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THE INTERNATIONAL URANIUM MARKET

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INTRODUCTION

The international uranium market is affected by many of the same concerns that now attend all trade in energy: the adequacy of the resource base, price uncertainty, and worries about security of access. Uranium, like energy generally, is now a strategic commodity for reasons of economic security. Uranium is also the subject of international security concerns because of its association with the proliferation of nuclear weapons. Proliferation is a subject of disagreement among nations--with some arguing that access to uranium or enriched fuel should be coupled to restraint in technological decisions and acceptance of wide-ranging safeguards; the net result is yet another dimension of uncertainty about an energy commodity that many nations feel is vital to their future.

These security concerns are related to the nature and behavior of the international market for nuclear fuels. For example, political aspects of security become more salient if the uranium market is tight, or if there is little flexibility in supply arrangements. Conversely, an oversupply situation--or growing diversity of supply--lessens the impact of political and other constraints. Security problems are both perceptual and real. There have been periods in which political disruptions coincided with tight market conditions, resulting in justifiable concerns. But there are also concerns that arise because of uncertainty, and at least some of this uncertainty is due simply to lack of information. Without adequate information, the worst is usually assumed. Thus, a clearer view of the nature of supply and demand, of government policy formulation, and of market functioning can help relieve at least some of the security worries felt by those in charge of national energy policies. It is the purpose of this paper to improve this understanding.

In the chapters that follow, we consider 1) how one might think about uranium demand, resources and supply, 2) how producers and consumers see the market and are likely to behave, including specifics about export and import commitments, and 3) how these actors are brought together in the international market. Our general conclusion is that much of current anxiety about future uranium supply results primarily from a brief but difficult period in the mid- to late-1970's; and that current conditions and trends are so favorable (at least to consumers) that there is now little basis for concern. Inventories, contractual positions and producer commitments--when compared with realistic (or even unrealistic) demand estimates--imply a buyer's market for at least the next decade. The result will be considerable increases in market flexibility and resilience to shock, and real prices that are low relative to those of the past few years.

But while the energy security concerns of consumers are alleviated by these market changes, other problems are created. There is a need to reconsider assumptions about desired directions of technological development, for many current programs were planned in an era of pessimism about uranium supply and prices. Similar questions must be raised about nonproliferation policies that depend on some level of control of fuel supplies by the industrial nations. With a soft and more diversified uranium market, any leverage that may have existed in the past is rapidly being eroded. Finally, as world prices turn soft, there may be significant problems created for U.S. uranium producers, who have relatively high costs in relation to several large-scale foreign suppliers.

II. URANIUM DEMAND

2.1 Introduction

The demand for uranium is a function of the demand for nuclear fuel at the point of loading new or existing reactors, as modified by other components in the chain of fuel processing and management. For light-water reactors there are several steps in fuel preparation--including UF_6 conversion, enrichment, and fuel fabrication--plus the transportation between the sites where these processes take place. Thus the demand for uranium in the form of U_3O_8 occurs as much as two years before demand at the reactor, even ignoring the role of inventories. In addition, fuel processing--particularly the enrichment step--usually involves long-term contracts. Since enrichment is available from only a small number of suppliers, yet is essential, this service often is lined up well in advance of reactor construction. If reactor schedules slip, then enrichment contracts themselves can become a key determinant of uranium demand at the mine. The fuel preparation for heavy water reactors also involves a series of processing steps, but it is simpler than that of the LWR (most importantly it avoids enrichment) and thus the linkage of reactor operation to U_3O_8 demand is more direct.

Then there is the influence of inventories; as illustrated in Figure 2.1, these occur in three forms for the LWR cycle. There is the stock of U_3O_8 and UF_6 before enrichment which may be held by producers or consumers, or by conversion and processing firms at various points along the supply chain from the mine to the enrichment plant. Second, there are stocks of enriched material, which may be in the form of enriched UF_6 or in partially-fabricated or completed fuel assemblies.

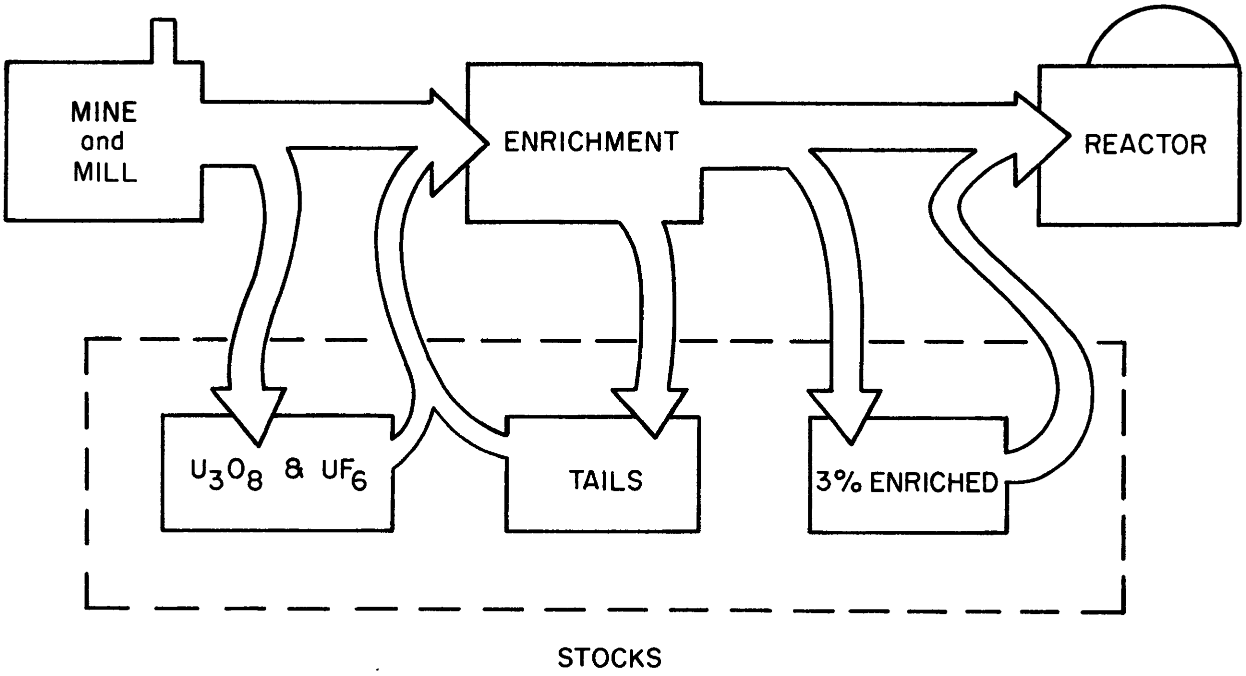

Figure 2.1

URANIUM STOCKS IN THE LWR CYCLE

These stocks may be held by enrichment authorities, by consuming utilities or their governments, or by fuel fabricators. Finally, there is the stock of tails which results from enrichment plant operations. If an enrichment plant operates at 0.30 percent tails assay, while it could process to 0.20 percent or below, then the tails from the 0.30 percent operations represent a stock of uranium which can be fed back into the system.

In the sections that follow, we begin with an analysis of reactor growth, and then look briefly at the various factors that interpose between the expected reactor population and its demand for U_3O_8.

2.2 Fuel Demand at the Reactor

2.2.1 Economic and Technical Determinants of Demand

At the point of entry into the reactor, the demand for uranium is almost completely a technical matter of reactor design and operation, and the number of reactors in operation. For current light-water reactors (and the heavy-water CANDU reactor as well) there is no viable substitute for uranium.* Moreover, uranium represents only a small portion of nuclear power cost. At roughly $40 per pound (in 1979 dollars) U_3O_8 constitutes only about 30 percent of the cost of fabricated fuel, and fuel represents only about 20 percent of the busbar cost of

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*One qualification to this statement is the use of plutonium in thermal recycle. However, its likely impact is small. There is strong resistance to this fuel technology on nonproliferation grounds. Even at uranium prices considerably higher than today's, the economic advantage does not appear strong enough to overcome this opposition. Figure 2.1 omits these stocks of potential fuel materials, uranium and plutonium, which are now held primarily at the reactor in the form of spent fuel assemblies.

electricity from a nuclear plant. Thus only about 6 percent of nuclear power cost is attributable to uranium. Uranium prices could go up by 50 percent in real terms, say to $60 per pound, and the cost of nuclear power would increase by only 3 percent. These differences are not significant in the choice of nuclear vs. other sources of power generation, or in the likely growth of electricity demand itself. Thus at the point of use the demand for enriched fuel is almost completely inelastic to the price of U_3O_8.

For any given reactor, of course, the pattern of fuel demand is a function of the operating characteristics--primarily the reactor capacity factor. In general, utility operators try to attain as high a capacity factor as possible, and early plans in the industry anticipated capacity factors in the range of 75 to 80 percent. In practice, these factors have averaged about 55 to 60 percent, due largely to problems of reactor down-time. A secondary influence on uranium demand is the response of utility fuel management procedures, given the capacity factors that each individual plant is able to realize: fuel which has not reached design burnup by the scheduled refueling date may be left in the reactor, if possible, reducing the demand for new fuel.

In the long run of 20 to 30 years, there are new technologies--such as the uranium-plutonium breeder or thorium-based cycles--that could provide viable substitutes for uranium. Beyond the end of the century there may be a real cost trade-off between uranium-fueled LWRs and these alternatives, and uranium price will play a role in that calculation. There are still other technical changes which--though not driven by uranium prices--may nonetheless have a significant effect on demand and price. For example, laser isotope separation may allow recovery of more uranium-235 from natural uranium (and existing tails), and LWRs may be developed which achieve higher burn-ups and neutronic efficiencies.

But these prospects are decades distant in having a significant impact. They may have some influence on the current price of uranium--because of expectations about the longer-term future. But the uranium prices of the recent past, and those expected over the next ten to twenty years, have little or no effect on orders of reactors with current LWR or HWR technology. Over the next couple of decades, therefore, the demand for uranium, at the point of fuel use, may be simply derived from expectations about reactor growth and operational characteristics, independent of costs and prices in the uranium sector.

2.2.2 Reactor Growth

The early 1970's saw the high water mark of official optimism about nuclear power, and since then reactor growth projections have been reduced repeatedly. So too have expectations about uranium needs. In Figure 2.2 we illustrate this trend with estimates of reactor growth which are published periodically by a OECD/IAEA Working Group [1]. The estimates cover the "world outside Communist areas" (WOCA). Each estimate is built up from forecasts by the appropriate government authority or nuclear-industry agency in each country. Thus these projections tend to reflect official nuclear plans or ambitions rather than independent external judgments. These projections have dropped rapidly since 1975, and the estimates for 1980, 1985, and 1990 have fallen by more than a factor of two in the last decade.*

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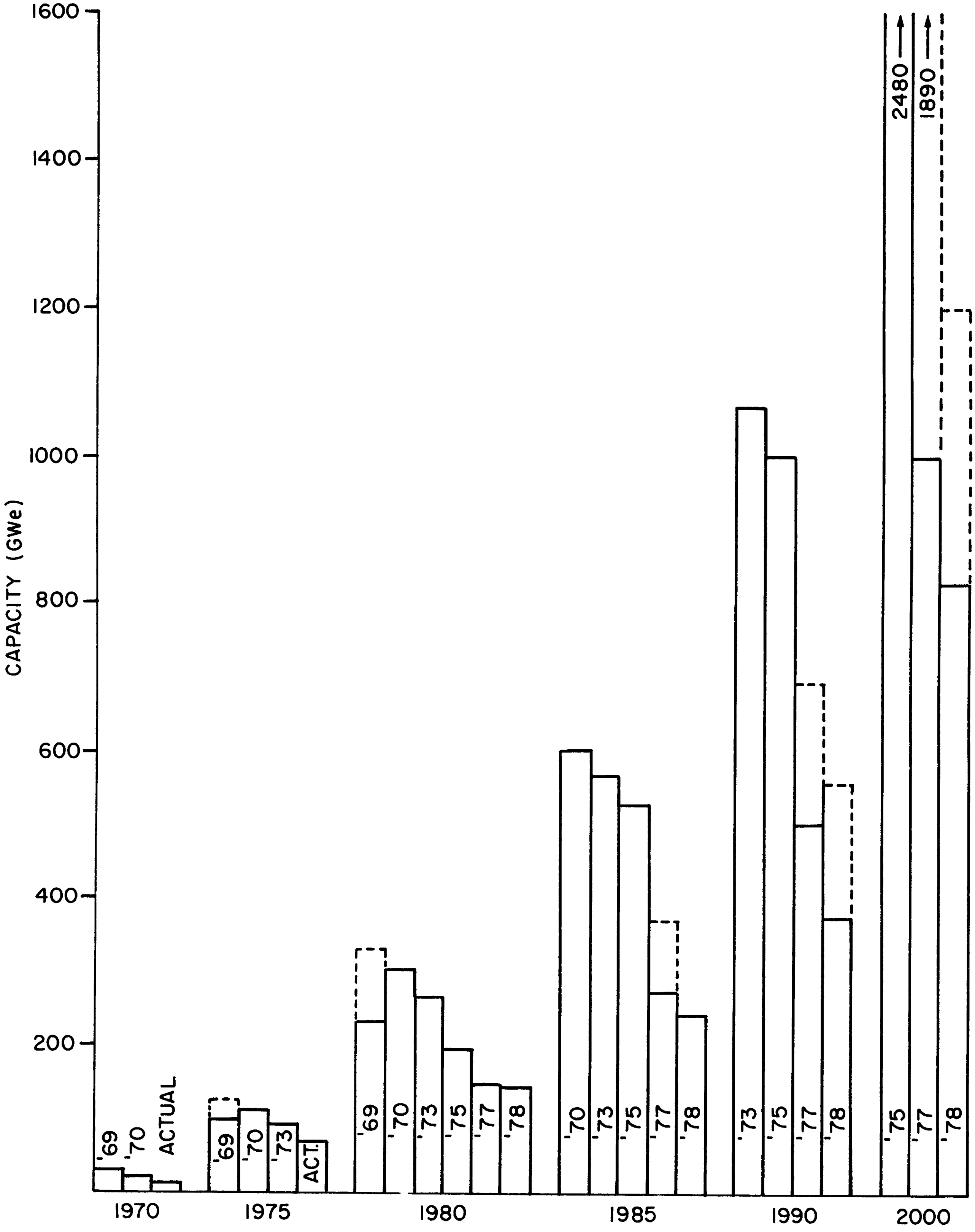
*The change has been less severe in some countries than in others. For example, in France, projections have the status of official plans, which are closely coordinated bureaucratically. Because of this, and perhaps because of a less effective nuclear opposition movement, French projections have dropped only by about 30 percent while those of other countries have dropped by 50 percent or more.



SOURCE: TABLE A-3, APPENDIX

NOTE: WHERE APPROPRIATE, SOLID LINES INDICATE LOW ESTIMATES, DASHED LINES HIGH ESTIMATES.

Figure 2.2

OECD-NEA/IAEA NUCLEAR GROWTH PROJECTIONS

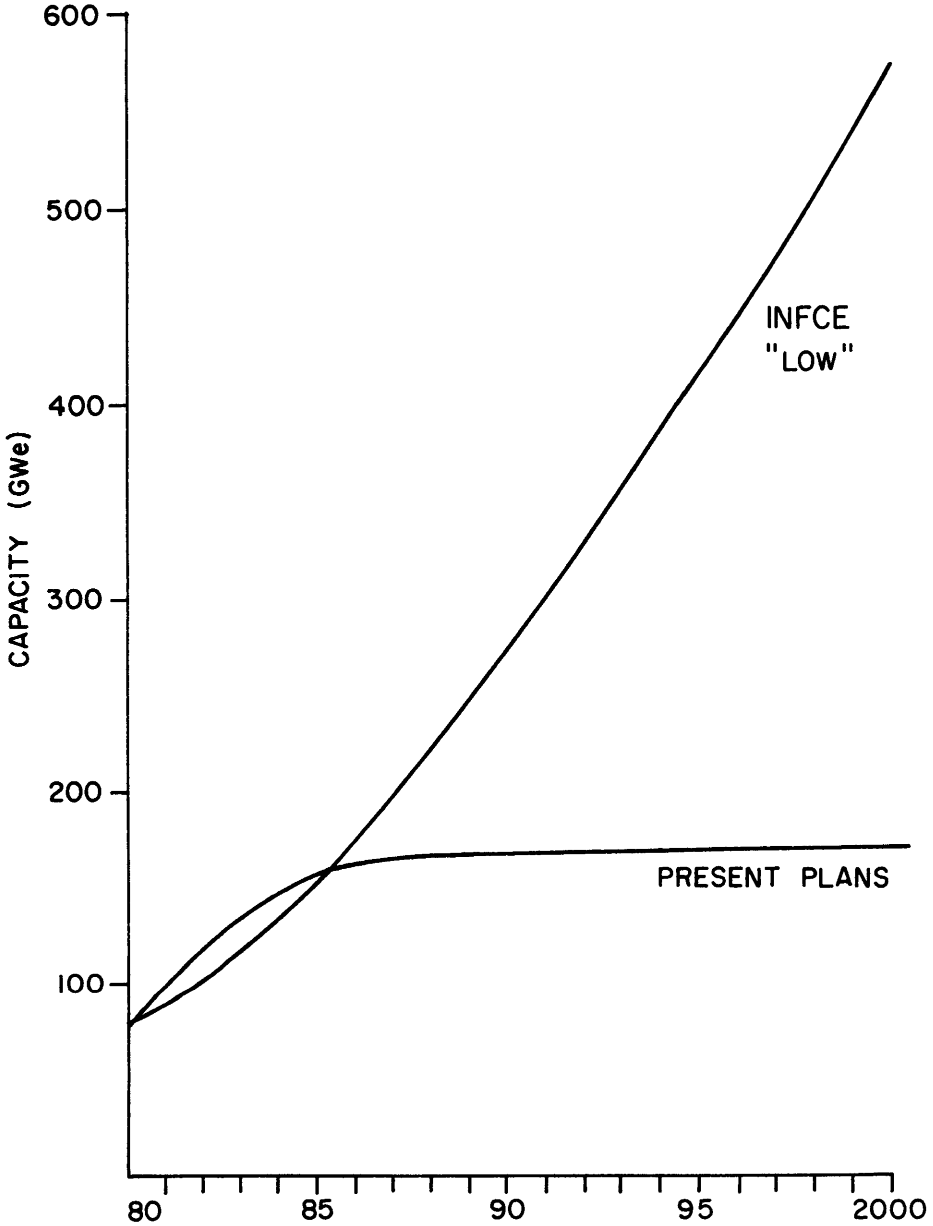
From the perspective of the international uranium industry, reductions of the magnitude shown in Figure 2.2 have profound implications. For example, the projected uranium requirements for 1985 dropped by nearly 40,000 MTU in estimates made between 1975 and 1978--an amount comparable to current annual world production. Given the long lead times and lifetimes of mining investments, it clearly would be unwise for the uranium industry to base its investments on official nuclear growth projections.

As a guide to future discussions of supply, demand and market function, it is useful to consider nuclear growth prospects as they appear today. We use two published tabulations for this purpose. The first is a projection prepared in connection with the International Nuclear Fuel Cycle Evaluation. During the first half of 1978, countries with nuclear power plants were asked to make official high and low estimates of growth through 2000. These estimates are thus very similar to those presented in previous NEA/IAEA working group reports. (Indeed the INFCE estimates are used in the most recent report in this series.) Since nuclear growth expectations have almost uniformly declined since early 1978, we have chosen to use the "low" estimate, reproduced here in Figure 2.2.

A more conservative view of reactor prospects can be constructed by considering only those reactors to which some contract commitment has been made--that is, reactors that are either operating, under construction, or ordered. Reactor lists of this form are published by several groups, usually based on utility surveys. In Figure 2.3 we also summarize the tabulations of one source (Nuclear News, August 1979). To simplify, we have made no distinction between reactors at various stages of completion; we include those for which letters of intent exist, as well as those operating and under construction. Until about 1986, this reactor growth projection is slightly above the INFCE projection, due to utility optimism about completing reactors. After 1986, the INFCE projections rapidly grow to exceed present utility reactor commitments. All the new reactors shown in the INFCE projection after this date have yet to be ordered. Even if ordered, their completion is a decade or more away.

Thus the actual future path of reactor growth probably lies somewhere between the two forecasts shown in Figure 2.2. In our view the INFCE low forecast is now unattainable. It is hard to imagine reactor installation being much above the "present plans" level through 1990. Given the lead times for reactor licensing and construction, the rate of new orders over the next five years would have to be incredibly high to come anywhere near the INFCE forecast by the end of the century. Of course, while reactors may be ordered in some parts of the world, there will be cancellations elsewhere, and it is even possible that installations over this period would be even below the "present plans" level. Probably the growth prospects are above the "present plans," particularly after 1990, but closer to the lower than to the upper line in Figure 2.3.

The ultimate outcome cannot be forecast at this time; it depends primarily on the outcome of public debate about nuclear power in several developed countries. Nonetheless, analysis of potential developments in uranium can be carried out using a range of possible outcomes, and through the rest of this study we use these two forecasts to establish that range.



