18
Average enrichment (w/o ^{235}U)	0.90	0.83	depleted	depleted
Natural uranium equivalent (t/GWe · yr)	44.7	46.6	—	—
Separative work equivalent (1000 SWU/GWe ·yr)	6.3	4.3	—	—
Fissile Plutonium (t Pu/GWe · yr)	0.22	0.21	0.43	1.35

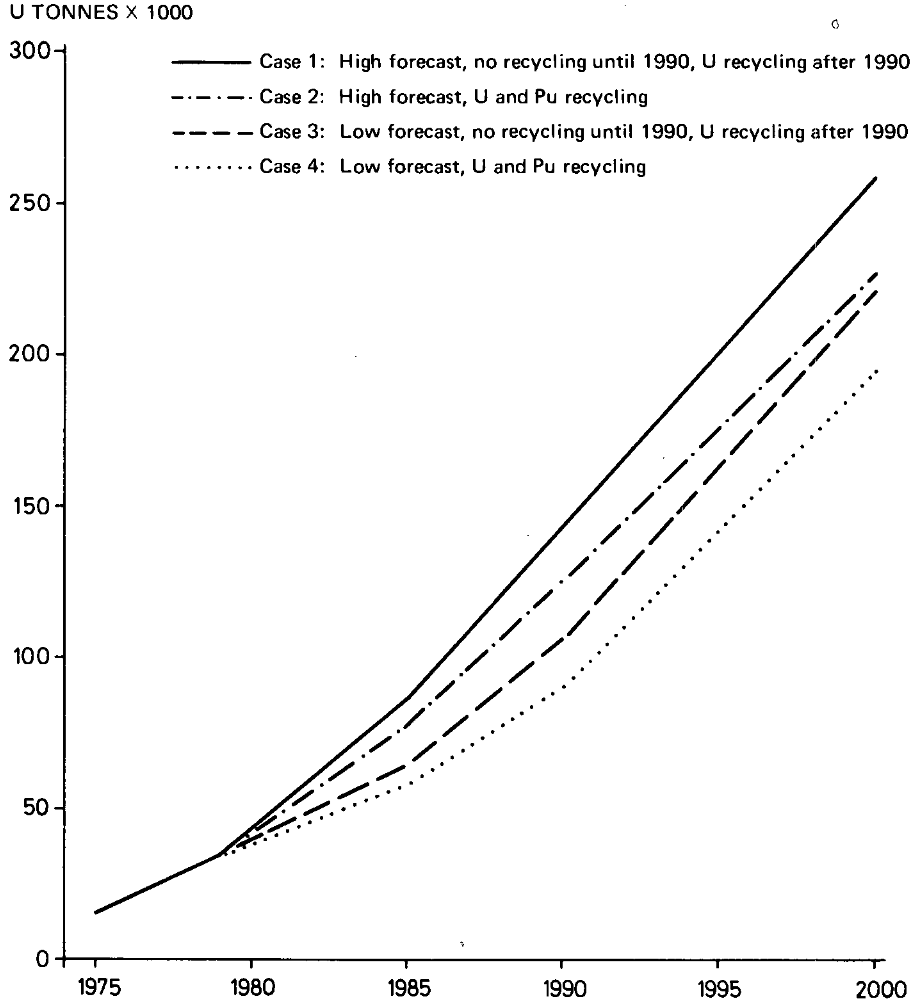
[1] Fuel amounts are in metric tonnes of heavy metal; tails assay = 0.25%; 1 GWe · yr = 8760 GWh.
[2] Depending on position in core or blanket.

Table 4: Fuel Cycle Lead and Lag Times in Years

Reactor type	LWR		HWR		FBR	
	Initial	Replacement	Initial	Replacement	Initial	Replacement
Mill out to Conversion out	0.25	0.25				
Conversion out to Enrichment out	0.25	0.25	0.5	0.5	0.5	0.5
Enrichment out to Fabrication out	0.5	0.25				
Fabrication out to Reactor site in	0.25	0.25	0.25	0.25	0.25	0.25
Reactor site in to Fuel testing end	0.25	0.1	0.25	0.1	0.25	0.1
Fuel testing end to Operation start	0.5	0.1	0.5	0.1	0.5	0.1
Operation end to Reactor out	0.1	0.1	Continuous refuelling; since economics of reprocessing are questionable no reprocessing of HWR fuel was assumed.		0.1	0.1
Reactor out to Storage pond out	0.8	0.8			0.8	0.8
Storage pond out to Central storage out	5.0[1]	5.0[1]			5.0[1]	5.0[1]
Central storage out to Reprocessing out	0.2	0.2			0.2	0.2

[1] 5 years' lag time assumed before 1990, 1 year lag time after 1990.