SOURCE: TABLE A-4, APPENDIX

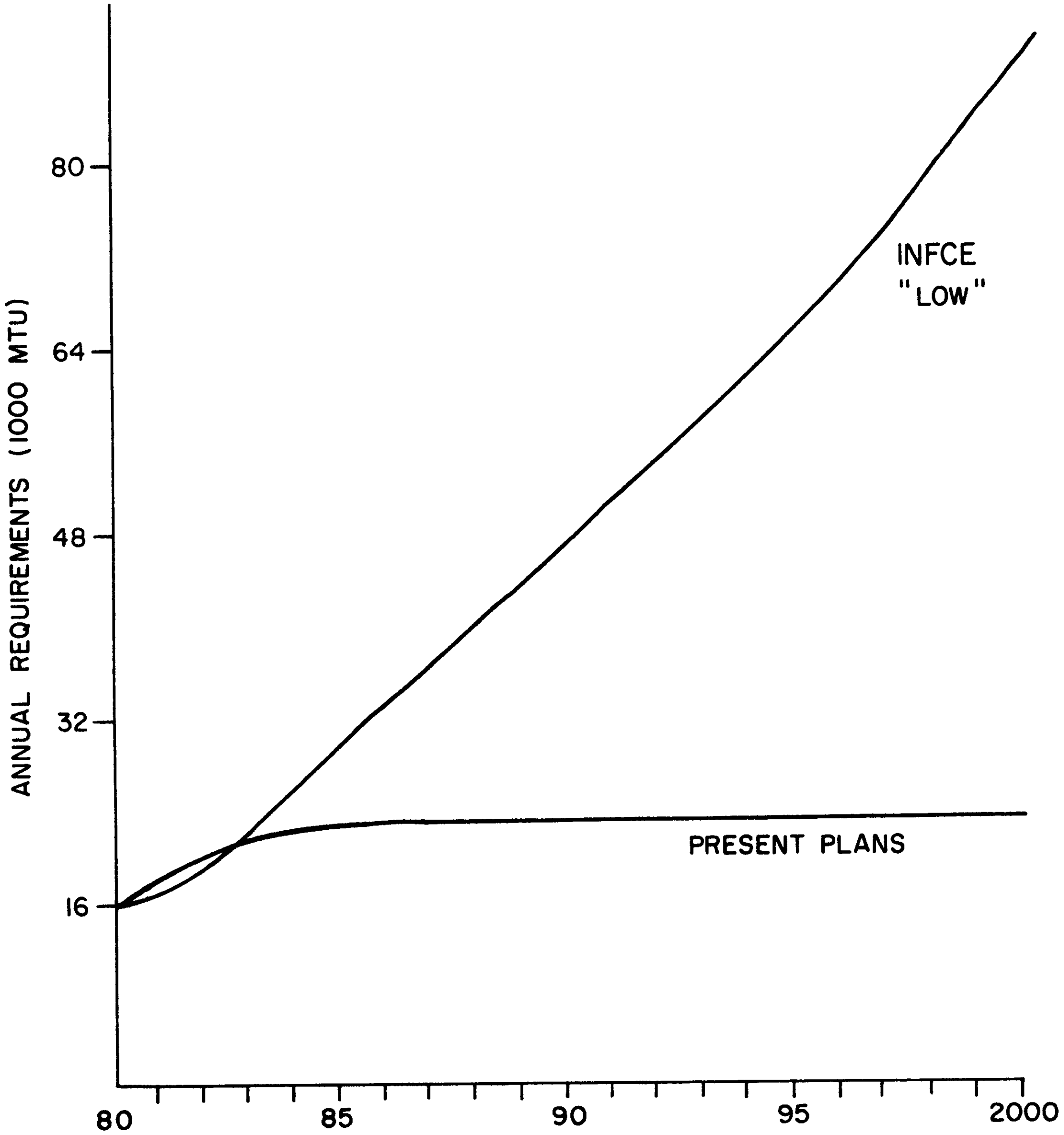
Figure 2.3

PRESENT PLANS AND INFCE NUCLEAR GROWTH PROSPECTS
(non-U.S. WOCA)

2.2.3 Associated Uranium Use

Using assumptions and procedures discussed in the Appendix, these nuclear growth scenarios can be converted to uranium requirements, as indicated in Figure 2.4. Being a compilation of official country estimates, the INFCE reactor projections lead to a consumer view of uranium demand. As noted above, this expectation has a much greater chance of being high than low. On the other hand the preservation of the option for higher growth has an important value to national energy planners, and one would expect optimism in these estimates. Uranium producers are likely to take a more conservative view of demand, unless (as we shall discuss below) the risk of overestimating demand is borne by consumers or their governments. The "present plans" estimate (based on the Nuclear News survey) is what producers might, with some optimism, regard as demand directly due to reactor requirements over the next decade. Once again, it is very unlikely that new reactor orders could make a significant contribution to demand until after 1990. Note that these projections do not include other sources of demand such as stockpiles or enrichment contract requirements in excess of reactor needs.

Here it should be noted that in this study all estimates of uranium demand at the reactor have been based on a reactor capacity factor of 70 percent. As noted earlier, the reactor experience to date is closer to 60 percent. Thus our demand estimates are most likely high, perhaps by as much as 15 percent depending on the success of the nuclear industry in improving plant performance. In any long-term analysis of the industry, this uncertainty about reactor capacity factors lends an important component of uncertainty to forecasts of uranium demand at the mine.



SOURCE: TABLE A-10, APPENDIX

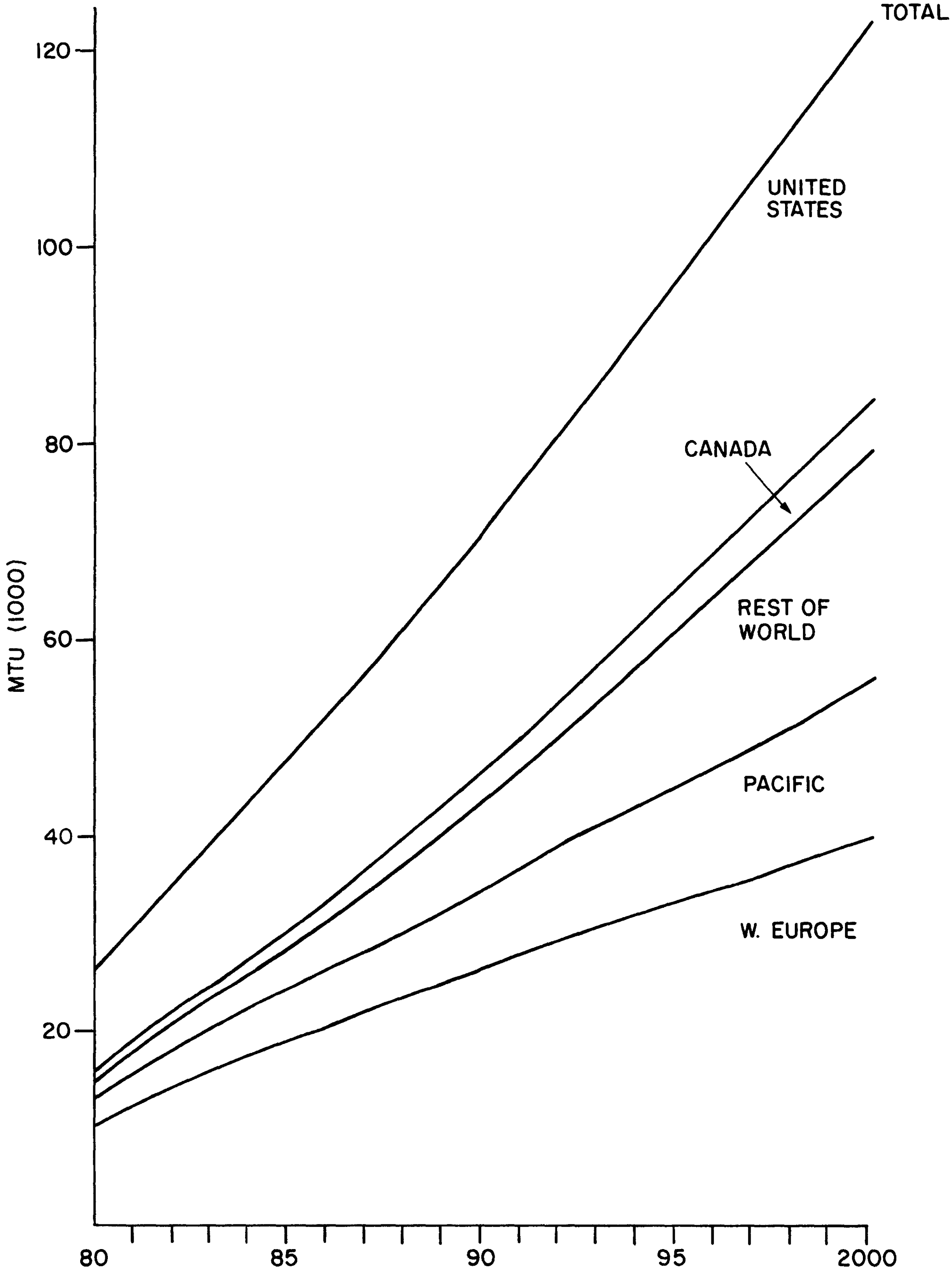
Figure 2.4

ANNUAL URANIUM REQUIREMENTS
(non-U.S. WOCA)

The near-term demand picture is still more complicated than indicated by these aggregated data. This simple view would be relevant if the world market were homogenous, free of constraints, and without major risks. However, the uranium market is fragmented along geopolitical and other lines and flows of material are subject to a number of constraints. As a result, a given producer will not have equal access to all demand and a given consumer will not have equal access to all sources of production. For example, U.S. producers are principally oriented toward U.S. demand and central African producers toward demand in France.

In Chapters 4 and 5 we look in some detail at the large producers and consumers, and in Chapter 6 a picture of the supply system as it will work in the early 1980's is constructed. Therefore it is useful to disaggregate uranium demand forecasts by country and region. In the later chapters, the analysis is focused on the world outside the U.S., but at this point the U.S. is included in order to give an impression of its relative role in overall uranium demand.

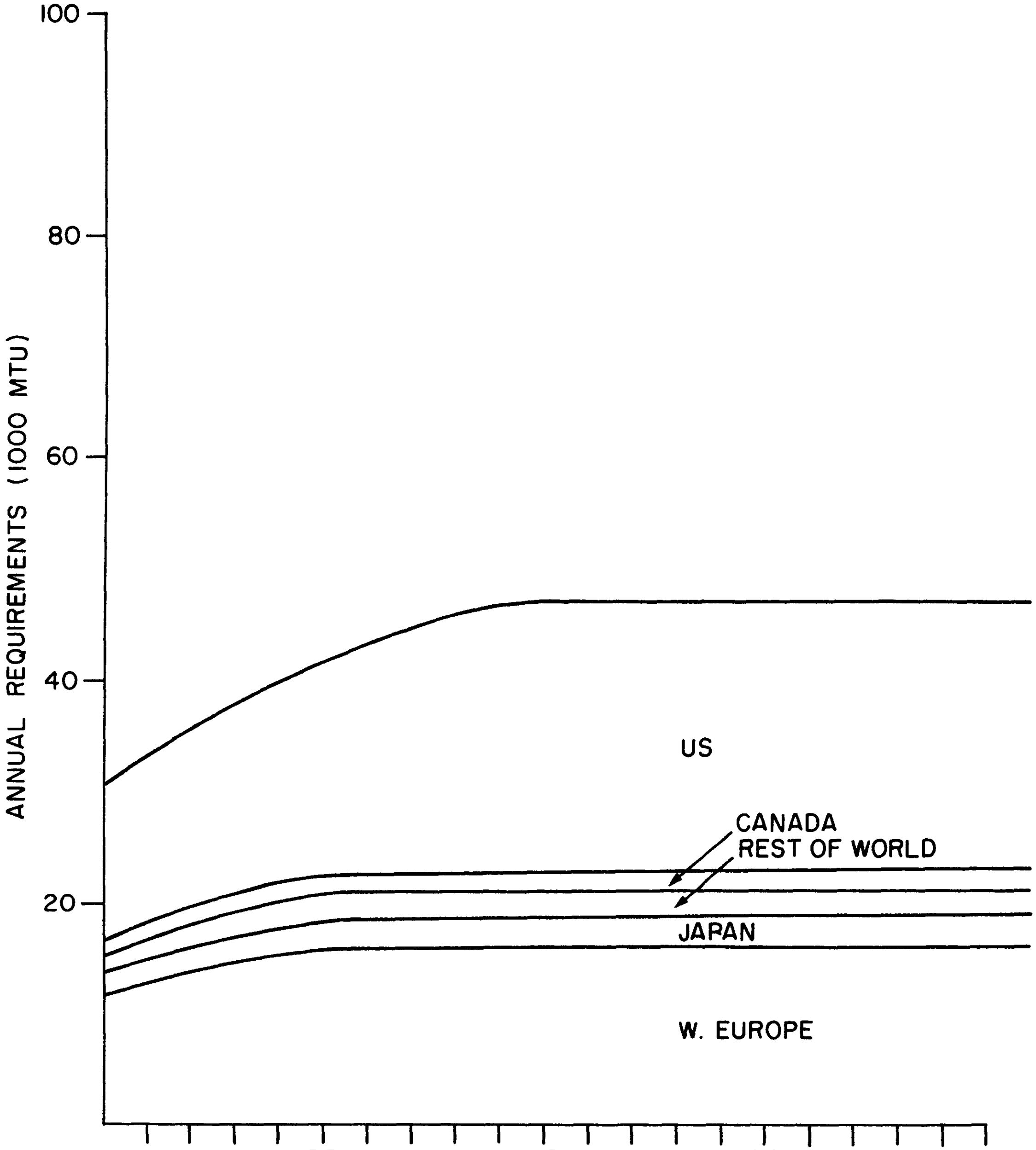
Figure 2.5 shows such a breakdown of the requirements implied by the INFCE low projection. Figure 2.6 shows the same breakdown for the "present plans" estimate, based on the Nuclear News utility survey. At present, U.S. requirements are about 45 percent of the world total; by the late 1980's, the INFCE projection shows this percentage as declining to about 34 percent, while the current plans projection shows a relatively constant ratio. Both projections indicate that about 80 percent of non-U.S. demand in 1985 will be in Western Europe and Japan, though the INFCE projection shows this share declining to about 70 percent by the mid-1990s. In absolute terms, the INFCE projections show demand outside the major industrialized consumer countries (Europe, the



SOURCE: TABLE A-11, APPENDIX

Figure 2.5

OECD/INFCE URANIUM REQUIREMENTS



SOURCE: TABLE A-12, APPENDIX

Figure 2.6

URANIUM REQUIREMENTS FOR "PRESENT PLANS"
(INFCE groupings)

U.S., Japan, and Canada)--largely in the developing countries--growing from a present 1200 MTU annually (5 percent of total world demand) to nearly 20,000 MTU in 2000 (18 percent of total demand in that year); the current plans projection is for only 6 percent from the late 1980s on. The disaggregation of future demand is thus rather uncertain, depending on what one assumes about future reactor orders.

The possibility of changes in supply policies for political reasons, or due to changes in market conditions (e.g., technical or labor difficulties for a major producer or change in enrichment contracting policy) means that this demand structure may shift in ways that open up new sales opportunities for producers. Extra production capacity may be maintained for this purpose. Similarly, the threat of supply insecurity may lead to diversification and over-contracting by consumers. The result of these uncertainties is thus a level of market activity, and supply capability, greater than might be expected from actual reactor requirements under efficiently functioning market conditions. Indeed, the present high global uranium production level--compared to actual reactor requirements--is at least in part a measure of these producer and consumer responses to perceptions of instability and uncertainty. Part of the excess over actual requirements is due to conservative consumer behavior (over-contracting, stockpiling, and so forth), and part due to producer anticipation of new market opportunities.

2.3 The Role of Enrichment

Enrichment plants may be operated at a waste or "tails" stream of anywhere between 0.2 and 0.3 percent U_{235} or higher. At 0.2 percent tails, a 1000 MWe reactor operating at a capacity factor of 70 percent, would require 138 MTU of natural uranium feed for a year's operation. If the tails assay is increased to 0.3 percent, 172 MTU are required, and a higher quantity of U_{235} goes into the stock of uranium held in the form of tails. At some additional cost (for re-gasification of the UF_6) these tails can be run back through the enrichment process, and processed to a lower assay, thus extracting more U_{235}.

In the past, decisions about enrichment operations and contracting have had a major effect on the demand for uranium feed. In the early 1970's, for example, the United States government had a stockpile of some 38,000 MTU, and it was decided to reduce this stockpile through a "split tails" program. The enrichment plants were run at 0.25 percent tails assay, but enrichment contracts were written as if they were running at 0.20 percent. In effect, the stockpile of natural uranium was to be converted into a stock of "pre-enriched" 3-percent material--used to meet part of customers' needs--plus a larger stock of U_{235} in enrichment tails (see Figure 2.1). The reasons for this policy had to do with a combination of factors, including a desire to reduce government-held stocks of raw materials and a perception of a coming future shortage of enrichment capacity [2]. For this discussion, what was important about this procedure is that U.S. stocks were substituted for mine and mill output, and the net demand on the uranium sector was reduced to about 90 percent of what it would otherwise have been.

Shortly thereafter, another change in U.S. enrichment policy had an even larger effect on uranium demand, in the opposite direction. In 1973 the AEC switched to long-run, fixed commitment (LFTC) contracts. The LTFC contracts required that utilities make firm long-term commitments for enrichment services, and through the associated feed requirements, for uranium. The AEC also decided that orders would be accepted only for reactors that would require the enrichment of initial cores by July 1982. By most accounts, the result of these requirements was a new wave of commitments to reactors here and abroad and thus to new long-term uranium demand [2].

These rigorous enrichment conditions have subsequently been relaxed--in part due to competitive pressure from new European enrichment ventures. New enrichment contracting flexibilities, including the option of a customer-specific variable tails assay and stretchout provisions, will reduce the direct future influence of enrichment program decisions on uranium demand. Of course, the recent relaxation of these contract requirements reduced demand expectations for the uranium industry, at least in the near term.

At this point, the influence of widely shifting enrichment contracting conditions appears to be a phenomenon of the past so far as the uranium market is concerned. U.S. stocks of U_3O_8 have now been converted into enriched form, and the tails assay seems to have settled at around 0.2 percent both in the U.S. and in European enrichment ventures. However, the existing stocks are large, both of natural uranium and of enriched material. And due to a combination of less-than-completely-flexible enrichment contracts, and reactors that are either slipped in schedule or cancelled, the inventories of enriched material will continue to build in the near future. No doubt these inventories are substantially larger than those that consumers had originally planned to develop. This buildup of stocks naturally adds to the demand for uranium at the enrichment plant, although enrichment contract terms will probably exert only a small influence on future uranium demand.

2.4 The Role of Stocks

The demand for stocks is the total of several diverse effects. First, there is some working inventory in the system, which increases more or less in proportion to throughput. Then there are stocks--usually of U_3O_8 or 3 percent UF_6--which are held for security reasons. These may be held by utilities or by governments and the size of the stock varies according to the country and the holder's perception of future risks of loss of supply. Finally, there are what we might call "unanticipated stocks." That is, procurement plans and commitments are usually based on some particular reactor forecast, and when reactor expectations are scaled down, the consumer builds inventories he had not planned to acquire. Once on hand, these inventories overhang the market, and create uncertainty regarding future uranium demand.

There is an inherent difficulty in estimating how big these "unanticipated inventories" are, or in predicting how they will be managed. Though utilities or consumer countries may publish data on existing and planned reactors, they rarely release data on stocks of fuel materials, or on the desired levels of these stocks. Indeed, some consumers may have no firm policy about the desired level, given reactor forecasts and anticipated conditions in the world uranium market. At the very least, different countries appear to be following very different strategies in this regard, as discussed in Chapter 5 below.

Footnotes Chapter 2

1. OECD Nuclear Energy Agency and the International Atomic Energy Agency, *Uranium Production and Short-Term Demand* (Paris: OECD, 1969). OECD Nuclear Energy Agency and the International Atomic Energy Agency, *Uranium Resources, Production and Demand* (Paris: OECD, 1970, 1973, 1976, 1977, 1979).

2. T.L. Neff and H.D. Jacoby, *Nuclear Fuel Assurance: Origins, Trends, and Policy Issues* (Cambridge: M.I.T. Energy Laboratory, Report No. MIT-EL 79-003, 1979) and T.L. Neff and H.D. Jacoby, "Supply Assurance in the Nuclear Fuel Cycle," *Annual Review of Energy*, Vol. 4 (Palo Alto, CA: Annual Reviews Inc., 1979), pp. 259-311.

III. URANIUM SUPPLY

3.1 Introduction

The supply of uranium is a function of numerous factors. At the simplest level, the supply of uranium depends on the geologic endowment. Given perfect knowledge of the occurrence of all uranium, one could estimate production costs and derive a supply curve--the amount of uranium that would be available at a given price. If uranium were like many other minerals, one would expect increasingly large quantities to become available as prices increased and as one thus had incentives to mine lower grades of ore, or deposits that were more difficult to exploit. For example, such a picture might emerge for a resource that had many different geologic expressions, or occured in deposits of vastly different size. Alternatively, one might believe that uranium is discretely deposited in such a way that there is not an continuum of occurrences, grades and sizes of deposit, but rather a limited quantity of high or moderate grade material in a limited set of geologic environments. In this case, known deposits would represent a larger fraction of total potential than under the former hypothesis.

Since we do not have perfect knowledge of the uranium resource endowment, we cannot *a priori* distinguish between the two extreme views above. However, the way in which information about uranium is developed tends to bias one's perspective of the resources in the direction of the second view. There are several ways in which this occurs. First, it is economically attractive to explore only for those deposits that will be profitable in the relatively near term. Thus information is biased toward higher grade or more easily discovered and exploited deposits. Regions further out on the supply curve tend to be explored only accidentally. Second, success in discovering reserves adequate to meet demand over the period of time in which uranium industry investments are repaid (perhaps two decades) tends to inhibit further investment in developing additional information. And if this success is achieved in one geologic environment or one geographic region, there is little incentive to look elsewhere. Until recently, for example, most effort in the U.S. was focused on sandstone deposits in a few proven basins, and in Canada (which was intensively explored for weapons purposes) on particular formations in the eastern provinces. At least in Canada, the result of adequate success in the East was the failure to discover even richer deposits in the West.

Third, commercial interest in uranium is relatively new and market trends over the period have discouraged development of information about resources that are more expensive to exploit. Before the last decade, much of the exploratory effort was directed toward meeting the weapons needs of a few countries. The search was limited to countries friendly to the weapons states--Canada, Australia, South Africa, and the Belgian Congo (Zaire) for the U.S. and the U.K.; former colonies in central Africa (Gabon and Niger) for France. Little effort was made elsewhere and even in the producer countries in question, exploration was retarded by saturation of weapons requirements and declining real prices. For example, the real price (corrected for inflation) offered by the U.S.A.E.C. in 1955 was not achieved again--in the commercial market--until late 1975; in the interim, it dropped by nearly a factor of four. Declining expectations lead to conservative exploration and development behavior, with an emphasis on exploiting known low-cost reserves.

Information development also has significant lead times. While the existence of a new deposit may become known shortly after initial exploratory work (though the companies involved have strong incentives to restrict the availability of such information), it may be some years before enough is known to make estimates of reserves. Companies will invest in developing such information only in response to market signals; thus additions to known reserves generally lag new demand indications. Overall resource and reserve estimates tend to lag even farther behind since time is required to analyze primary data and integrate them into a comprehensive view. As a result, published estimates of national or global reserves and resources may lag by a decade or so the occurrence of the forces that motivated the exploration and other work leading to their discovery.

Bias in the magnitude of such estimates may also be introduced by the particular interests of the entities that prepare the figures. Companies and producer governments may have an incentive to take a conservative view of their uranium reserves, lest the prospect of larger quantities undermine prices. On the consumer side, there is a complementary conservatism: utilities and consumer nations tend to take a worst case view of strategic energy commodities since the consequences of overestimating availability are usually much greater than those of underestimating it.*

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*Countries can, in fact, have opposed views of this. The U.S., for example, sees adequate uranium supply as desirable in reducing the need to commit to plutonium or other proliferation-sensitive fuel cycle steps worldwide. As a result, from the U.S. perspective, underestimating uranium resources may lead to worse consequences than overestimating them. This view is opposite to that held by countries that put a higher priority on energy supply.

Thus, many of the forces influencing perceptions and knowledge of uranium resources and reserves work in the direction of conservative estimates and toward a view of ultimately limited resources. Typical of such estimates is the Uranium Subpanel Report of the National Academy's Committee on Nuclear and Alternative Energy Systems (CONAES) [1], which displays several of the conservatisms noted above, including the national energy policy assumption that one should not count for planning purposes on resources that are not already known. The alternative position is well expressed by Landsberg in the Ford-MITRE Study [2]. Here, the process of information development and resource exploitation is seen more in economic terms (the CONAES Panel consisted of geologists); it implicitly assumes that resources of various qualities exist (the first view above) and that the problem is one of incentives to proceed to find and develop them.

3.2 Trends in Exploration and Discovery

Given these alternative views, it is instructive to examine trends in resource estimation and development. Outside the United States, the only consistent long-term series of estimates has been compiled by the OECD/IAEA working parties on uranium resources [3]. As with the nuclear reactor projections, uranium estimates are based on country submissions, though working party judgments are occasionally necessary. Two categories of resource certainty are considered:

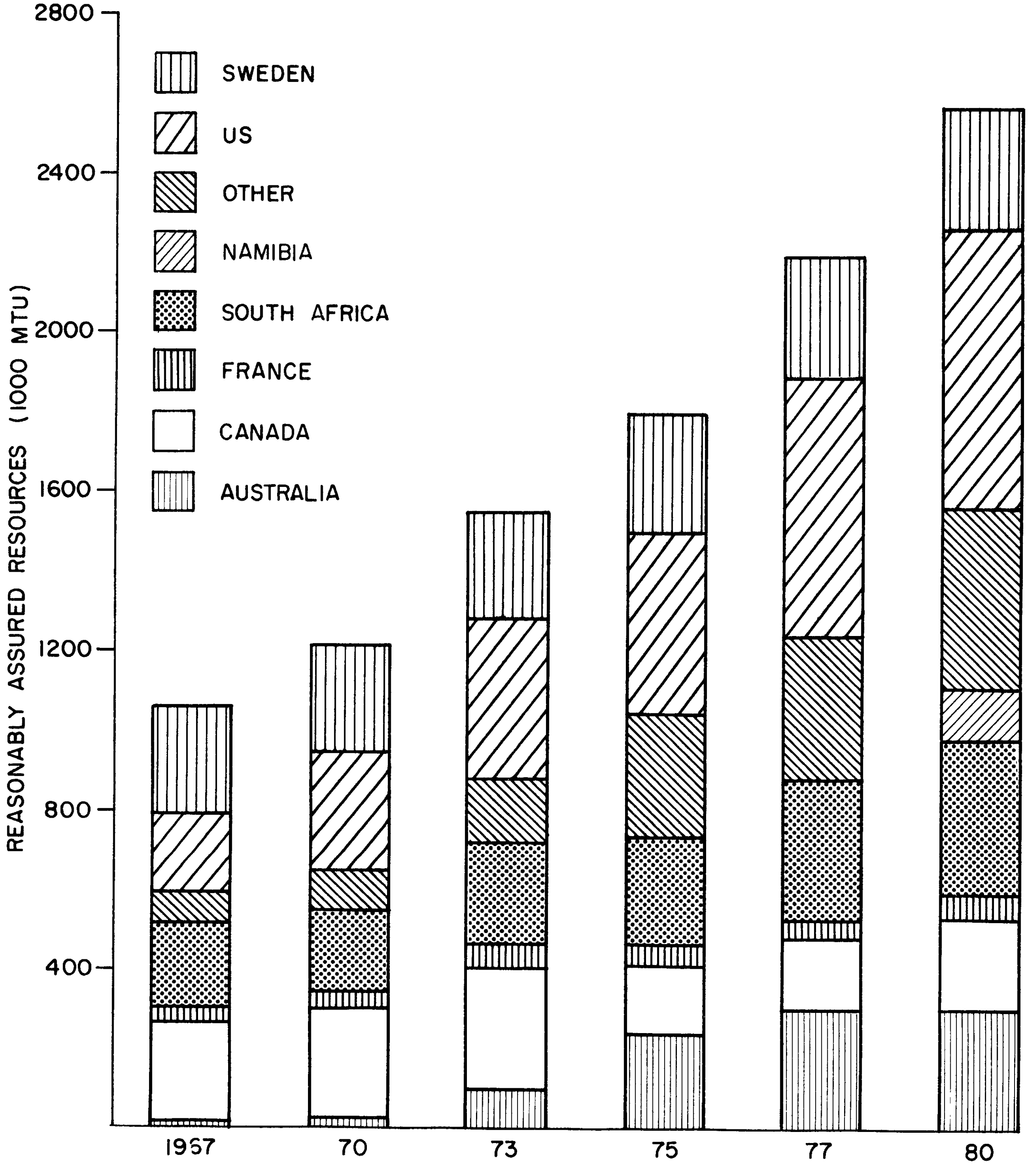
- "Reasonably assured" or (approximately) reserves for which there is direct quantitative geological evidence of grade and quantity, say by drilling.
- "Estimated additional" for which there is direct geological

evidence of material, generally in association with known and delineated deposits.

These two categories are parallel to the U.S. definitions of "reserves" and "probable potential resources." Until recently, the OECD/IAEA group did not estimate "possible" and "speculative" resources, as the U.S. has for many years.

Two price/cost categories are also considered. These categories have undergone two changes over time, the first due to changing production costs and inflation, and the second due to a switch from a commercial price to a forward cost basis. Thus, early reports refer to uranium available at a price of less than \$26/kilogram U (\$10 per pound U_3O_8) while later reports refer to uranium available at a cost of less than \$80 per kilogram U (\$30 per pound U_3O_8). The switch to a forward cost basis removes the effects of market price fluctuations in periods when tight market conditions drive prices well above production costs; production costs worldwide currently range from \$4 a pound (U_3O_8) to above \$20, while prices have been as high as \$40 or more in recent years. Despite these changes, efforts have been made by the OECD-IAEA group to make historical estimates comparable. This effort appears to have been most effective for the reasonably assured (reserve) category. Changes in cost categories, and further efforts to convert potential resources to reserves, tend to shift material into or out of the estimated additional category, either shifting into the reserve category, or into a higher cost bracket not considered in the estimates.

Figure 3.1 shows the reasonably assured, or reserve, estimates made since 1967; for convenience, the two price categories are lumped together. Figure 3.2 shows the corresponding estimates for estimated

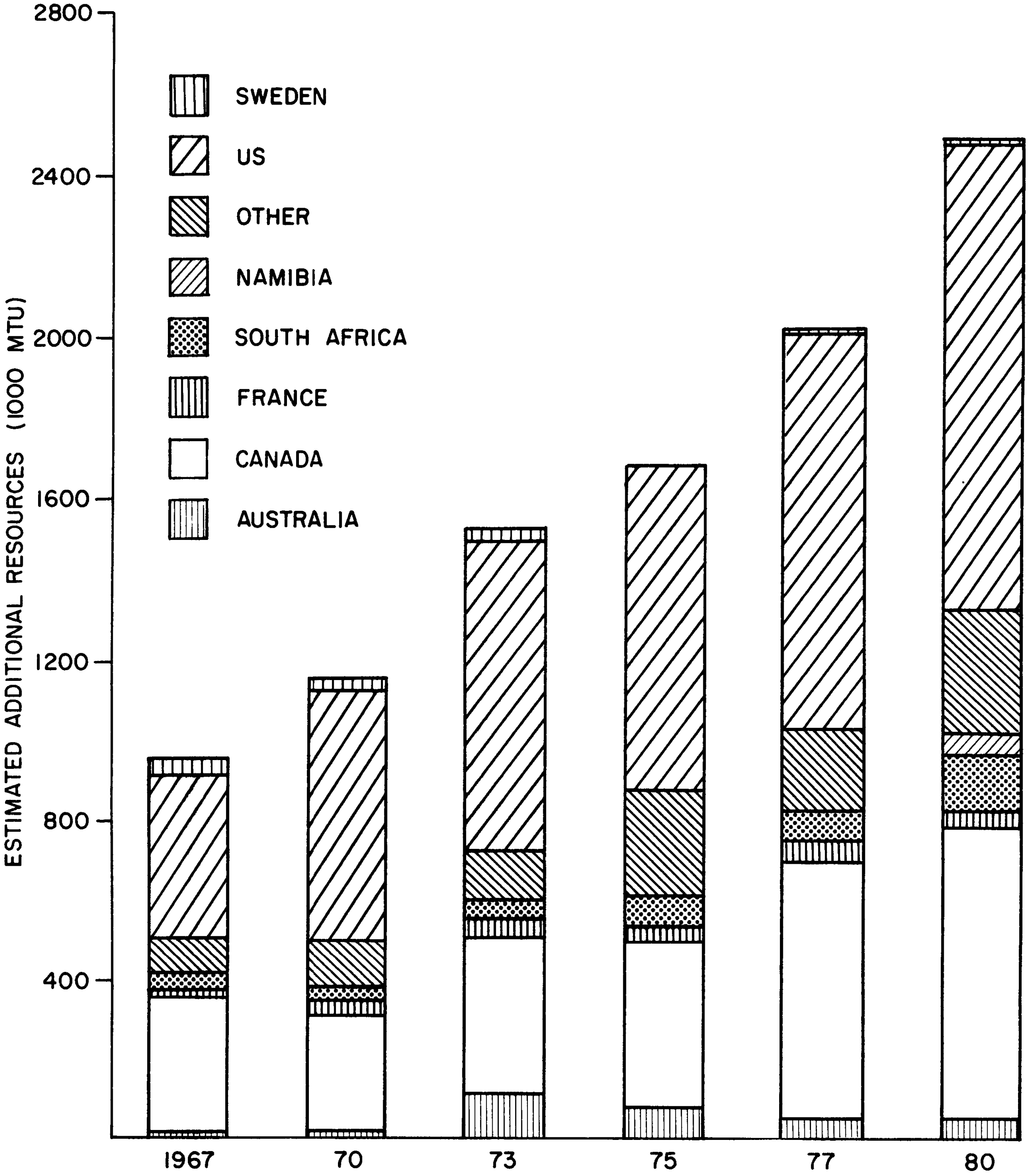


SOURCE: TABLE A-13, APPENDIX

NOTE: SOUTH AFRICAN ESTIMATE INCLUDES NAMIBIA PRIOR TO 1980.

Figure 3.1

OECD ESTIMATES OF REASONABLY ASSURED RESOURCES



SOURCE: TABLE A-13, APPENDIX

Figure 3.2

OECD ESTIMATED ADDITIONAL RESOURCES ESTIMATES additional resources. The largest shifts in and between categories are for Canada where the estimated additional category increased substantially in 1973 and the reserve category declined in 1975. Apart from this anomaly, the estimates track reasonably well over time. Detailed data are tabulated in the Appendix.

The reserve estimates are essentially those for uranium that would be available with some certainty on a relatively short time horizon, were there adequate demand. That is, these reserves are such that commercial mining investments and exploitation could be expanded within a few years (a period often set more by the need for environmental and other clearances than by construction times) following indications of sufficient demand. The reserves in Figure 3.1 also represent the resource data that have been the longest time in preparation. The initiation of the exploratory and other efforts that resulted in additions to reserves late in the decade (say 1980) occurred early in the decade. The present reserves shown are thus the result of expectations about current and future markets as they were perceived five, ten, or more years ago.

Several important conclusions emerge from Figures 3.1 and 3.2. The first is that reserves and resources have increased significantly, in absolute terms and relative to prospective nuclear growth. Outside the U.S. (and excluding Sweden, whose shales are unlikely to be exploited in the near term), reserves have increased by a factor of 2.7 and estimated additional resources by a factor of 2.6 since 1967. In absolute terms, non-U.S. reserves have increased by nearly one million MTU and estimated additional resources by more than 800,000 MTU. These additions occurred during a period in which non-U.S. reactors required a cumulative total of only 85,000 MTU and non-U.S. reactor requirements grew to an annual level of 14,700 MTU (1979). In comparison with past and present reactor requirements, additions to reserves and known resources have been very large.

Perhaps more interesting is the comparison with estimated requirements forward in time. In 1967, known reserves and resources outside the U.S. stood at about 1.4 million MTU; at about this time,the estimate of non-U.S. nuclear growth 10 to 12 years ahead (1980 estimate made in 1969) was for 240 GWe. This lead time is what realistically might be required to move substantial known reserves and resources into production. The estimated growth in capacity would require about 39,000 MTU annually in 1980 (actual growth, of course, has been much less than this), for a ratio of reserves and resources to annual forward needs of about 35. That is, reserves and resources in 1967 were 35 times expected annual requirements eleven years ahead; alternatively, the resource time horizon was 30 to 40 years off, if no additional reactors were considered. In 1978, non-U.S. nuclear growth for 1990 was estimated (by the INFCE working group and the OECD) at about 274 GWe, requiring about 43,000 MTU annually. Shortly thereafter, known reserves and resources were estimated at about 2.9 million MTU for a ratio of the latter to forward annual requirements of about 70--about twice that a decade earlier.* Thus the uranium resource situation outside the U.S. relative to expected nuclear growth has improved significantly. Of course, the nuclear growth estimates play an important role in this: high early

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*As noted above, the INFCE estimate now appears very unrealistic, at least for this decade; the known uranium resource horizon is thus even more distant.

estimates may have stimulated exploration and development while lower recent expectations mean that discovered resources will go farther.

While uranium may prove different from other minerals and energy sources, it is worth noting that known forward supplies of oil and of many minerals have--over much of this century--displayed resource horizons that indicated depletion at the then current consumption rates within, say, twenty or thirty years. Of course, the resource horizon has always retreated ahead of time and consumption; we have not run out. The reason is that knowledge about reserves and resources is usually gained only at some cost, and investments to produce this information will be made by the private sector only if there is a prospect for a relatively near-term payoff. This term rarely extends beyond a few decades and for private resource exploiters there is little need to know about material that might be needed beyond this horizon.* As noted above, the underlying question is whether there exist undiscovered resources and undeveloped reserves that will reveal uranium to be like other natural resources. Discovery and other trends are suggestive of this and there is no strong evidence to the contrary.**

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*Government programs to assess resources reflect a social interest in the longer-term view.

**Very large deposits of relatively high-grade ore continue to be found in traditional producer countries like Canada and Australia and in new countries like Namibia and Brazil. This does not mean that certain limited geographic regions--such as the current sandstone regions of the U.S.--will not come to resemble terminally depleting regions in a few decades. However, this limited view would not generalize worldwide or even to the rest of the U.S.--there has been too little exploration and uranium has been found in increasingly many new geological environments. And even in the U.S. sandstone basins, there appear to be large deposits at greater depths (e.g., Gulf's Mt. Taylor property). Thus while costs may rise in some areas, there appears to be uranium available.

Figures 3.1 and 3.2 also show a changing pattern of geographic origins for reserves and resources: major new additions have been made in areas that have not traditionally produced uranium. Niger's known reserves have increased by about 150,000 MTU since 1967, a seventeen-fold increase; Brazil's reserves--little evident before 1975--have reached about 75,000 MTU; and Namibia's uranium reserves have increased to an estimated 117,000 MTU. Overall, reserves in countries other than traditional producers (Canada, Australia, the United States, France, and South Africa) have increased by about 580,000 MTU since 1967, about 210,000 MTU being added since late 1977 alone. Non-traditional (prospective) producers thus account for more than half of the increase in reserves over the past decade. A similar statement applies to known resources. For consumer countries concerned about supply security and supply diversification, this is a very important development. It also reinforces the suspicion that exploration and reserve development--rather than geologic scarcity--are the principal barriers to knowledge of much greater uranium reserves and resources. Evidence for this comes also from major new discoveries in traditional producer countries such as Canada and Australia. Many of these discoveries are in new geologic environments, such as calcrete and unconformity-related deposits and often have ore grades well above those already being mined. Some major discoveries, such as the reported half million tons at Roxby Downs in Australia, do not yet appear in official estimates. This deposit alone is comparable to non-U.S. cumulative uranium consumption through 2000 for all presently committed reactors. The view that uranium is a mature resource whose exploitation is proceeding to lower and more costly grades and environments is thus contrary to the most recent evidence.

3.3 Capacity Development and Production

The supply of uranium is determined not only by geologic factors and investments in reserve and resource information. Several different groups of actors are involved in producing uranium and they often act with different motivations. Historically, governments have played a key role. Initially, in the 1940s and 1950s the governments of weapons states and those of a few key producer countries promoted the development of uranium production and production capacity. Bonuses, guarantees, loans, and incentive prices motivated the discovery of uranium and the development of a major industry, especially in Canada, Australia, France, and South Africa. Later, as weapons demand fell but before commercial demand rose, producer governments took actions to protect their domestic industries.

3.3.1 Production History

Historically, uranium production worldwide rose to a peak in 1959 in response to weapons procurement efforts. It subsequently fell with the decline of weapons demand and the delay of commercial nuclear power. During this period producer governments instituted support programs in order to maintain a viable industrial base pending growth of commercial demand; in some cases, substantial stockpiles accumulated. These programs were most effective in the U.S., especially in the initial years of commercial nuclear power growth, due in part to protectionist import restrictions (exercised through the U.S. enrichment monopoly).* Production has only recent reached the levels attained in 1959. These features are shown in Figure 3.3.

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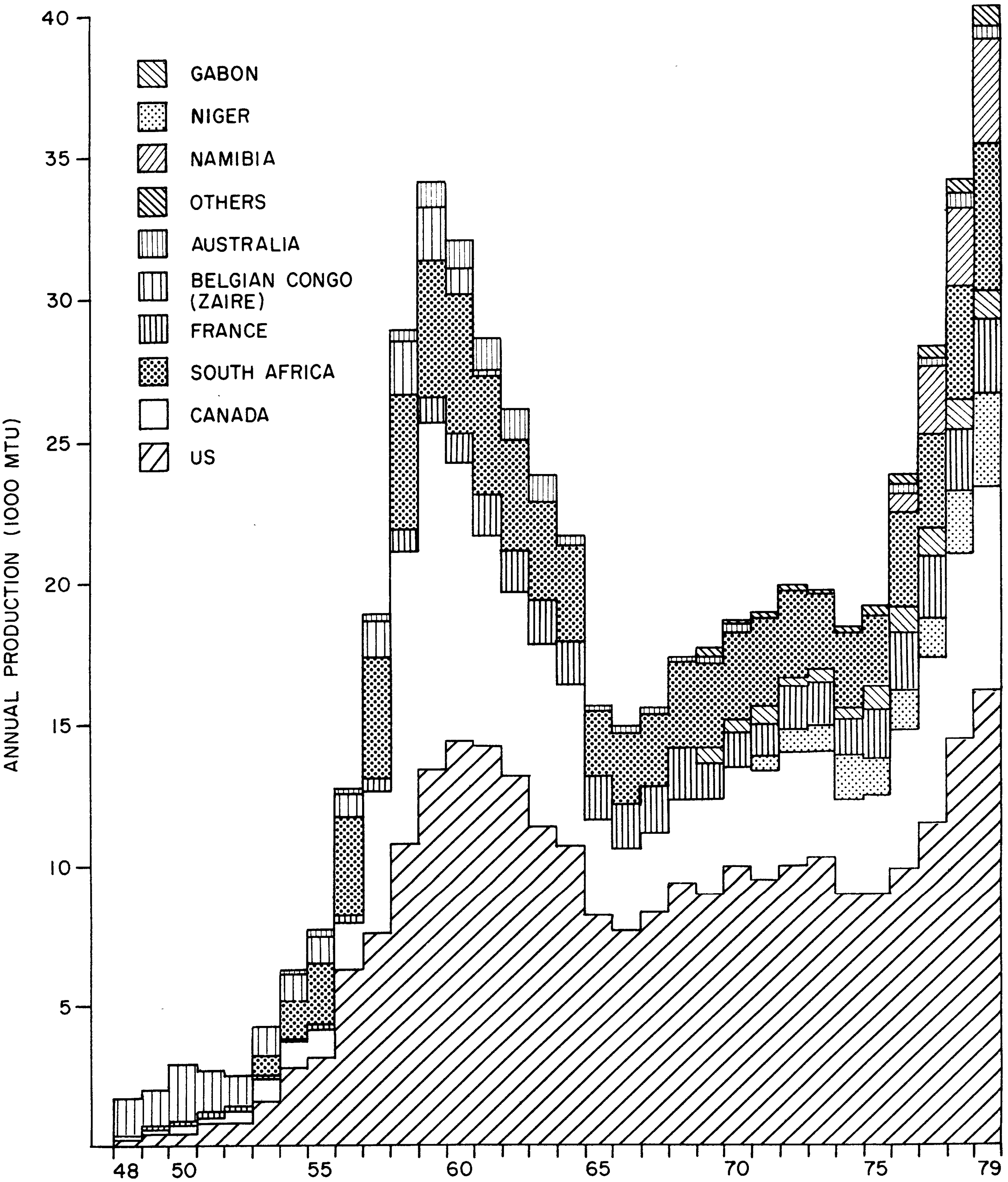
*For further details of this history, and the linkages to other nuclear issues, see [4].