Figure 1: Annual World Uranium Requirements[1]

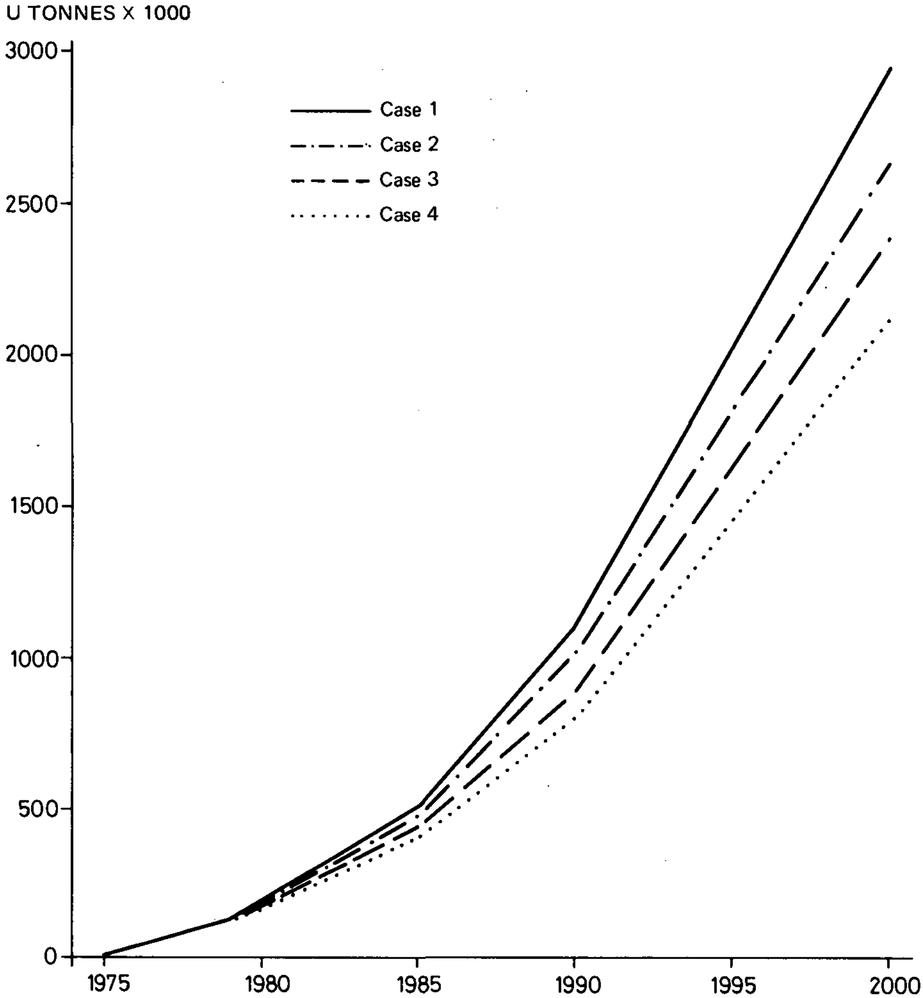


[1] Not including Countries with Centrally Planned Economies

The nuclear-fuel-cycle characteristics of these reactor types are summarized in Table 3. A tails assay of 0.25% and a constant load factor of 70% were assumed. The delay times of the nuclear fuel cycle are displayed in Table 4. It should be noted that a five-year delay was assumed for reprocessing until 1990, and a one-year delay after 1990.

Based on the nuclear power forecasts in Table 2 and the above assumptions, the requirements for uranium and nuclear-fuel-cycle services were computed. To show the influence of some key parameters, computations were carried out for four cases:

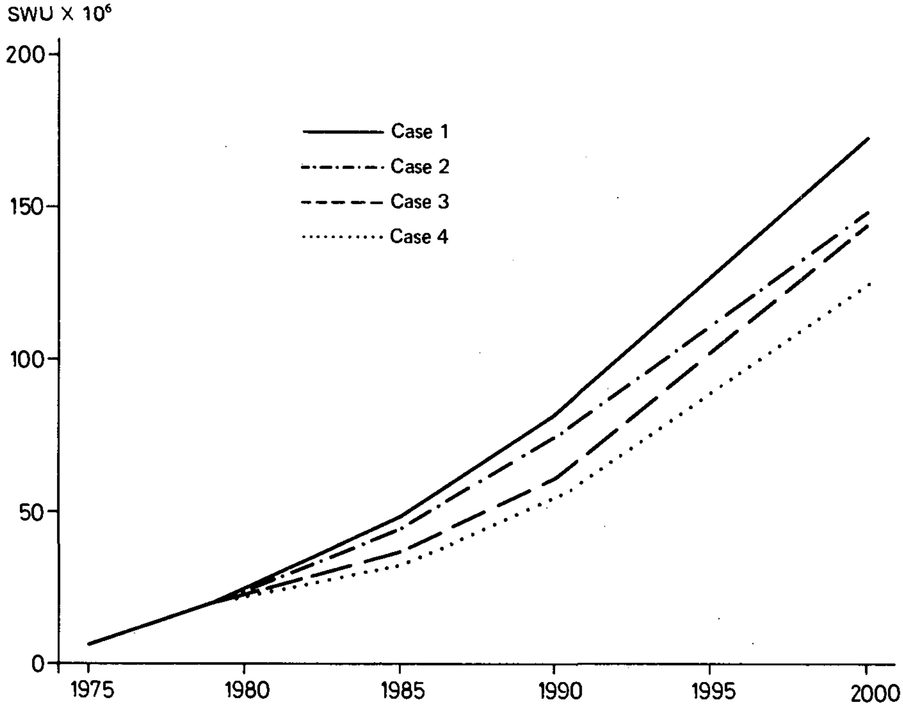
Figure 2: Cumulative World Uranium Requirements[1]



[1] Not including Countries with Centrally Planned Economies

Case 1:
High forecast, no recycling until 1990, uranium recycling after 1990;
Case 2:
High forecast, uranium and plutonium recycling from 1981 onwards;
Case 3:
Low forecast, no recycling until 1990, uranium recycling after 1990;
Case 4:
Low forecast, uranium and plutonium recycling from 1981 onwards.

Figure 3: Annual World Separative Work Unit Requirements[1]



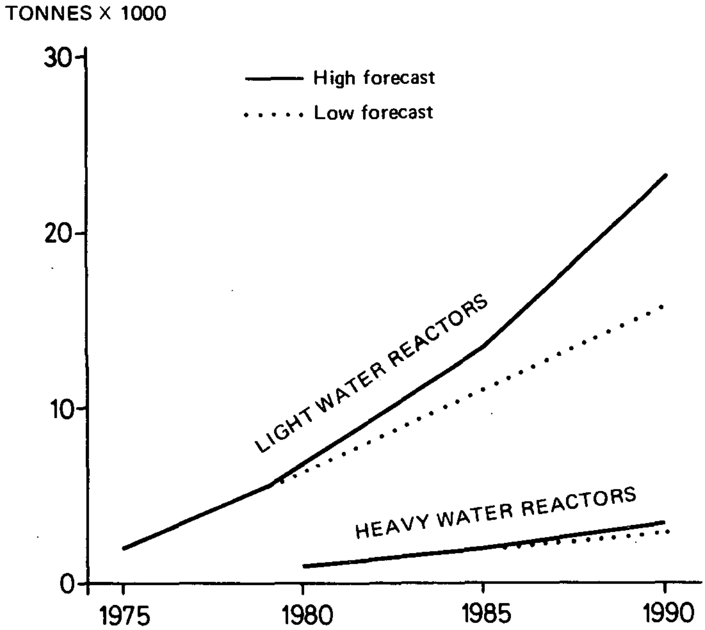
[1] Not including Countries with Centrally Planned Economies

ESTIMATED DEMAND FOR URANIUM AND NUCLEAR FUEL CYCLE SERVICES

Uranium Requirements. It is estimated that uranium requirements will reach about 40 000 metric tonnes of heavy metal per year in 1980 (Figure 1). For 1990, the estimates for uranium requirements range from 90 000 t/a (Case 4: low forecast, uranium and plutonium recycling) to 140 000 t/a (Case 1: high forecast, no recycling). For the year 2000, the requirements are estimated to range from 200 000 to 300 000 t/a. Cumulative uranium requirements are estimated to be about 0.8 to 1 million tonnes in 1990, and 2 to 3 million tonnes by the year 2000 (Figure 2). It is interesting to note that nearly the same amounts (1.8 to 2.6 million tonnes) would be required to meet the lifetime fuel requirements of the LWR's expected to be operating in the year 1990.

Separative Work Requirements. The annual separative work requirements are estimated at about 22 X 10^6 SWU/a in 1980, and 55 X 10^6 to 80 X 10^6 SWU/a in 1990 (Figure 3). For the year 2000, the estimates range from 120 X 10^6 (low forecast, uranium and plutonium recycling) to 180 X 10^6 SWU/a (high forecast, no recycling).