SOURCE: TABLE A-14, APPENDIX

Figure 3.3

HISTORIC URANIUM PRODUCTION

It is useful to compare historical production with actual reactor requirements during this period. Reactor requirements were computed from historical dates of initial operation for each existing reactor, assuming operation at 70 percent capacity factor and 0.20 percent tails assay. These assumptions probably overstate requirements: enrichment plants often ran at higher tails assay but utilities delivered uranium as if tails assay were set at 0.20 percent (the additional uranium came from U.S. stockpiles rather than contemporary commercial sources) and capacity factors were well below 70 percent.* Annual reactor requirements are compared with production in Figure 3.4. Since weapons requirements were dropping rapidly in the post-1965 era, much of the excess of production over commercial requirements was stockpiled. In the U.S.and other weapons states, distinctions between military and non-military stocks are somewhat artificial. It is evident from Figure 3.5 that stock accumulations in the U.S. may have been of order of 100,000 MTU.** Abroad, a similar quantity seems possible, held primarily by Canada, South Africa, the United Kingdom, and Australia.

The global supply/demand balance has actually been closer than suggested in Figure 3.4 because of enrichment contracting requirements. The introduction of fixed-commitment contracts and new enrichment plant feed requirements in 1973 tended--when compared with slipping reactor schedules--to result in uranium demand above that required for actual reactor use. The effect of these rigid delivery requirements would have

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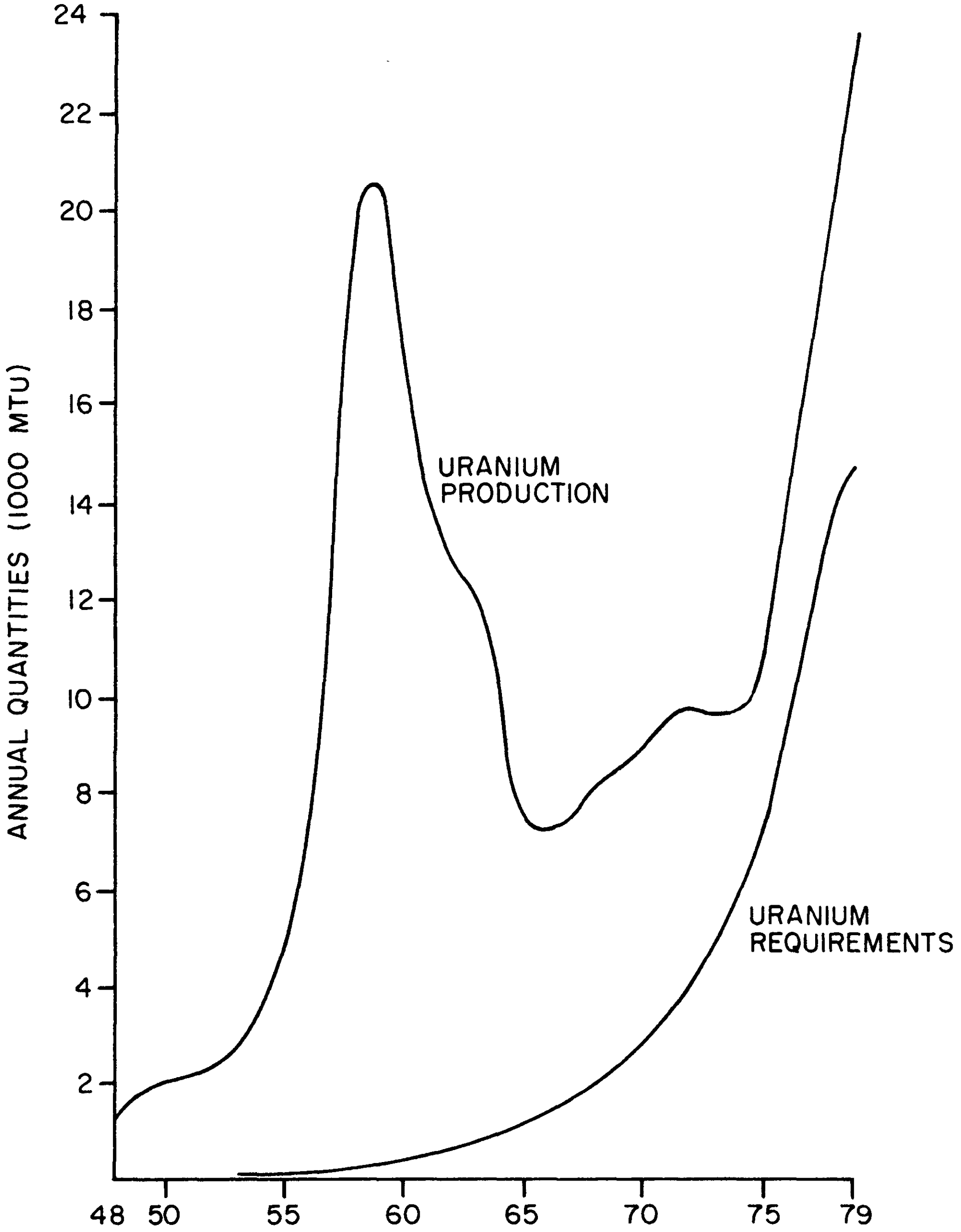
*A potentially countervailing factor might have been the failure of early fuel to achieve design burnup; however, this problem primarily affected early fuel loadings whose aggregate volume, compared to current consumption, was small.

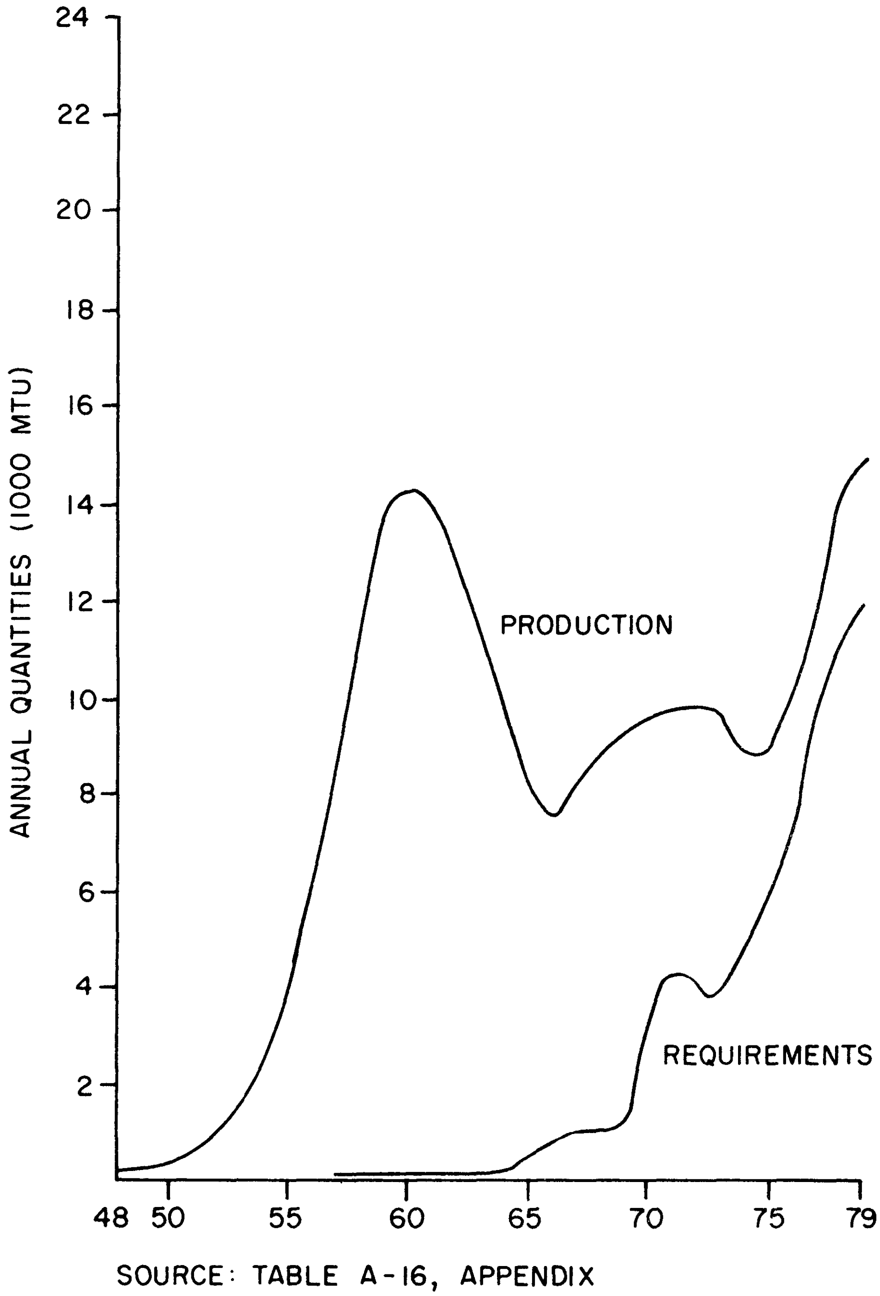
**Non-military stocks have, on several occasions, been reported as being in the vicinity of 50,000 STU_3O_8.



SOURCE: TABLE A-15, APPENDIX

Figure 3.4

WORLD URANIUM PRODUCTION AND REQUIREMENTS
(non-U.S. WOCA)



SOURCE: TABLE A-16, APPENDIX

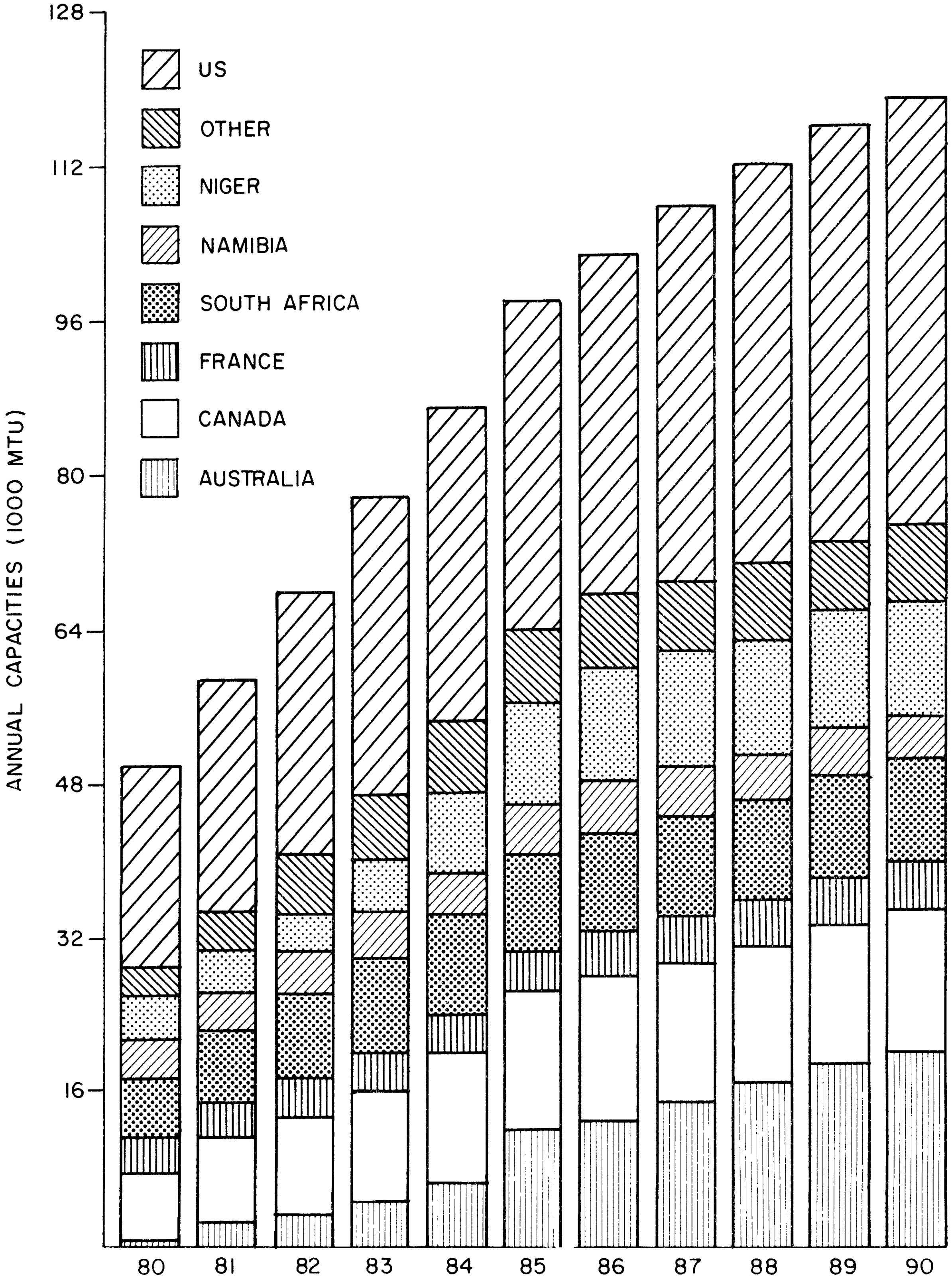
Figure 3.5

HISTORIC U.S. URANIUM PRODUCTION AND REQUIREMENTS been most strongly felt in the last few years and in the future; but recent changes allowing deferrals and creating more flexible conditions have, in part, relieved this strain on consumers. Nevertheless, substantial inventories have been built. As of January 1, 1980, U.S. utilities, reactor vendors, and other companies reported inventories of 40,000 MTU (natural uranium equivalent--about 30 percent was already enriched). About 82 percent of total inventory was held by utilities. The pattern abroad varies and will be discussed in the next chapter.

But the most striking feature of Figure 3.4 is its revelation of the relative immaturity of commercial uranium demand, compared to the length and magnitude of previous industry efforts. Reactor requirements were still less than half of production as late as 1974 and today are still only about two-thirds of production levels. It is only in the past few years that requirements and supply have begun to appear to be related. In a sense, one can thus argue that a mature commercial uranium market is only beginning to emerge internationally.

3.3.2 Forecasts of Plans and Potential

It would clearly be interesting to continue the above retrospective comparison of supply and requirements prospectively forward in time. Superficially, this might appear simple: one could project uranium requirements forward in time--as in Chapter 2--and, independently, estimate production capabilities. Estimates of attainable production capabilities are presented by several groups, the best known being those of the OECD-NEA/IAEA working group (as published in the "Redbook" series [3]). In Figure 3.6 we present the most recent (February 1980) results of this group. The attainable production capacity estimates are just that: estimates of what might be achieved given adequate incentives and



SOURCE: TABLE A-17, APPENDIX

Figure 3.6

ATTAINABLE PRODUCTION CAPACITIES

few new obstacles to exploitation. As discussed in the next chapter, estimates for some producers are close to what is realistically planned; for others, the attainment of the estimated production levels is quite problematic. In Figure 3.7, we show the 1979 Redbook [3] estimates of planned production capacity for which (at least) initial investment has been made and clearances granted. For at least some countries, the planned capacities are considerably lower than the attainable.

3.4 Demand/Capacity Balance to 2000

How do these attainable and planned production estimates compare with the reactor requirements projected in Chapter 2? Figure 3.8 gives the answer. For continuity, historical production and requirements are shown up to 1979; after that the attainable and planned capacity estimates are compared with the uranium requirements resulting from both the INFCE and present plans growth projections. As discussed above, the present plans projection includes only those reactors for which (at least) a letter of intent has been issued. The INFCE projection includes a number of new reactors abroad coming on line in the mid-1980s. Since this projection was made (early in 1978), there have been few orders abroad and there is little likelihood--given reactor lead times--that reactor demand in excess of the present plans projection could arise until quite late in the decade.

Figure 3.8 shows clearly that production presently exceeds reactor requirements.* The magnitude of the disparity in the near-term future

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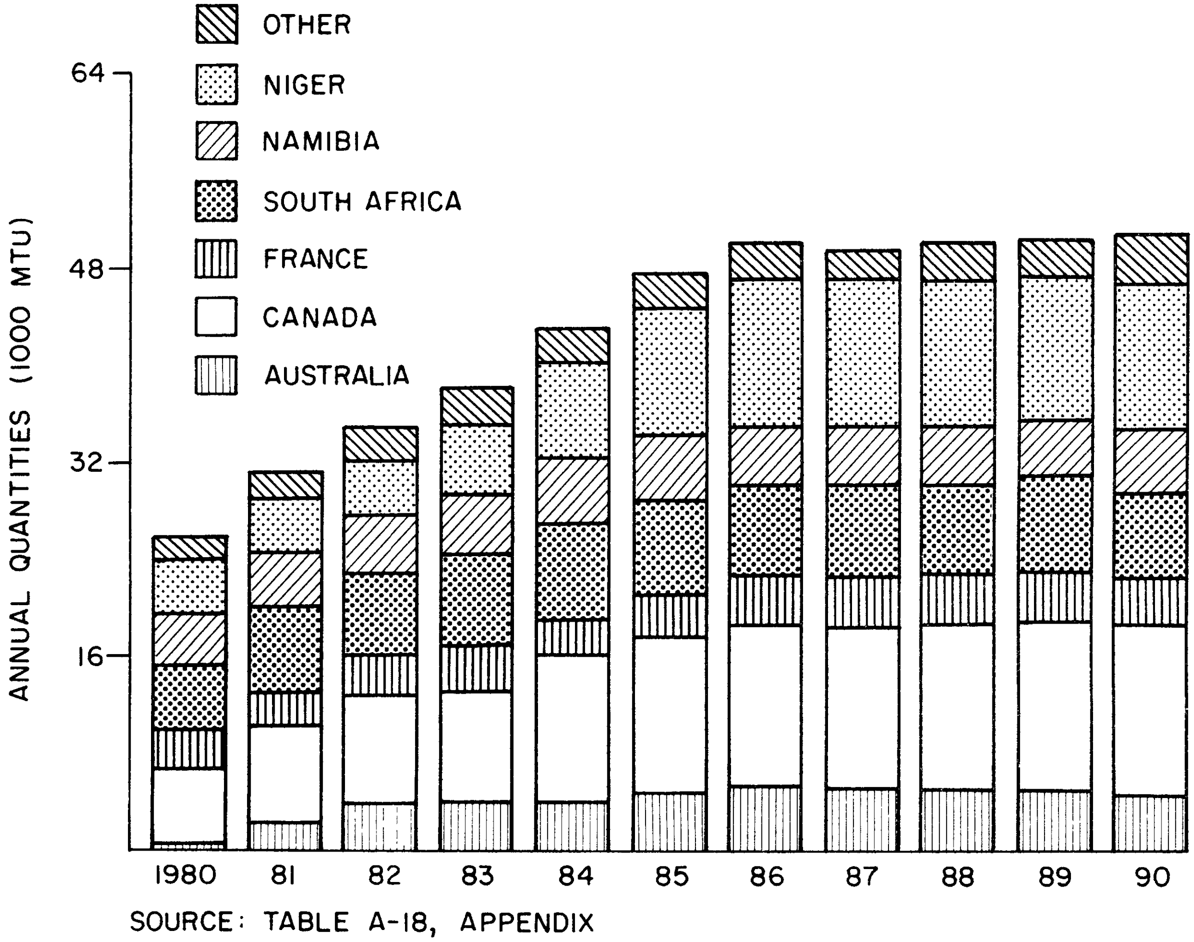
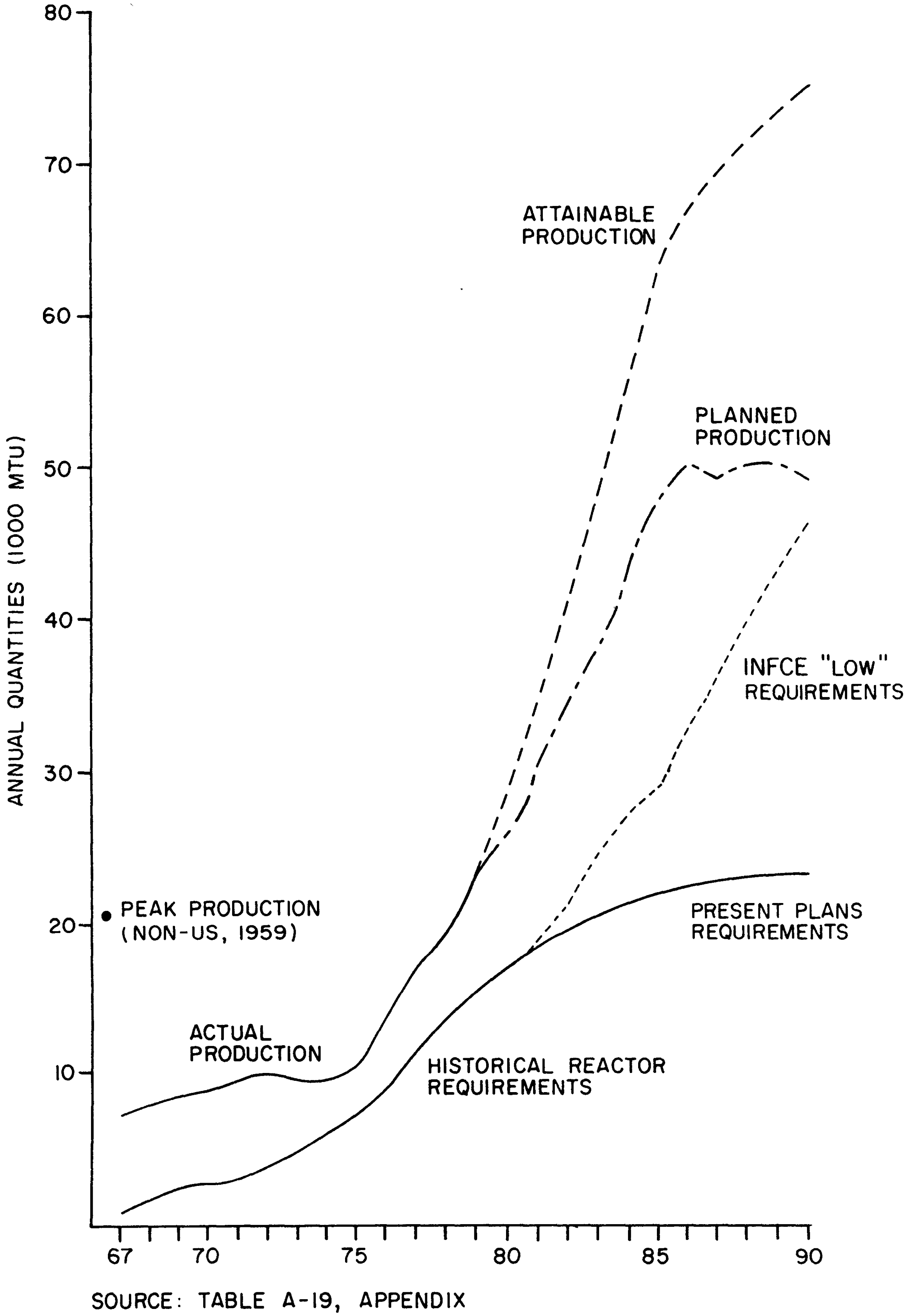
*Total demand also includes desires for inventories and enrichment plant feed requirements in excess of reactor needs. However, both appear to be of declining importance.



SOURCE: TABLE A-18, APPENDIX

Figure 3.7
PLANNED PRODUCTION CAPACITY



SOURCE: TABLE A-19, APPENDIX

Figure 3.8

URANIUM PRODUCTION AND REQUIREMENTS
(non-U.S. WOCA)

depends on the momentum in current plans and on the extent to which existing production capacity is utilized. Figure 3.8 suggests that even if production were just to continue at current levels, requirements would not come into balance with supply until perhaps 1985. Moreover, new production capability for which mine and mill investments have already been made will come into existence in the next few years. The obvious conclusion is that unless measures are taken to restrict use of existing and prospective uranium production capacity, there will be a general and substantial oversupply of uranium, at least during the 1980's. This prospect is discussed in greater detail in Chapter 6, after a review of conditions in the major supplier and consumer countries.

Footnotes, Chapter 3

1. Report of the Uranium Resource Group, Supply and Delivery Panel of the Committee on Nuclear and Alternative Energy Systems, Problems of U.S. Uranium Resources and Supply to the Year 2010 (Washington, D.C.: National Academy of Sciences, 1978).

2. Nuclear Energy Policy Study Group, Nuclear Power Issues and Choices (Cambridge, MA: Ballinger Publishing Co., 1977).

3. OECD Nuclear Energy Agency and the International Atomic Energy Agency, Uranium Production and Short-Term Demand (Paris: OECD, 1969). OECD Nuclear Energy Agency and the International Atomic Energy Agency, Uranium Resources, Production and Demand (Paris: OECD, 1970, 1973, 1976, 1977, 1979).

4. T.L. Neff and H.D. Jacoby, Nuclear Fuel Assurance: Origins, Trends, and Policy Issues (Cambridge: M.I.T. Energy Laboratory, Report No. MIT-EL 79-003, 1979) and T.L. Neff and H.D. Jacoby, "Supply Assurance in the Nuclear Fuel Cycle," Annual Review of Energy, Vol. 4 (Palo Alto, CA: Annual Reviews Inc., 1979), pp. 259-311.

IV. MAJOR URANIUM PRODUCERS

The global view that emerges in the preceding section is of ample supply in relation to actual demand. Yet there have been serious disruptions and continuing concerns about uranium supply on the part of consumers, and differing perceptions of market conditions on the part of producers. These problems are situation-specific. In the sections that follow we review conditions in principal producer countries, including export commitments. In Chapter 5 major consumers are reviewed.

International trade in uranium is highly secretive, not only for the usual commercial reasons, but because of its strategic importance to both energy and international security. There are no comprehensive, public sources of contract data, as there are for many other commodities. Producers and consumers do not ordinarily disclose quantities of imports or exports, or their origin or destination. As a result, it is necessary to build up a picture of market activity from fragments of information appearing in mining or financial journals worldwide. In some cases, considerable inference is necessary, though cross checks between supplier and consumer data are often possible. The information presented below was derived from such a review effort--going back ten or more years in industry journals* and company annual reports--and from privileged communications from suppliers and consumers. Where possible, the information has been checked with companies and government agencies, and with the few industrial data

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*These include Nucleonics Week, Nuclear Fuel, Nuclear Engineering International, the Mining Journal (London), The Financial Times, Canadian Mining Journal, the Canadian Minerals Yearbook and others.

sources available.* However, the reader is cautioned that the picture that emerges should be regarded as impressionistic, rather than exact in every detail. There are enough conflicts between data sources to suggest the possibility of incompleteness or incorrect details in all available sources. But we believe the larger view that emerges is roughly correct and suitable for policy purposes.

The producer countries considered here are Australia, Canada, Niger, South Africa and Namibia. Together, these countries are expected to account for 90 percent of prospective non-U.S. production in 1985 and virtually all internationally-traded uranium.

4.1 Australia

As in other major producing countries, the Australian industry arose in response to the weapons needs of the United States and the United Kingdom. Uranium was discovered at Rum Jungle in the Northern Territory in 1949, and subsequently at other sites--notably the Mary Kathleen mine in Queensland. Liberal financial incentives administered by the Combined Development Agency--and contracts with the CDA, the USAEC and the UKAEA--led to production which began in 1954 and rose to a peak of 1200 MTU in 1961. However, as was the pattern elsewhere, this boom soon began to falter. All contracts terminated by 1964, by which time total cummulative weapons-related production had amounted to about 6,700 MTU. Because of the economic importance of the uranium industry, the

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*These include publications of Nukem (Hanover), Nuclear Assurance Corporation and the Nuclear Exchange Corporation. In general, these information sources serve producers and consumers seeking to make new supply arrangements and thus emphasize a disaggregated approach. Our work is different from, though complementary, to theirs in that it is intended to provide an aggregated view more suited to an overall, policy-oriented understanding of the market.

Australian government (through its Atomic Energy Commission) arranged for continued production at Rum Jungle. Australian production ceased in 1971. By 1971, a national stockpile of about 1700 MTU had been built up.

Uranium production did not resume until 1976, with the revival of output at Mary Kathleen (which still possessed reserves of about 7000 MTU and an operable mill). In the meantime a number of new uranium discoveries had been made, including Nabarlek, Ranger, Beverly and Koongarra in 1970, Jabiluka in 1971 and Yeelirrie in 1972. Their collective reserves are now estimated at nearly 350,000 MTU. Anticipating a major commercial market beginning in the mid to late 1970s, the owners of Mary Kathleen, Ranger and Nabarlek wrote contracts for future output with utilities in West Germany, the U.S. and, especially, Japan. By the end of 1972 a total of more than 8,000 MTU had been committed (with government approval) for delivery over the period 1977 to 1986. No further contracts were to be approved until late 1979.

4.1.1 Industry Structure

In Australia the structure of the uranium industry has undergone a number of changes, largely as a result of changing government policies. Before the election of the Labour Party in 1972, the industry was largely a free-enterprise activity. After the elections, however, the government took greater control over the industry, beginning with denial of approval for additional contracts for Mary Kathleen, Ranger and Nabarlek. The propriety of earlier contract approvals was also questioned. Although it was decided to honor these contracts, the uncertainties created in this period were such that uranium exploration all but ended. In late 1974, a new policy was announced. Its key conditions included:

- Greater government ownership and financing exercised through the Australian Atomic Energy Commission (AAEC) (beginning with a 50 percent share in Ranger and financing of nearly three-quarters of the development costs);
- Sole authority to explore--beyond existing licenses--in the Northern Territory would be vested in the AAEC;
- Existing contracts would be honored, using the AAEC stockpile and output from Mary Kathleen production and, eventually, from Ranger; and
- All future sales would be made by the AAEC.

A number of trade unions and environmental groups also became involved in efforts to block uranium mining and exports. As a result, the government initiated the Ranger Uranium Environmental Inquiry (the Fox Commission) to evaluate the environmental implications of uranium mining. While the Labour government is often portrayed as being generally opposed to uranium development, the record reveals a more complex perspective. For example, the Australian Atomic Energy Commission provided funds to restart Mary Kathleen's production in 1974 (and thus obtained a 41.6 percent ownership share). It also undertook or encouraged a higher level of exploration work in the Northern Territory.

Governmental policy on ownership has undergone significant changes since the election of the Liberal Party* in 1975. The requirement of strong government participation has weakened, as have restrictions on foreign capital involvement. The government announced its intention to sell its shares of Mary Kathleen and Ranger. The Ranger share has now been sold but buyers have not been found for the Mary Kathleen share.

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*This party would be termed "conservative" in U.S. political parlance.

Former plans to require a minimum of 75 percent domestic ownership have apparently been softened. A 50 percent ownership share seems to be the current goal, though there are ventures that involve a higher foreign participation. A softening international market will likely create incentives to allow greater foreign involvement.

Thus at present, the uranium industry in Australia is dominated by domestic private firms; government participation is declining; and foreign concerns continue a strong presence, especially in exploration. The status of major current ventures is shown in Table 4-1. Several other smaller deposits are also in the process of delineation and planning. These include Ben Lomond and Maureen in Queensland and Lake Way in the Western territory. In addition to Australian interests, there is involvement by French, American and Italian concerns.

4.1.2 Trade Patterns

Most of future Australian uranium production remains unsold. Future contract commitments and recent deliveries total about 43,000 MTU. More than three quarters of these exports were committed after the resumption of sales in 1979. Current export commitments are shown in Figure 4.1. As noted above, only the Mary Kathleen mine is currently delivering, having begun production in 1976 and exports in 1977. Deliveries under Ranger and Queensland Mines contracts are being made from the government stockpile.

Before the accession of the Labor government in 1972, a number of contracts were signed totalling 8600 MTU through 1986. Japanese utilities (Chubu, Kyushu, Shikoku, Chugoku, and Hokkaido) were responsible for over 70 percent of the contracted amounts. Mary Kathleen also holds three contracts from this period, one with the U.S.

Table 4.1

STATUS OF MAJOR KNOWN DEPOSITS

<table>
<tr><th rowspan="2">Deposit (Territory)</th><th rowspan="2">Year Discovered</th><th rowspan="2">Average Ore Grade</th><th colspan="2">Resources*</th></tr>
<tr><th>R.A.R. (MTU)</th><th>E.A.R.</th></tr>
<tr><td>Mary Kathleen (Queensland)</td><td>1954</td><td>0.12 percent</td><td colspan="2">6500</td></tr>
<tr><td></td><td colspan="4">Conzinc Riotinto Australia, Ltd. (CRA), a subsidiary of Rio Tinto Zinc, (U.K.) owns 51 percent. The AAEC owns 41.6 percent; the remainder is in private Australian hands. RTZ has a 72.6 percent share in CRA which it intends to reduce to 68.2 percent through an Australian public offering. MKU is producing at a rate of 770 MTU/y.</td></tr>
<tr><td>Koongarra (Northern)</td><td>1970</td><td>0.34 percent</td><td>13,500</td><td>11,500</td></tr>
<tr><td></td><td colspan="4">Deposit is wholly owned by the Canadian-origin company Noranda Australia, Ltd. Despite serious environmental obstacles, the company is seeking clearance to produce at 850 MTU/y beginning in 1981.</td></tr>
<tr><td>Nabarlek (Queensland)</td><td>1970</td><td>2.37 percent</td><td colspan="2">10,000</td></tr>
<tr><td></td><td colspan="4">Owned by a privately-held company, Queensland Mines, Ltd. (Australia). Ore has been mined and is awaiting processing, expected to begin in late 1980 or early 1981 at a rate of about 1350 MTU/y.</td></tr>
<tr><td>Ranger (Northern)</td><td>1970</td><td>0.25 percent</td><td colspan="2">85,000</td></tr>
<tr><td></td><td colspan="4">Originally discovered and developed by Peko Wallsend, Ltd. and Electrolytic Zinc Industries, Ltd. (both of Australia) as equal partners. Labor government appropriated 50 percent in 1974 in exchange for 72.5 percent development financing ($22.6 million spent). The government share was sold in 1980 in a deal which transferred total ownership of Ranger to a new consortium, Energy Resources of Australia, Ltd., with Peko Wallsend and Electrolytic Zinc each holding 30.49 percent, 14.02 percent to be offered to the Australian public, and the remaining 25 percent being split between Japanese and West German concerns. Approval for production has been granted: 2540 MTU/y beginning in late 1981 or early 1982, rising to 5080 MTU/y if and when warranted.</td></tr>
</table>

Table 4.1, continued

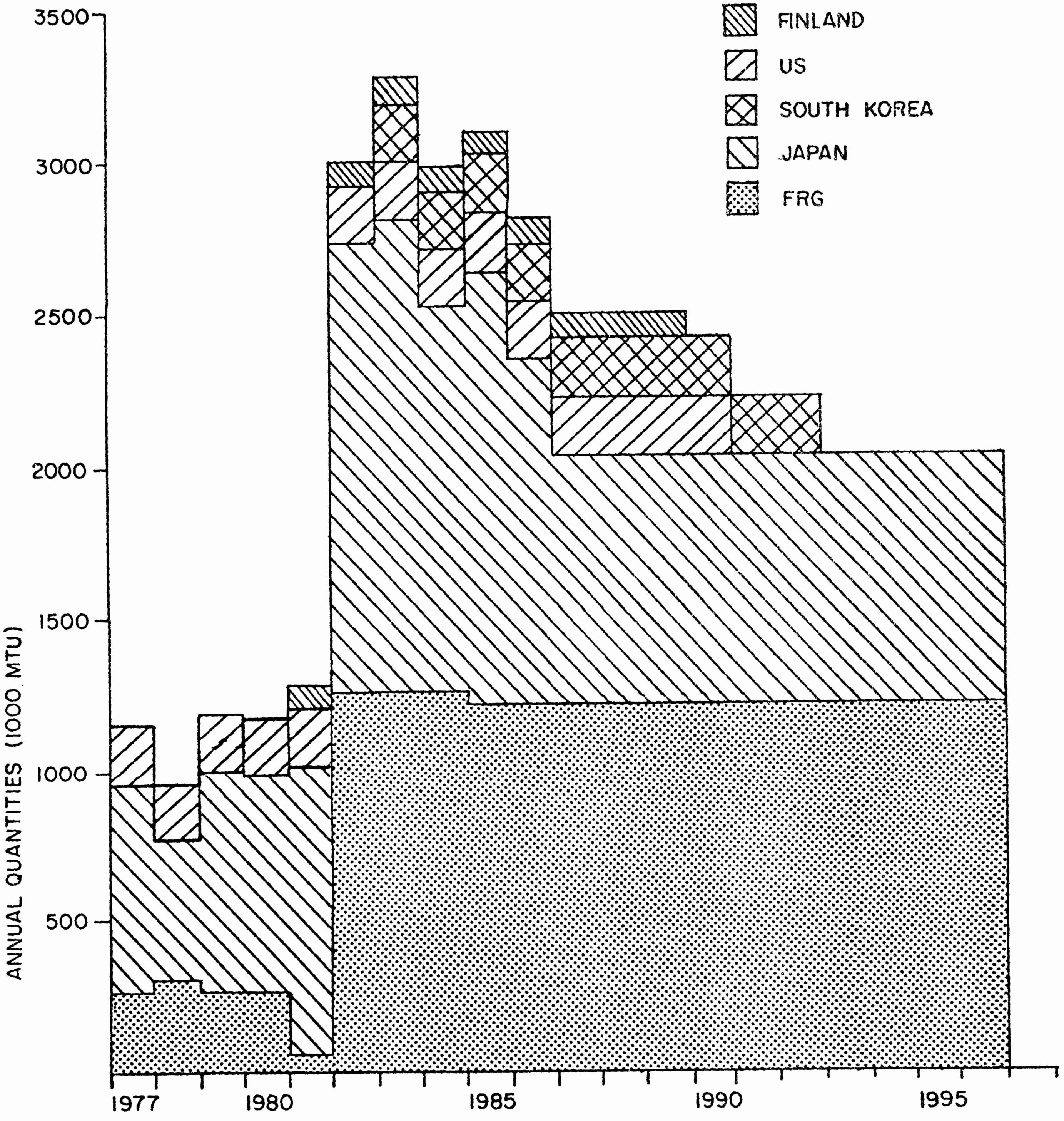
Deposit (Territory)	Year Discovered	Average Ore Grade	Resources	
			R.A.R. (MTU)	E.A.R.
Beverley (South Australia)	1970	0.24 percent	8,500	3,700
	Ownership distributed between Oilmin Group and others for 50 percent, and 50 percent for Western Nuclear, Inc. (U.S.). Production goal is 1150 MTU/y.			
Jabiluka (Northern)	1971	0.39 percent	146,000	30,000
	Pancontinental (Australia) owns 67 percent; Getty Oil (U.S.) owns 33 percent but provides most of the financing. Approval for production has been delayed and startup before 1985 seems very unlikely. Production plan is for 2500 MTU/y initially, 3850 MTU/y by third year and 7600 MTU/y by fifth year, given sufficient market opportunities.			
Yeelirrie (Western)	1972	0.15 percent	39,000	
	Western Mining (Australia) owns 75 percent but will receive only 50 percent of output; Esso Exploration and Production (Australian subsidiary of U.S. firm) owns 15 percent but will receive 40 percent of output; Urangesellshaft** owns 10 percent and will receive same share of output. Production has been approved for 2500 MTU/y beginning in late 1984 after pilot plant testing is completed.			
Roxby Downs (South Australia)	1976	0.01-0.20 percent	500,000***	
	Western Mining (Australia) has a 51 percent controlling interest with British Petroleum's purchase of 49 percent from Western approved by the Australian government in 1979. While low in grade, and at significant depth (1000 to 2000 feet) uranium is associated with one to two percent copper and could be coproduced. Likelihood of development is enhanced by the election of a Liberal Party government in South Australia.			

Notes:

* R.A.R. is Reasonably Assumed Resources (see Chapter 3); E.A.R. is Estimated Additional Resources. Where only one number is given, the data did not allow this distinction.

** Other reports put Urangesellshaft's share at 20 percent, reducing Western Mining's share.

*** Estimates for Roxby Downs are still uncertain and may be influenced by domestic political considerations.



SOURCE: TABLE A-20, APPENDIX

Figure 4.1

Australian Export Commitments

(Commonwealth Edison) and two with West Germany (Brunsbuttel). The latter appear to be through Rio Tinto Zinc of London, which holds a majority share in Conzinc Rio Tinto, one of the Mary Kathleen partners.

Since sales were resumed, a total of three contracts have been signed, and a significant amount of uranium has been committed as equity. American Electric Power and Korea Electric have signed, respectively, 9- and 10-year contracts with the Ranger consortium for more than 3500 MTU total, while Queensland has agreed to sell 730 MTU to the Finnish utility TVO over a 9-year period. In addition, both Ranger and Western Mining, owner of Yeelirrie, have allocated some future production to equity holders. About 830 MTU per year will go to Ranger's Japanese shareholders under equity arrangements, and almost 1200 to the German participants. For Yeelirrie, Urangesellschaft is scheduled to receive 10 percent of production, an amount equal to its equity share, while Esso Australia is slated to receive 40 percent of production for its 15 percent equity holding. However, since both Esso and Urangesellschaft are international traders in the uranium market, the final destination of the uranium is not known with certainty; we have not included the Yeelirrie equity shares as exports.

Obviously, the vast majority of committed uranium has yet to be delivered. Of total Australian export commitments, West Germany and Japan are the largest customers, each receiving about 44 percent. The remaining but much smaller export commitments are to the United States, South Korea, and Finland, in declining order of importance.

Under present plans, Mary Kathleen will continue to produce about 770 MTU/year, Nabarlek will begin to produce about 1350 MTU/year in

1981, and Ranger will come on line with about 2500 MTU/year in 1982. Yeelirrie (which appears to have written no contracts as yet to supplement its equity shares, but whose development has government approval) plans to be producing about 2500 MTU/year by 1985. Thus, as of 1985, Australian production is planned to be about 6700 MTU/year. Allowing for expansion of Ranger output (to about 5000 MTU/year) and a go-ahead on Jabiluka, Koongarra, Beverley and Roxby Downs--and no major obstacles--Australian production could be pushed as high as 23,000 MTU/year by the end of the decade.* By contrast, current contract commitments are less than 3000 MTU/year in 1985, and drop to less than 2500 MTU/year in 1987. Planned and potential production capacity is compared with export commitments in Figure 4.2.

Even if one considers only the four ventures for which approval has been granted, and to which substantial commitment has been made, Australian producers will have to find markets for three to five thousand MTU per year by the mid-1980s. Of this, 1000 MTU/year might be sold by Esso, a partner in Yeelirrie, perhaps in the United States. But three to four thousand MTU annually will have to be sold independently by Australian companies in the world market.