Figure 4: Annual Fabrication Requirements[1]



[1] Not including Countries with Centrally Planned Economies

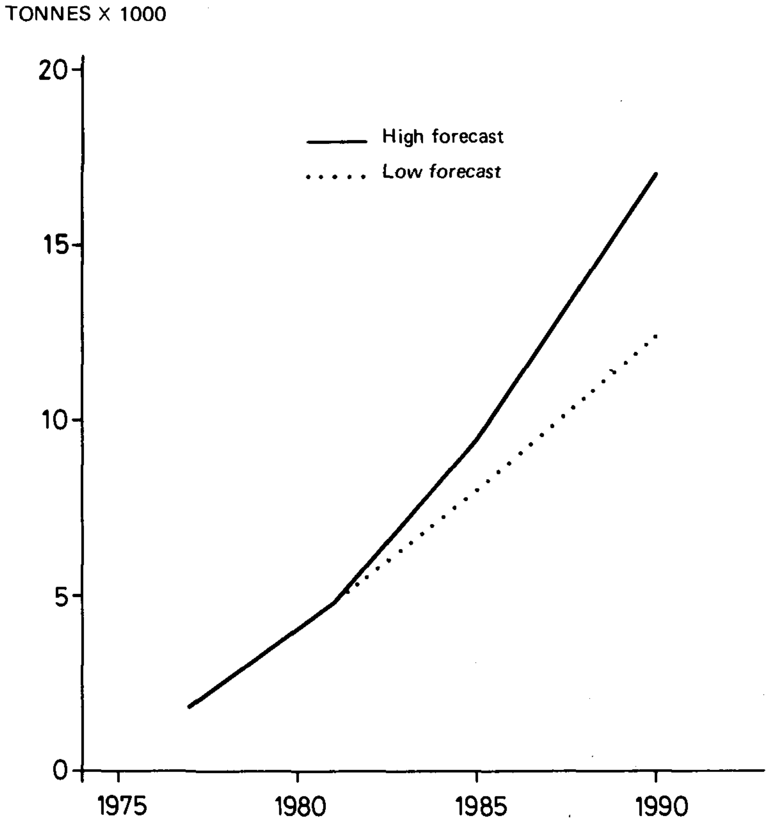
Fabrication Requirements. The requirements for fabrication of LWR fuel are estimated at about 6000 t/a (heavy metal) in 1980, and 16 000–23 000 t/a in 1990 (Figure 4).

Reprocessing Requirements. The reprocessing requirements for LWR fuel are estimated to be about 4000 t/a (heavy metal) in 1980 and 12 000–17 000 t/a in 1990 (Figure 5). The planned reprocessing capacities are inadequate to meet this demand. Further delays of the start-up of reprocessing plants may occur. It will be necessary to store irradiated fuel for several years.

TENTATIVE CONCLUSIONS

Although they are derived from a relatively narrow range of assumptions for nuclear power capacity, the alternative estimates of demands for uranium and nuclear-fuel-cycle services differ by about 50%. If plausible variations in breeder penetration, load factors, tails assays and fuel performance were taken into account, a ratio of 2 between maximum and minimum possible demands for the 2000 could easily be approached. Thus, for instance,

Figure 5: Annual Reprocessing Requirements for Light Water Reactor Fuel[1]



[1] Not including Countries with Centrally Planned Economies

a 15% (instead of 5%) breeder penetration by the year 2000 would decrease annual natural uranium demand by about 10%, a drop of load factor from 0.7 to 0.6 would drop the demand by another 10%, a decrease in tail assay from 0.25% to 0.2% would drop the demand by 8%.

These momentous uncertainties, characteristic of medium- and long-term demand projections, offer a sharp contrast to the inflexibility of short-term requirements. Once a nuclear plant is ordered, the demand for the fuel services required for its core and for its replacement loadings is practically fixed (subject to minor trade-offs) and it can only be delayed in time by accepting exceedingly heavy additional costs.

The demand for uranium can be characterized as being uncertain in the future and inelastic in the present. It faces sources of supply which, with the exception of fabrication and conversion facilities, are characterized by long planning times, lengthy prospecting and construction times, and above all by heavy capital investments.

This combination offers an almost ideal framework for instability and wild price fluctuations if consumers and suppliers operate independently seeking temporary guidance in their changing estimates of the future markets. The long stagnation of uranium prices at abnormally low levels followed by a rise of 600% to 700% for spot deliveries within less than three years should convince all parties concerned that reliance on the invisible hand of Adam Smith will not lead to optimal solutions in the development of nuclear power.

Co-operation between consumers and producers of uranium and nuclear-fuel-cycle services is therefore essential. Some steps along this road have already been taken in the fields of enrichment and reprocessing. Much remains to be done in those areas. But ever more must be done in the areas of uranium prospecting, production and procurement. It would be to the benefit of all concerned if this co-operation in planning and risk sharing were achieved ahead of time rather than in an aftermath of struggles and disappointments.