How much of this production capacity will actually be installed and operated clearly depends on perceptions of market opportunities and on governmental assistance in overcoming environmental and other

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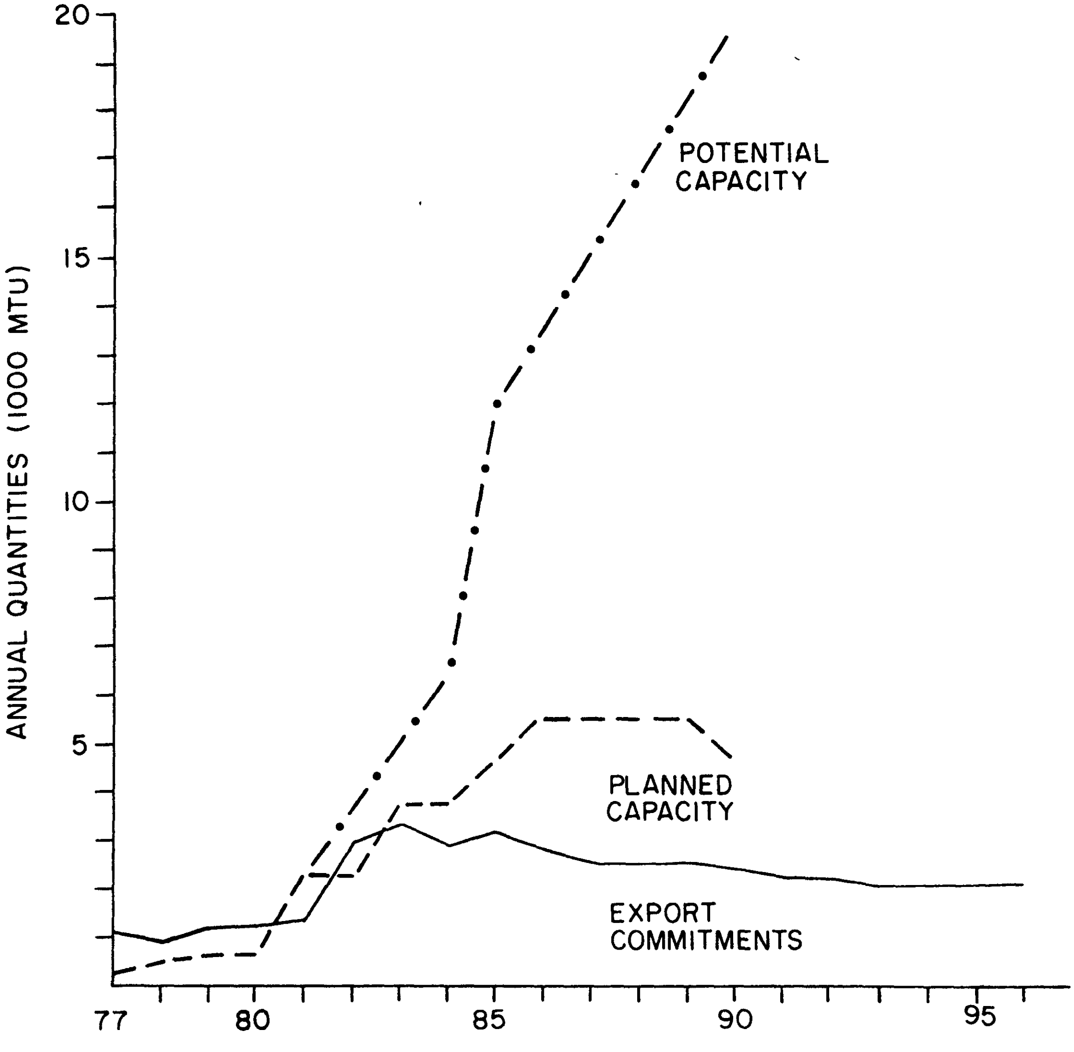
*The 1979 Redbook (see reference [1], Chapter 2) lists a maximum production capacity of 20,000 MTU/year in 1990; our estimate is the same, except for an additional 3000 MTU/year for Roxby Downs.



SOURCE: TABLE A-20, APPENDIX

Figure 4.2

AUSTRALIA: PLANNED AND POTENTIAL CAPACITY COMPARED WITH EXPORT COMMITMENTS obstacles. Compared to production costs in the United States and perhaps elsewhere (e.g., Namibia) Australian uranium is inexpensive, being on or near the surface, relatively high in grade, and low in extraction cost. But financial incentives would have to be large enough to justify the political and other costs involved in large-scale development. The current expansionist momentum of the Australian industry--despite the apparent lack of immediate contract opportunities--and the generally favorable attitudes of national and territorial governments, suggests that even today's decreasing prices provide more than adequate near-term encouragement. In the longer term, deeper political and economic issues are involved, as discussed below.

4.1.3 Government Role

Speculation about future uranium development depends heavily on one's view of the role to be played by national and territorial governments. Uranium is linked to several key economic and political issues. These include:

- Environmental protection and aboriginal rights,
- Domestic and international economic strategy,
- International and regional security relations,
- Nonproliferation.

Aboriginal rights and environmental protection are central to the domestic politics of uranium. These issues are raised particularly by uranium developments in the East Alligator River area of the Northern Territory, where the Ranger and Jabiluka deposits are located. These issues were explored in detail in the report of the Fox Commission.* Both parties have embraced the report, which recommends cautious development of uranium resources. This caution, and the need to make complex trade-offs, imply that phased development is more likely than simultaneous development of several mines, at least in the same geographical area. For example, the delay of Jabiluka may have been a compromise (with aboriginal and environmental forces) to allow Ranger to go ahead.

Economic issues associated with uranium are somewhat more problematic. Uranium development is capital-intensive and, if it draws capital away from other job-creating investments, it would be seen as aggravating unemployment, already a serious problem for the governing Liberal party.** Large-scale uranium production also could alter Australia's international balance of payments and monetary situation. Attainable production in 1985 could earn more than $1 billion a year in foreign exchange, about ten percent of the current export volume.*** Such an increase in export surplus could put upward pressure on the value of the Australian dollar. If the government resists this pressure, attempting to maintain the previous value for the currency, some of the measures that are commonly used may result in expansion of the domestic

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*The Fox Commission [1] enquiry was initiated by the Labour government in 1974 but its work was not completed or received until after the Liberal party came to power.

**For example, see [2].

***For a detailed study of the economic impact of uranium development, see [3].

money supply, aggravating inflation. In either case, the competitiveness of Australian rural and industrial exports in world markets would suffer, increasing unemployment. This secondary effect on employment is in addition to that occasioned by a shift of capital to the less labor-intensive mining sector. Domestic and international economic issues are thus linked at a particularly sensitive political point. The Labour government's experience in 1972-75, and its political failure, are evidence of the significance and sensitivity of this issue. A mineral and agricultural products boom in the early 1970s led to a growing balance of payments surplus and pressure to appreciate the Australian dollar. The Labour government resisted this development and rapid inflation occurred. The reduced competitiveness of exports, aggravated by Labour policies to increase wages and tighten credit led to an increase in unemployment, from about 1 percent to more than 5 percent. Thus the problem of surpluses resulting from natural resource exports is a difficulty for any Australian government. In this connection, it should be noted that decisions will have to be made between expansion of coal exports and those of uranium.*

These effects would lead one to expect a cautious, moderate pace in uranium development. Uranium decisions are also affected by Australia's evolving role in the international political system. Australia appears to be taking an increasingly independent posture in foreign policy, especially in the Pacific basin, and as mediator between the developing

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*For the Australian views of these issues, see [4], [5] and [6].

and industrialized countries.* As a major raw material exporter, Australia has interests in common with many developing countries, especially in such areas as measures to improve price stability (as in its activity in association with other bauxite producers). And Australia is showing increasing sensitivity to the economic interests of developing countries in the region. But Australia is also part of the industrialized world and still depends, at least in part, on U.S. efforts to maintain regional stability. Being part of both worlds might enhance Australia's ability to act as mediator--it also creates conflicts.

Nonproliferation is one such area, and in this domain trade and foreign policy issues are being drawn together despite efforts to keep them separate.** The Liberal government went ahead with uranium under the terms of reference of U.S. policy: uranium would be exported under full-scope safeguards and retransfer conditions embedded in bilateral agreements. This policy is motivated by a need to provide

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*For example, in March 1975, Prime Minister Fraser asserted that, "Trade and foreign policy used to be kept strictly apart in our time, trade and foreign policy need to be kept strictly apart for the future. These rules of principle apply all the more strongly to small countries because if the international world order becomes a jungle it is the small countries that suffer; they are defenseless against the retaliation of major powers. Resources diplomacy is one of the things that will help plunge the world into a major depression and chaos. The continued expansion of world trade, the availability of world developmental capital, and access to adequate power are the three great economic problems facing advanced western countries, indeed the the entire trading world. For world trade to continue to grow we have to meet new challenges. Trade is an increasingly politicized issue, not only domestically, but also internationally, because of its importance in the north-south dialogue." [7]

**For a general overview of the changing orientation of Australian foreign policy, see [8].

fuel assurance as a way of reducing incentives to pursue proliferation-sensitive nuclear technologies. However, there is evidence that these measures may not succeed in stopping the spread of weapons capability. Australia, like the U.S., will have to decide whether and how to allow uranium exports to flow into sensitive fuel cycle operations, including reprocessing, enrichment in Japanese facilities, or breeder reactors. The present government went ahead with uranium development and exports during the INFCE exercise, when it seemed that consensus on a common technological and nonproliferation path might be possible. To the extent that conflict remains over technological paths now that INFCE is over, Australia will have to rationalize its role in nuclear commerce. Recent government proposals include the possibility of generic approvals of reprocessing material of Australian origin under suitable conditions (which include Australia's judgment of the necessity of reprocessing for technological, economic or waste management reasons). This stance is significantly more relaxed than that of the U.S. under its legislation (the 1978 NNPA), which calls for case-by-case rather than generic approvals. However, Australian policy is still evolving and the ultimate outcome is still uncertain.

The U.S. policy has held a potential self-contradiction that would also affect a rigid Australian policy: fuel assurance has been implicitly coupled with a threat to withhold fuel supply if the technological behavior of recipient nations does not conform to U.S. norms.* While this approach has thus far been aimed at other major

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*See [9].

industrialized countries--because of their nuclear leadership role--the ultimate objective of U.S. policy has been to restrain sensitive technological commitments in the developing world. To the extent that Australian policy follows this lead, Australia is open to charges of discrimination or failure to supply an important energy commodity. To the extent that it deviates from solidarity with the U.S. it risks a weakening of relations with a traditional industrialized leader in the area. Australia's position is thus extremely sensitive: the conflicts in U.S. policy are drawn even more sharply for Australia, and may create significant problems in her relations with neighboring countries. If external conflicts over nuclear policy should heat up, these issues could serve to revitalize the internal debate over the whole question of nuclear trade. There are thus many reasons to expect caution in uranium development.

These complexities are perhaps in part responsible for the disparity in political attitudes toward uranium in Australia, especially within the Labour Party. Some leaders are opposed to uranium development and have even threatened abrogation of existing contracts if the Party comes to power.* However, the Party is far from homogeneous in its outlook. Other party leaders favor moderate development, with suitable controls and greater public participation. In this connection, it is our impression that the trade press does not give an adequate picture of the richness of the Australian situation. The issue of uranium development vs. no development, in fact, is intertwined with a "public vs. private" debate. The industry press tends to call attention to threats that the

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*For a general discussion of the union movement, see [10] and [11].

Labour party would abrogate or limit supply contracts (most of which are private). It does not often highlight the possibility that under Labour exports would go ahead but with greater public ownership at the expense of private industry. The latter is the more realistic possibility in our view. As noted above, Labour went ahead with uranium development, with public funds, during its last term in office--a period that is, with little justification, viewed even retrospectively as anti-uranium.

Such debates serve to create uncertainties about Australia's future role in the world market. It is possible to entertain a view of Australia as the future Saudi Arabia of uranium, with a capacity (real or threatened) large enough to give it a dominant position in setting market and nonproliferation conditions; it is also possible to view it as sufficiently conflicted over internal or foreign policy issues as to have little material to export. As long as there are not major changes in political conditions or assumptions, or proliferation events traceable to the uranium market, the latter result seems unlikely. The greatest likelihood is that Australian output and exports will expand (as long as there is adequate world demand) but that they will do so more rapidly under a Liberal than under a Labour government. Not only are the cautions noted above more keenly felt by Labour, but the restraint of private initiative in favor of public involvement advocated by Labour is likely to lead to slower and more rigorously sequential development. Despite considerable environmental and other obstacles, it is more difficult for the current Liberal government to retard private and independent territorial interests favoring simultaneous development.

These same observations also suggest that a Labour government would also be more likely to use existing and potential government mechanisms to influence prices and contract conditions.* There now exist export and price review procedures. The second Fox Commission report of 1977 recommended a Central Marketing Authority and before the government's share of Ranger was sold, consideration was apparently given to having such a body market the government share. Current plans are for an Australian Uranium Export Authority (AUEA). The Authority's duties are to include advising the Minister of Trade and Resources, collecting data and analyzing the uranium market, gathering information on domestic and foreign uranium resources, and studying commercial arrangements for the upgrading and enrichment of domestic uranium within and outside Australia. More importantly, the Authority is to determine export prices, and the rate of Australian production.

Due to the delays in the creation of the AUEA, the Trade and Resources Minister was empowered to regulate uranium exports under the authority of the Customs Act of 1901. At the time of the announcement in mid-1978, the Minister said that shipments would be approved on an individual basis, with three preconditions necessary: the project must have government approval for production, the export contract must have approval, and Australian safeguards policy must be complied with. Other considerations to be taken into account include the quantity being exported, the terms of the contract (duration, quantity sold, shipment method, price payable, the manner of payment), and the end use of the uranium.

The market power implicit in these regulations has not yet been

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*Discussions of cartelization in the early 1970's were initiated under a Liberal government, though actual cartel participation was initiated by the Whitlam Labour government.

fully tested, with only three contracts having been considered thus far. But it appears that government did not exercise great influence over the economic terms of recent sales. Undoubtedly, this was due in part to Australia's relatively weak market position: with production coming on line in an era of rising inventories, excess production and softening prices, Australia has had difficulty in making sales at all. And a liberal government seeking to shift uranium fully back to the private sector may also be reluctant to threaten opportunities by imposing severe price conditions on top of existing nonproliferation requirements. But the governmental mechanisms now in place could--in principle--be used to assist in coordinating international market activity with other producers. The uranium cartel activity of the early 1970s was initiated in a depressed market period even without such powers.

4.2 Canada

The Canadian uranium industry began in 1942, with a U.S. request that the Eldorado Gold Mining Company reopen a mine closed in 1940 to provide uranium for the Manhattan Project. In 1944, the Canadian government acquired the shares of the company and formed a Crown Corporation called Eldorado Mining and Refining, Ltd. and two years later passed the Atomic Energy Control Act which remains the basic legislation governing nuclear energy in Canada. In addition to Eldorado, several private producers were mining large amounts of uranium by the 1950s, the British and American weapons programs being the principal customers, as with Australia. But in Canada the scale was greater; and so were the difficulties when weapons demand decreased rapidly in the mid-1960s. Canadian production reached a peak of 12,200 MTU in 1959, a factor of ten larger than the Australian peak (reached in 1961). By 1967, Canadian output had dropped to 2800 MTU as a result of termination of U.S. and U.K. contracts and a protectionist embargo on imports by the U.S. (U.S. production dropped from a peak of 14,500 MTU in 1960 to about 7,500 MTU in 1966.) The effect on the Canadian industry would have been even more severe if it had not been for a stretchout of U.K. purchases (nearly 1000 MTU annually through 1971) and intervention by the Canadian government through large stockpile programs which permitted the principal producers to continue operations. Between 1963 and 1970 Canadian government stockpile purchases totalled over 7,000 MTU at a cost of C$ 101.4 million. The industry depression of the mid-1960s is responsible in part for the continuing role played by the Canadian government in uranium affairs, and provides a well-remembered backdrop to more recent industry attitudes and plans.

4.2.1 Industry Structure

Uranium production occurs principally in Ontario and northern Saskatchewan. Uranium deposits in Ontario are relatively low in grade (with uranium averaging less than 0.1 percent of ore) while those in Saskatchewan are relatively high (fractions of 1 percent up to 45 percent). Early production in Saskatchewan came from the Beaverlodge facilities of Eldorado Nuclear, a Canadian Crown company under government ownership. Eldorado also managed national stockpile activities through July, 1970. Beginning January 1, 1971, stockpiling activities were controlled by a joint venture--75 percent government-owned--managed by a newly created Crown Company, Uranium Canada Ltd. (UCAN), whose directors were all federal government officials. In Ontario, Rio Algom and

Denison Mines produced--and will continue to produce--more than half of Canada's uranium from deposits at Elliot Lake.

The number of major producers in Canada is increasing rapidly and the important producers of the past (Eldorado, Denison, and Rio Algom) are increasing output. In Ontario, Denison Mines (at Elliot Lake) will probably reach 2300 MTU for 1980 and Rio Algom (expanding and reviving its Quirke and Panel mines nearby) will probably reach 2800 MTU annual production. Madawaska Mines, Ltd.* has revived the Faraday mine in the Bancroft area to produce uranium (about 300 MTU annually) largely for Italy's AGIP, which provided much of the financing. Agnew Lake Mines** has operated a heap-leaching operation in Ontario that will yield about 400 MTU annually in 1980.

But the largest producer in Ontario--directly or indirectly--is the Rio Tinto Zinc Corporation, Ltd. of the U.K. Through interlocking corporate entities, RTZ controls both Rio Algom and Preston Mines, which will produce around 76,000 MTU over the next 40 years under contract with Ontario Hydro. RTZ directly owns 80.9 percent of Preston and 51.3 percent of Rio Algom. Until recently, when the companies were merged, Preston was an organization without employees and with a board of directors identical with that of Rio Algom. Preston owned 43.8 percent of Rio Algom (thus increasing RTZ's interest there); it also had a management contract with Rio Algom to reactivate and operate its other

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*Madawaska is owned 51 percent by Federal Resources (U.S.) and 49 percent by Consolidated Canadian Faraday.

**Agnew Lake Mines is owned 90 percent by Kerr Addison and 10 percent by Uranerz Canada, Ltd., a subsidiary of Uranerzbergbau Gmbh. of West Germany. Production is to be split according to these equity shares.

major asset, the old Stanleigh Mine from which Ontario Hydro's uranium will come. This complex subsidiary-parent relationship--with a few other RTZ subsidiary relationships included--means that RTZ has a larger interest than may at first have been apparent.*

In Saskatchewan, Eldorado is expanding its production near Uranium City, to reach perhaps 700 MTU annually by 1981. At Rabbit Lake, joint venture activity by Gulf Minerals Canada, Ltd. (a subsidiary of Gulf Oil Corporation of the U.S.) and Uranerz Canada, Ltd. (a subsidiary of Uranerzbergau, Gmbh., a company with close ties to West German utilities) reached a production level of 1730 MTU in 1979. At Cluff Lake, Amok (a consortium of four French organizations)** expects to reach production levels of 1000 MTU in 1981 and 1500 MTU by 1982.

Plans for the development of Cluff Lake were the occasion for Saskatchewan's searching examination of uranium development issues, the so-called Cluff Lake Board of Inquiry [12]. The board gave a general go-ahead to uranium, under rigorous conditions. Under Canadian law, mineral resources within provincial boundaries are owned by the provinces; Yukon and Northern Territory resources are federally owned. The provinces thus have considerable powers to regulate occupational health and safety and environmental impacts, to require employment of local (native) workers, to assess royalties and to participate in exploration and mining ventures. The provinces have exercised all of

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*Rio Algom also owns 10 percent of the Rössing Deposit developed by RTZ in Namibia, thus extending the corporate web of interrelationships to the international sphere.

**Amok's equity is distributed as follows: Compagnie de Mokta (25 percent), Compagnie Francaise des Minerais d'Uranium-CMFU (20 percent), Pechiny Ugine Kuhlmann (25 percent), and Commissariat a l'Energie Atomique (30 percent).

these powers. For example, through the Saskatchewan Mining Development Corporation (SMDC) the province participates in most exploration ventures (at up to 50 percent). The province can also buy into new developments such as that at the fourth major deposit, Key Lake. Equity in this development--which may reach an output level of 2300 MTU annually by 1983--is distributed half to SMDC, 33.3 percent to Uranerz Canada, Ltd. and 16.7 percent to Eldorado Nuclear, Ltd.

It should be noted, however, that provincial powers are limited at least in theory by several circumstances, partially deriving from uranium's special status. By the legal doctrine of paramountry, federal legislation overrides provincial legislation should the two conflict. The federal Atomic Energy Control Act and other federal laws regulate such matters as uranium exploration, development, mining, health and safety, price, stockpiling, and export conditions. Since many of these questions are covered by provincial laws, duplicate regulations exist. Thus far no conflict between them has been brought to the courts, though the AECA has been challenged and its constitutionality upheld. In general (and again--in principle) the federal government has jurisdiction wherever international or interprovincial questions are involved. It could, for example, overide British Columbia's moratorium if it chose; but the political problem of federal control over resource policy is presently a very sensitive issue in Canadian politics. This political question also finds expression in mineral taxation. According to Canadian law, provinces may levy only direct taxes, i.e. those levied on some good and payable by its owner. The classic direct tax is a tax on land or property. The provinces may not levy indirect taxes--those intended to be passed on to a purchaser, such as a sales tax--nor may they tax in order to regulate interprovincial or international trade. In fact they do both by writing mineral taxation laws phrased so as nominally to be taxes on "mineral lands." Again, this procedure has been upheld by the courts. Saskatchewan's de facto royalty laws add significantly to the export price of its uranium, which nonetheless remains competitive due to its low extraction costs.

As is evident in this review, foreign involvement in Canadian uranium production--even in some of that for domestic uses--is high. This appears to be in contradiction to official policy which calls for a maximum of 33 percent foreign ownership. Legislative efforts have been made recently to rationalize this situation, with proposals to allow up to 50 percent ownership as long as Canadian control is assured. While the effort to increase Canadian shares in investment and control is part of a more general drive to use internal sources of capital and implement a better resource policy, there is clearly some distance to go in achieving these goals in the uranium sector.

4.2.2 Trade Patterns

Canada's past and future exports of uranium are the largest of any producer. Since commercial contracting began in 1966, Canadian producers have entered into arrangements to export about 126,000 MTU. Of this about 44,000 MTU were exported prior to 1980, leaving a forward commitment of at least 82,000 MTU.*

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*These are the quantities for which we have been able to find confirmation. There may be some recent spot sales that do not appear in our tabulations or older commitments that have escaped our discovery efforts.

Japan is Canada's largest customer, receiving 36.5 percent of lifetime export commitments; West Germany is next with 21 percent followed closely by the U.K. (13.5 percent), the U.S. (10 percent), Spain (6.8 percent), France* (5.8 percent), and Italy (2.5 percent). South Korea, Finland, Belgium, Sweden, and Switzerland (in descending order) receive the remaining 4 percent.

Under Canadian law, export commitments made since September 1974 must be approved by the Atomic Energy Control Board for conformity to nonproliferation conditions, price, arrangements for uranium value added in Canada (primarily UF6 conversion), and other conditions (such as the requirement that sufficient reserves be held for domestic needs). Approvals granted as of the end of 1979 totaled about 65,000 MTU. Thus about 61,000 MTU was either (1) committed prior to September 1974, (2) extends beyond the official ten-year approval horizon, or (3) has not yet received approval on export conditions. With the exception of the French purchases from Cluff Lake beyond 1983, there appear to be few major contracts in the third category. However, the AECB has delayed contract fulfillment in at least a few instances, until price or conversion requirements were met. An example is the Madawaska contract with AGIP (Italy). AGIP had provided major mine financing and expected to receive uranium at about $32/pound; Canadian officials insisted on an increase to about $42/pound.

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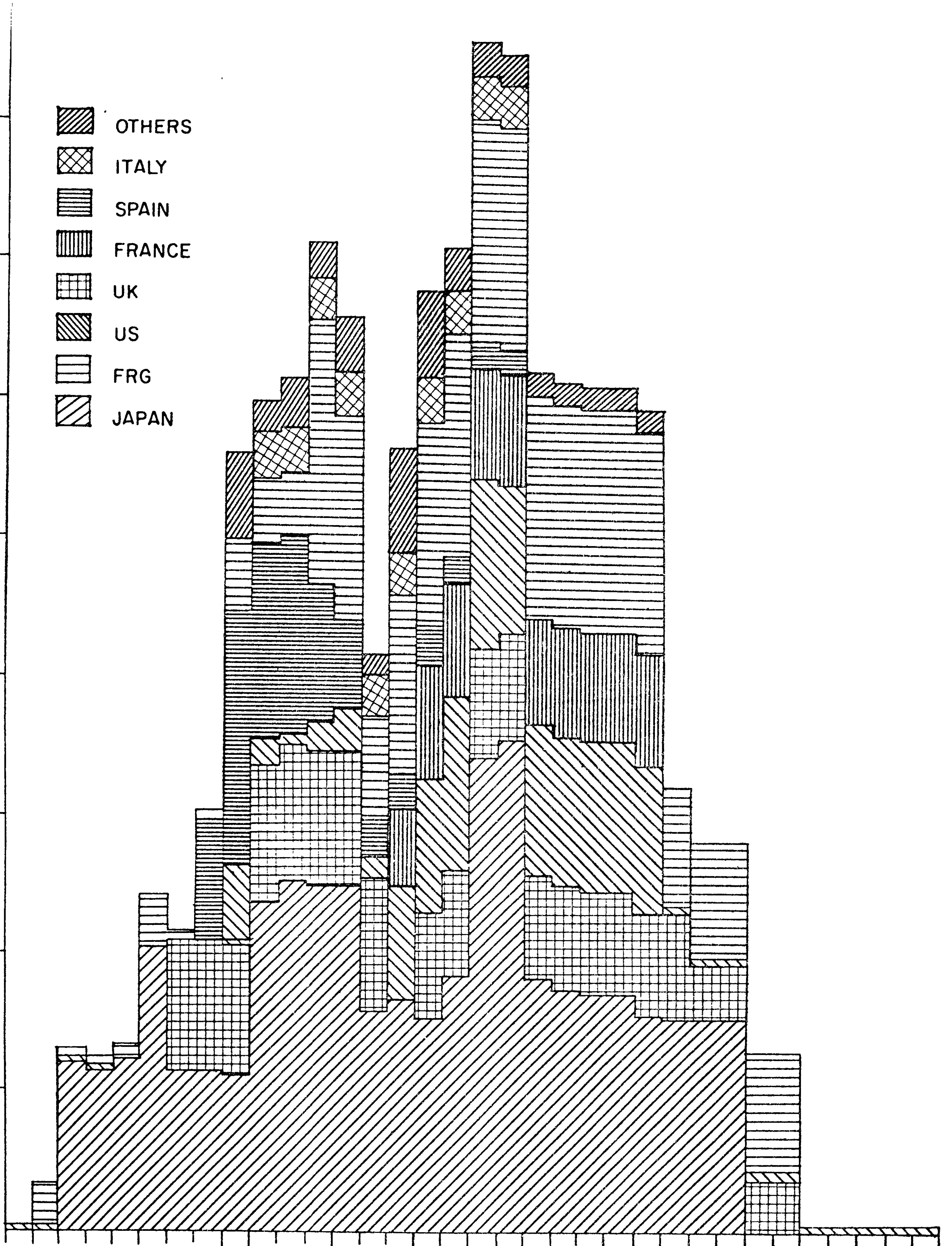
*France's supply is entirely from the Amok consortium's Cluff Lake operation. Although Amok has received only a two-year export authorization on its French contracts, this approval is renewable and we have assumed exports will go to France for at least ten years, as is the case with exports to Germany from Cluff Lake.

In Figure 4.3, we show annual export commitments by country of destination. It should be noted that exports prior to 1980 include a number of spot sales while commitments beyond 1980 are all long-term contracts. The latter reach a peak of slightly more than 8500 MTU in 1984 and forward commitments decline rapidly in the late 1980s and early 1990s. Exports are not, however, the only commitments made by domestic producers: there are also contracts to Ontario Hydro totaling more than 76,000 MTU, to meet fuel needs into the next century. In Figure 4.4 we show domestic requirements and export commitments as they compare with historical production and planned capacity.

4.2.3 Government Role

The Canadian government is unavoidably involved in uranium activity for reasons that go beyond its participation in weapons procurement, and its support of the industry in the years between weapons and commercial procurements. Uranium is linked to several important current areas of domestic and international concern. These include:

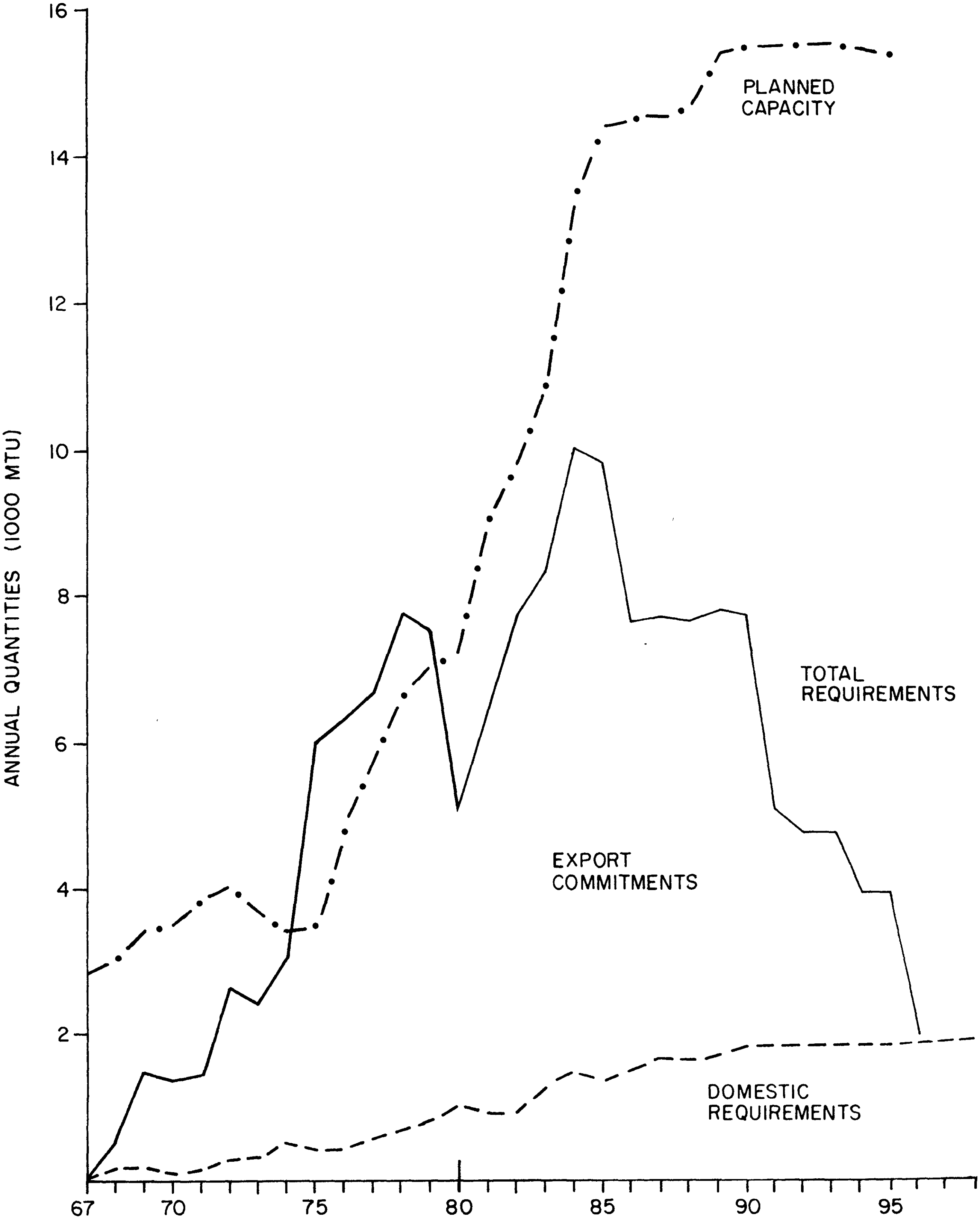
- Natural resource policies. Many Canadian leaders believe the economy and foreign trade are excessively dependent on natural resource exploitation [13]. Also, there is a strong body of opinion that holds that foreign ownership and control (primarily by U.S.-based organizations) is too great. In uranium, these sentiments have led to restrictions on foreign ownership, the requirement of a maximum domestic value added (to date this involves requiring conversion to UF6 in Canada, where capability exists), and the imposition of government controls on export prices.



SOURCE: TABLE A-21, APPENDIX

Figure 4.3

CANADIAN EXPORT COMMITMENTS
(COMMERCIAL CONTRACTS AND FIRM EQUITY COMMITMENTS)



SOURCE: TABLE A-22, APPENDIX

Figure 4.4

CANADA: PLANNED CAPACITY COMPARED WITH EXPORT COMMITMENTS AND DOMESTIC REQUIREMENTS

- Social and infrastructural problems. Canada is a large country with a population concentrated in a few centers. Development outside these areas has historically involved extensive government action. In the northern areas of the provinces, native peoples' rights also are an important political issue. Thus new uranium activities, as in northern Saskatchewan, unavoidably involve governmental involvement in infrastructural development and concern for environmental effects and the rights of the original inhabitants.
- Federal/provincial relations. Because of the nature of the Canadian confederation, the federal government must be sensitive to provincial interests, both ethnic (as in Quebec) and economic. For uranium, this situation is complicated by the fact that production in Ontario is primarily committed to domestic use, while that from new districts in Saskatchewan will be sold abroad. This circumstance raises questions about relations between sectors that meet domestic needs and those that earn foreign exchange (which now take on geographical identity), and interprovincial economic equity. Further, there is a coupling between domestic provincial ambitions and foreign policy.
- Domestic energy security. Concern that Canada might deplete uranium reserves, to the detriment of domestic energy security, has led to a governmental requirement that a portion of reserves be held for future domestic use.

- Nonproliferation. The 1974 Indian explosion (which involved Canadian material) pushed Canada to the front of the nonproliferation issue and led the Canadian government to assume a greater role in setting conditions on exports.

Of these, the issues of greatest current importance appear to be nonproliferation and the balance between federal and provincial interests--especially since these two issues intersect. Their overall effect seems to be a pressure toward softening Canadian commitments to nonproliferation as they have been expressed through uranium export policy. Following the Indian explosion, Canada was compelled to take actions independently through its primary source of leverage, uranium supply. The resulting crisis--which primarily affected Canada's industrialized trading partners--was relieved by the entry of the United States into the issue, and by the INFCE discussions. The INFCE allowed Canada to retreat gracefully (if temporarily as far as the Euratom countries were concerned) from confrontation and to delay permanent formulation of nonproliferation conditions. (Interim agreements are without prejudice as to the outcome of post-INFCE negotiations.) A key issue will be whether Canada will hold veto power over reprocessing, enrichment, or retransfer of its uranium. To argue for such a right would be to follow the current U.S. policy lead; to accept softer conditions (such as prior consultation or generic approvals) might be interpreted as a break with of the U.S. in this area.

We believe it unlikely that Canada will hold to the rigorous nonproliferation conditions of recent years. In part this is because of actions by the U.S. When the U.S. retook the lead on nonproliferaton, it removed Canada from its unaccustomed central position, and reduced the relative importance of international security issues in the resources debate in Canada. But the U.S. is itself in a difficult position with its policy after INFCE; the strict terms of the Nuclear Nonproliferation Act of 1978 reduce the U.S.'s negotiating flexibility with its allies over the future evolution of global nuclear development.

The complexities of this debate are not unnoticed in Canada. Not surprisingly, they arise most visibly in Saskatchewan, which has the most at stake in conditions on uranium exports. The Cluff Lake Board of Inquiry argued that nuclear proliferation can only be solved by a comprehensive multinational effort and that unilateral actions are ineffective if not counterproductive. The Board warned that the withholding of uranium from world markets would probably have harmful effects for nonproliferation; also such a move would conflict with attempts to ameliorate global energy problems. According to the Board, it is incomprehensible to speak of a Canadian contribution to proliferation through its uranium exports: "proliferation exists because of the security structure, not because of Canadian uranium."[14]

The Board went further in criticizing the philosophical foundations of the nonproliferation policies articulated by the U.S. and other countries, including--by implication--the Canadian federal government. A few excerpts from the report make this clear:

- Both sides feared that nuclear weapons could get into the hands of less responsible governments but the supporters of nuclear power claimed that they would refrain from making nuclear materials available to any nation likely to experience a civil war or subnational coup while the opponents of nuclear power wanted Third World nations to develop alternative sources of energy. Nations in the Third World know that both superpowers had serious civil wars themselves and that unstable or dictatorial governments are by no means the special preserve of

> underdeveloped and developing nations. We agreed that assumptions of inferior qualifications for nuclear energy did sound like a modern version of the White Man's Burden.
>
> o Both sides of the nuclear debate accepted in their evidence that the balance of nuclear terror between the superpowers had helped to keep the world free of a major war for over three decades. We concluded that the non-aligned nations of the Third World considered that international security for them would be as well preserved by a balance of nuclear terror in which they had a reasonable share.
>
> o Both protagonists before us argued for international justice. The pro-nuclear witnesses argued for the right to make nuclear energy available to the Third World for peaceful purposes under strict safeguards to prevent making nuclear weapons. The non-nuclear witnesses argued that nuclear power was unsuitable for many of those nations and that the traditional non-industrial way of life should be preserved. The Third World considers that these arguments mask the real reason--any proliferation would be a shift in the distribution of power in international decision-making. We agreed that it is a redistribution of this power which they want. International justice and equality requires not simply a redistribution of wealth or resources, but also of global prestige, bargaining power in political and economic agreements, and a voice in international organizations. We deplored the fact that nuclear weapons are used as a measure in the allocation of power in the world community [15]

In making these arguments, the Board, and the provincial government that endorsed and implemented the report, show more sympathy for the developing country point of view than for that of the Canadian federal government. With its heavy dependence on agriculture and natural resources, Saskatchewan also shares other common ground with the developing world.

However, the Province is also part of the Confederation and perspectives on resource and export policy must ultimately be reconciled. In a reopened debate on nonproliferation policy there is much to favor the influence of Saskatchewan's view. There are the paradoxes and internal contradictions of a restrictive policy, and Canada is not likely to take a hard line position without seeing how to eliminate or resolve them. Also, there is a rapidly softening uranium market in which competitive advantage is easily undermined by restrictive political conditions.

Though internal and external factors may suggest a loosening of political conditions on uranium exports, the nonproliferation debate may have helped create mechanisms for imposing economic conditions on exports. The Atomic Energy Control Board (AECB) functions both to impose both political and economic conditions, and the latter function is potentially important as the uranium market softens. Canadian interests are united in wishing a maximum return for natural resources; the ability to maintain prices would help fulfill this desire. The difficulties in doing so, however, are both internal and external. Internally, it is difficult to control producers: if world prices threaten to drop below levels judged appropriate by the AECB, there will be pressures from low-cost producers (mining costs in Saskatchewan are relatively low) to go ahead with exports even at lower prices. Participation in a producer cartel would also require such a disciplining of internal industry activity. This is probably very difficult to do, except perhaps for a short period.

4.3 South Africa

Uranium production in South Africa also was initiated in response to the weapons needs of the United States and United Kingdom. Uranium is extracted from material mined with gold as the primary product. Production began in 1952 and rose to a peak of 4,960 MTU in 1959, when more than two dozen gold mining operations were involved. Weapons demand and uranium output then fell to a minimum of 2260 MTU in 1965, the last year of deliveries to the Combined Development Agency. Since uranium was a by-product of gold production and since uranium recovery facilities were already in place, uranium output was continued after 1965 at a level of several thousand MTU per year. Fluctuations in uranium production--notably a decline in the mid-1970s--occurred because of changes in gold prices. The ratio of uranium to gold in the South African reefs is relatively constant (at a value of about twenty) and changing gold prices appear to result in changes in the grade of ore mined--in both gold and uranium values. Given limits on ore treatment volumes, the result can be changes in uranium as well as gold output levels.

Until about 1976, South African uranium production exceeded commercial contract deliveries, with the excess being sold to the weapons states or put into inventories. These inventories were then drawn down somewhat in the late 1970s when contracts exceeded production capacity. Total South African production from 1966 until the end of 1978 was nearly 39 000 MTU; there are public indications of commercial deliveries totalling only about one-fourth of this. The implication is either that other, more secret, transactions may have taken place (perhaps involving sales to the U.K. or other weapons states) or that South Africa holds a substantial stockpile. The total amount to be accounted for is about 30,000 MTU. South African stocks are now being built up as production grows to exceed export commitments.

4.3.1 Industry Structure

Of more than forty gold-producing mines (most in the Witwatersrand basin), about one-half are currently producing uranium, or proposing to do so. Most of these mines are controlled by the major mine financing groups, the most important of which for uranium is the Anglo American Corporation.* The current expansion in uranium production in South Africa results from the extension of uranium recovery to additional gold mines and from new uranium-oriented mining ventures.

With one exception, commercial uranium output has been sold through the Nuclear Fuels Corporation (Nufcor), a corporation owned by mining interests but using conversion facilities originally transferred to it from the government. The exception is the uranium produced as a by-product of copper mining by Rio Tinto Zinc (London) at Palabora (about 100 MTU/year). Until a few years ago, Nufcor was an exclusive intermediary between producer and consumer. However, in the mid-1970's tight market conditions created opportunities for mining companies to negotiate directly with consumers for the financing of output expansion. The result has been an improvement in information concerning trade patterns (as discussed below) since such direct arrangements give important clues to uranium transactions.

South African production reached a record 5200 MTU in 1979 and will expand rapidly in the next few years as the result of recent investments. A maximum annual production capability of 10,600 MTU is projected for 1985 (1979 Redbook). This estimate does not include production from Namibia, discussed below.

4.3.2 Trade Patterns

South Africa's participation in international uranium trade is veiled in greater secrecy than that of any other producer. In general,

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*For details about individual mining ventures, the reader is referred to the excellent study, [16].

sales are not announced or acknowledged, and there are strong legal restrictions on disclosures by potential South African sources. What information is available, beyond occasional trade press reports, must be obtained from consumers or inferred from financing or other arrangements made by South African mining companies. The analysis in this section is based upon a systematic but intrinsically uncertain process of such inferences, along with discussions with individuals in consumer nations.

Commercial uranium exports from South Africa appear to have begun in 1969 with sales to Japan and West Germany. Through the 1970s, Japan was South Africa's principal trading partner, though significant exports were also made to Germany, the United States (to a reactor vendor and a fuel fabricator) and France. Smaller quantities were sold to Switzerland, Austria, Belgium, and, perhaps, Brazil and Spain. Total exports appear to have reached a level of about 2,500 MTU by 1976, comparable to annual production in that year.

A major change in this pattern began in the mid-1970's as the uranium market tightened, prices rose, and South African producers began to seek front-end and contract-related financing for expansion of output. A principal source of this financing was Iran, which at that time envisioned a large nuclear program and had already made an investment in the Eurodif enrichment venture. There are indications of uranium exports to Iran as early as 1977 as a result of financing arrangements made in 1975 with South Africa's Free State Saaiplaas Mine, and perhaps with East Rand Gold and Uranium.* There also are

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*Delivery was not directly to Iran, but to the U.K., to be converted to UF_6. The total amount involved appears to be of order 2000 MTU.

indications of deals for as much as 7,500 to 15,000 MTU with other South African mining interests; and it is also possible that Iran assisted in financing South African involvement in the Rössing Mine in Namibia.* (See below).

France also became involved financially, with an interest free loan in excess of $100 million to Randfontein Estates, negotiated late in 1976 or early in 1977. France is entitled to more than 750 MTU/year over ten years. Deliveries appear to have begun in 1978, though production difficulties have delayed deliveries. Other countries may also have been involved in financing, though the uranium commitments are probably relatively small. There are more recent reports that the material already delivered has been resold.

With the gradual decline in deliveries to Japan (which reached a peak in 1978) and West Germany, South Africa's principal customers in the 1980's appear to be France and Iran, with smaller commitments to the United States (a 1973 contract to Exxon Nuclear for perhaps 500 MTU annually to 1984), to Belgium (a 1978 contract for perhaps 150 MTU/year in the 1980s), and to a number of unidentified customers whose collective commitment is no more than a few hundred MTU annually. By 1983, long-standing commitments to Japan and West Germany will have declined to less than 700 MTU per year and they disappear entirely by 1986. Identifiable export commitments are shown in Figure 4.5 and compared with planned and attainable capacities in Figure 4.6.

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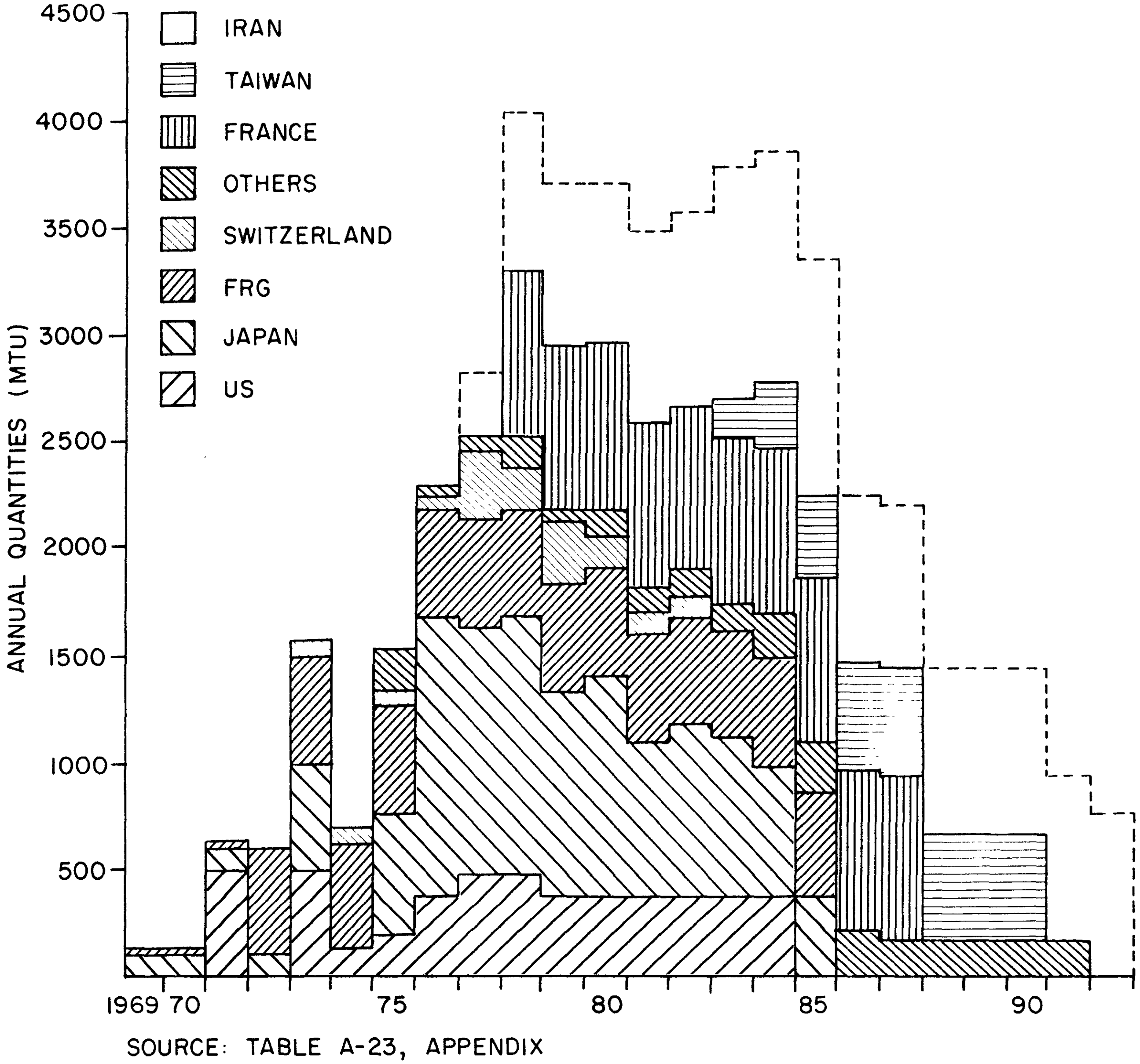
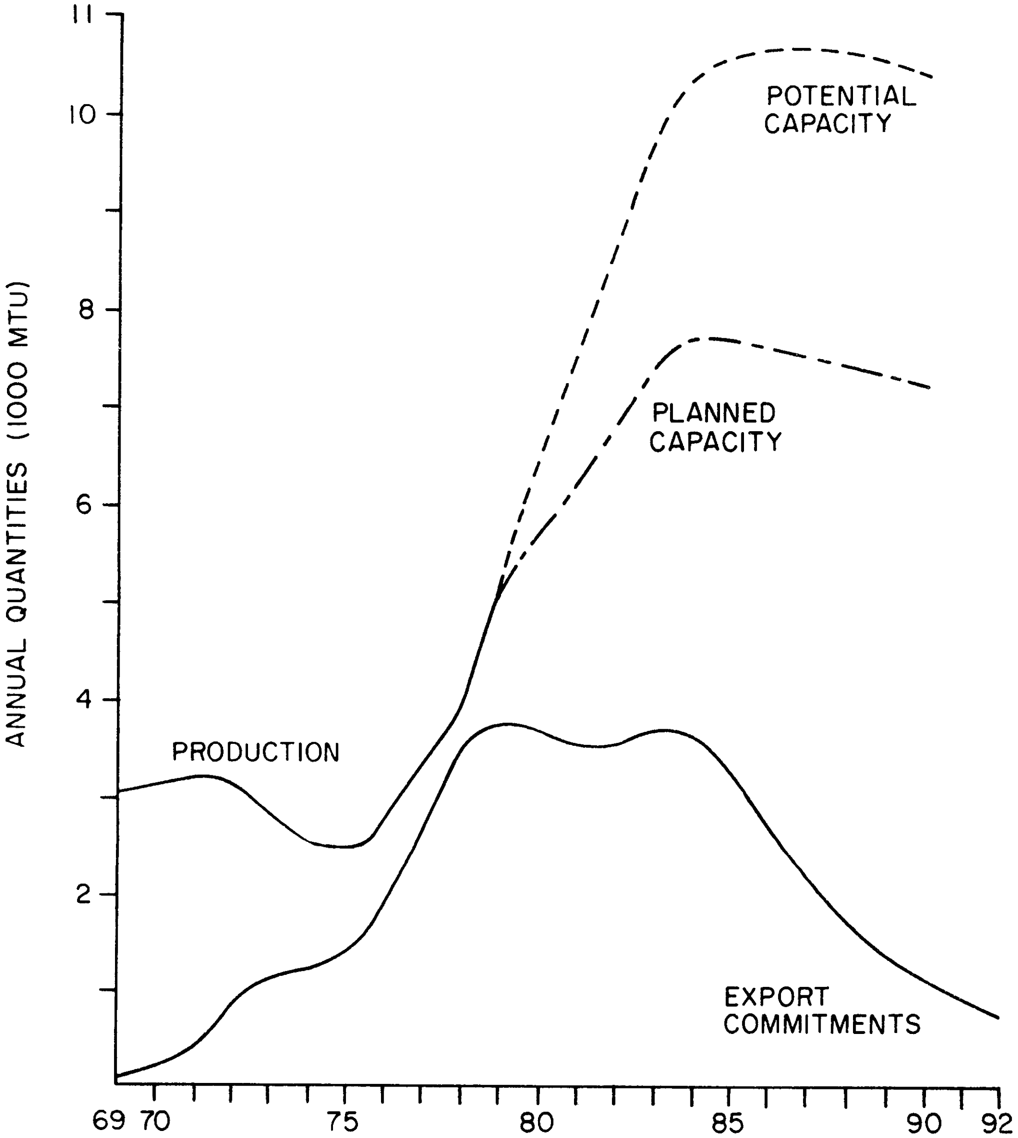
*Two South African groups have equity shares in Rössing: the private General Mining Corporation has a 2.3 percent share and the government-associated Industrial Development Corporation has 13.5 percent, for a total of 15.8 percent. Assuming a pro rata share of output this will amount to about 800 MTU/year.



SOURCE: TABLE A-23, APPENDIX

Figure 4.5

IDENTIFIABLE SOUTH AFRICAN EXPORT COMMITMENTS



SOURCE: TABLE A-24, APPENDIX

Figure 4.6
SOUTH AFRICAN EXPORTS COMPARED WITH PRODUCTION

Given current knowledge of future commitments and prospective growth in South African capacity, it appears that South Africa will soon have substantial excess supply. For example, commitments in 1983 appear to be about 2600 MTU, not including those to Iran, while planned capacity is expected to be about 7,900 MTU and potential capacity is as high as 10,000 MTU [17]. According to available information, contract commitments to Iran in 1983 were somewhere in the range of 1000 to 2000 MTU, though it is possible that some of this uranium may come from Namibia.* As with the French view of Iranian enrichment participation in Eurodif, South Africa's view appears to be that the uranium involved is Iran's responsibility. But whether resold by Iran or South Africa, the uranium involved represents a significant unanticipated source of supply to the world market. Directly or indirectly then, South African production capacity may exceed commitments to active consumer customers by as much as 5000 to 7500 MTU annually within a few years and even increase thereafter.

4.4 Namibia

Namibia has recently become a major contributor to world uranium markets. Production reached 3,700 MTU in 1979 and is expected to reach

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*Industry sources indicate that Iran was attempting to sell its contractually committed uranium from southern Africa in late 1979 with prices quoted as being in the low $30 range (this would be high enough to ensure a profit to Iran). Recent market changes may have made it more difficult to dispose of Iran's contracted supply, suggesting that this material will revert to South African control. Estimates of the total amounts available range from about 23,000 MTU to 38,000 MTU, quantities greater than we have been able to document, suggesting either that other Iranian involvement in South Africa or Namibia may have been missed or that industry estimates are double-counting South African and Namibian uranium. A consistent view is achieved if one assumes that Iran financed South Africa's share of Rössing and that uranium associated with this arrangement is variously attributed both to South Africa and Namibia.

5000 MTU annually in 1983. All of this is due to the Rössing deposit. Though the deposit has been known for more than fifty years, its development began in the mid-1960s, with mine and mill operations starting up in 1975 and 1976 respectively. Exploration in Namibia--especially in the granitic environs of Rössing--is active, with South African firms dominant.*

4.4.1 Namibia's Political Status

Namibia has been under the territorial governance of South Africa since 1920, and South African commercial, political and legal interests have shaped Namibian uranium development. For example, uranium exports are subject to the provisions of the South African Atomic Energy Act. However, there are profound tensions in this relationship that may, eventually, bring the Namibian independence that has been endorsed by the United Nations and by many foreign governments. The path to independence has been complicated not only by the opposition of South Africa (uranium and other mineral interests combine with political considerations to create strong incentives for South Africa to keep control) but also by tribal and racial conflicts within Namibia itself. The independence movement led by SWAPO (South West Africa People's Organization) has its political base in one large tribal grouping. Whites and other tribal groups are more sympathetic to some relationship to South Africa, while they tend to have long-standing antipathies toward the tribal groups

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*Previous OECD/IAEA and other reports tended to combine Namibian production with that of South Africa, or referred to a politically imprecise "Southern Africa." The independence movement in Namibia, as recognized by the United Nations and many major governments, seems to be resulting in a real separation between uranium operations in the two countries. For example, RTZ has moved its Rössing-related operations from South Africa to Namibia proper. How the direct South African participation in Rössing will be rationalized is still an open question.

supporting SWAPO. Conflicts between these groups has occurred at Rössing.

The United Nations has repeatedly called for free elections in Namibia under its supervision. South Africa has resisted, but instead conducted its own election in 1979. The result was a government that favors independence but with close ties to South Africa. The UN continues to pursue discussions with South Africa regarding the legitimacy of government in Namibia. As part of its long-standing effort, the UN has also called for sanctions against foreign governments who participate in trade with a South African-dominated Namibia. These U.N. actions have created problems for those organizations and governments seeking to benefit from Namibian uranium development. For example, Japanese companies were led to cancel a major contract with Rössing (though, as discussed below, Japan will still obtain uranium from Namibia under a different arrangement). There also are indications that West Germany has been involved in Rössing and will receive a significant share of its output, though there appears to be no official acknowledgment of this involvement.

Political evolution in Namibia will have a strong bearing on how Rössing's output is distributed and on the rate at which new deposits are developed. Uncertainty cannot help but slow the latter. The results of the recent elections--if they are sustained--tend to preserve the status quo for the South African and foreign interests involved in Namibia and one can expect existing trade patterns to be maintained. New elections with a clear SWAPO victory might temporarily disrupt Rössing operations and result in changes in long-run patterns of market participation; or perhaps only royalties would increase. Perhaps the most disruptive development would be the failure of a new government to attain legitimacy and a growth of conflict within the country.

4.4.2 Industry Structure

Because of the close association with South Africa and South Africa's rigid secrecy laws, there is little public information about financing, equity shares and contracts involving Namibian uranium. However, the fact that there is only one mine simplifies the task of making estimates of these quantities.

Rössing was developed by Rio Tinto Zinc, a multinational firm with uranium subsidiaries in Canada (Rio Algom), Australia (Conzinc Rio Tinto), and the U.S.; and with a copper and uranium operation at Palobora in South Africa. A breakdown of Rössing ownership shares is given in Table 4.2.

Directly or indirectly (through Rio Algom, Canada), RTZ has a majority share of 51.35 percent in Rössing; South African organizations control 15.7 percent and France's Minatome 10 percent. It is commonly believed that West German interests hold a significant fraction of the remaining 23 percent.

Table 4.2
Rössing Ownership Shares*

Rio Tinto (South Africa)	41.35 percent
Rio Algom (Canada)	10.0 percent
General Mining (South Africa)	2.3 percent
Industrial Development Corporation of South Africa	13.47 percent
Minatome (France)	10.0 percent
Others	22.88 percent

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*The RTZ (Rio Tinto S.A. and Rio Algom) share is from the 1978 RTZ Annual Report. Various other sources disagree slightly (less than 1 percent) on this and other equity shares; the numbers in Table 4.2 represent the authors' best judgment, based on evaluation of these conflicting sources.

These equity shares are not an adequate guide to actual flows of material, however, since RTZ and the South African organizations are not end users. Thus, nearly two-thirds of Rössing output is controlled by middlemen. To develop further understanding of Namibian operations it is necessary either to go to consumer data or to make inferences from financing arrangements. Both RTZ and South Africa apparently found financial backing for their shares of Rössing. RTZ appears to have obtained financing (through prepayment for future uranium deliveries) from the United Kingdom and, probably, Japan. South Africa may have obtained it from Iran.*

4.4.3 Trade Patterns

There are indications of uranium supply arrangements from Rössing to the United Kingdom by way of RTZ, from the late 1970's forward. Similarly, Japanese utilities have large contracts with RTZ beginning in the late 1970s. This uranium was almost certainly intended to come from Rössing, though by dealing with RTZ, the Japanese avoid the politically-sensitive question of its origin.** Similar arrangements, for smaller amounts, may have been made by other consumers, including the FRG (perhaps in addition to an equity share) and Spain. There also are indications that France may receive a larger share than indicated by Minatome's 10 percent equity (this equity share would entitle Minatome

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*There are also suggestions of direct Iranian financing of Rössing, though these reports may simply be different perceptions of a channel through South Africa.

**When the arrangement was made, Namibia was the only place RTZ could have obtained such a large amount of material with any certainty. Recently, the cancellation of the TVA-Rio Algom contract and other market developments might make it possible for RTZ to supply Japan from Canadian sources. Note also that Rio Algom is an owner of Rössing, though its share of output would only be about 500 MTU annually.

to about 500 MTU/year when production reaches an expected annual peak of 5000 MTU in 1983).

Finally, there are reports that Iran may be entitled to twenty percent of Rössing output, an amount comparable to if not identical with South Africa's participation share. Indeed, there have been press reports of confirmation of Iran's role in Rössing by the Chairman of RTZ; the reports also indicated that initial deliveries had already been made [18].

Fears of political instability and the political sensitivity of dealing with Namibia under South African rule have sometimes led to curious supply arrangements, in addition to those noted above. For an extended period in 1978, RTZ reportedly arranged for weekly airlifts of uranium from Namibia [19]. These flights landed not in England, but in France, where uranium was transshipped to consumers. The exploitation of Namibian uranium thus involves some rather special problems. As we have noted above, the question is not so much whether Namibian uranium will be available to the world market but rather what the supply arrangements will be, and whether current patterns will remain stable or require change.

4.5 Niger

As a uranium producer, Niger is just beginning to become significant on the world market. Although it is the fifth largest producer outside the Centrally Planned Economies, Niger's market share was originally quite small, growing from 4.4 percent in 1972, to 5.6 percent in 1977. However, three new finds are expected to raise that share to 11.2 percent by 1985, despite growing world production. By 1986, Niger may pass South Africa, becoming the fourth largest producer in the non-communist world.

Exploration in Niger was begun by France's CEA in the 1950s, and the first results were two small deposits (4000 and 6000 MTU), Azelik and Modaouela. These are high-cost deposits in the context of the resources more recently discovered in Niger. In 1966, the much larger Arlit deposit (about 40,000 MTU) was reported, and Niger's first commercial production began in 1971 (with about 400 MTU output). Subsequently, a slightly larger deposit, Akouta (perhaps 44,000 MTU), was discovered about 20 kilometers from Arlit. Production at Akouta began in 1978 at about 500 MTU. In 1978 a still larger deposit of about 70,000 MTU reserves was demonstrated at Imouraren. Production at Imouraren is scheduled to begin in 1982 or 1983 at about 2500 MTU annually. Two smaller recent discoveries, Arni and Abkorun, appear likely to begin production in the early to mid-1980's. Exploration is occurring in more than a dozen other concessionary areas and, if recent experience is any guide, the potential for new discoveries is great. In the 1979 Redbook, the OECD/IAEA working group estimates that Niger's output will increase from a 1979 production level of 3,350 MTU to 5,800 MTU in 1983 and 12,000 MTU in 1986 [17].

4.5.1 Industry Structure

The Niger government, through its state uranium organization Office National Des Ressources Minieres (Onarem) is a participant in all exploration and development in Niger, usually at a 30 to 50 percent level. Perhaps in reaction to its previous colonial status (independence from France came only in 1970), the Niger government has encouraged participation by a multitude of foreign private and quasi-governmental groups. France, Italy, West Germany, the United States, the United Kingdom, Spain, Canada, Nigeria, Iran, and Japan are all involved in Niger, though France (with Cogema, CFMU, Minatome and Mokta involvement) holds a larger equity position than any other country, comparable to that of Niger itself.

Mine development and production in Niger is generally under multinational consortia with major financing from the foreign participants. The first mine, Arlit, is operated by the Societe des Mines de l'Air (SOMAIR) with participation by the government of Niger and companies from France, West Germany and Italy. France, Japan and Spain are involved with Onarem at Akouta. Equity shares and prospective production levels for the five mines under development or likely to be developed by the mid-1980s are shown in Table 4.3.

Table 4.3

Ownership Shares

Mines in Niger Under Development

Mine	Ownership Share	Country	Organization
Arlit	33 percent	Niger	Onarem
(SOMAIR)	54.2 percent	France	Cogema CFMU Mokta
	6.4 percent	Italy	AGIP
	6.4 percent	W. Germany	Urangesellschaft
Akouta	31 percent	Niger	Onarem
(Cominak)	34 percent	France	Cogema
	25 percent	Japan	OURD
	10 percent	Spain	ENUSA
Imouraren	30 percent	Niger	Onarem
	35 percent	France	Cogema
	35 percent	United States	Conoco
Arni	50 percent	Niger	Onarem
(SMTT)	50 percent	France	Cogema
Abkorun	50 percent	Niger	Onarem
	50 percent	Japan	International Resources

In addition, there are about a dozen exploration concessions. Five of these are joint ventures between Onarem and Esso (U.S.), though Esso has now terminated active exploratory work on some concessions. Canada's Pan Ocean, Ltd. is in joint venture with Onarem in three concessions. On the Afasto-Est concession, the governments of Niger and Nigeria have joined with France's Cogemma, Britain's Central Electricity Generating Board and Japan's OURD. Similar arrangements--involving, in addition, Iran's Organization de L'Energie Atomique, and Germany's Saarberg-Interplan--exist for the Afasto-Ouest, Muasto-Est and In-Adrar concessions. But in all of the latter, as in the areas under active development, Onarem and Cogema have the largest equity shares.

Uranium is Niger's principal source of income and the government's share of revenue is the financial basis for national development. In addition, Niger often requires that foreign organizations involved in the country contribute directly to development projects, including some only very peripherally related to uranium production. In part because of the attractiveness of its uranium (including relatively low production costs), Niger's strategy of fostering multinational competition seems to have been effective in persuading foreign organizations to make infrastructural investments. And while France clearly has a dominant influence, the presence of many other groups helps keep ultimate control of Niger's uranium in the hands of the national government.

4.5.2 Trade Patterns

To a first approximation, the distribution of Niger's uranium appears follow the equity participation of the various participants. Thus of a potential production of 10,500 MTU in 1985, France might be entitled to about 4000 MTU, Japan to 1250 MTU and others to much smaller totals, as indicated in Table 4.4. Under the equity allocations, the Niger government retains the right to sell about 3900 MTU in 1985 . But with the exception of a few reports of spot sales, Onarem is--at least at present--apparently willing to sell its shares through its foreign equity partners.* To the extent that it is possible to find evidence, the principal buyer appears to be France, though Japan and other major consumers also have made purchases. Sales by Onarem to these countries appear to be at world market prices.

For the two producing deposits (Arlit and Akouta), indications are that most of Onarem's share has been allocated as discussed above; for the three deposits under development, there are no reports of allocations of Onarem's share. This presumably preserves maximum flexibility for the Niger government in dealing with its development partners--including leverage for inducing additional development investments. How future production from these deposits will be allocated beyond equity shares is thus intrinsically uncertain. It should be noted, however, that non-equity consumers--such as South Korea and other developing countries--are becoming more active in the world market. Niger will thus have more opportunities to sell directly. Whether it will take such opportunities or simply use them to improve its negotiating position with its equity participants cannot be projected at this time.

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*Onarem is known to have made sales to Belgium, the Netherlands, Pakistan, and Libya, totaling only a few hundred tonnes. Concern has arisen over the Libyan sale due to Libya's known desire to acquire nuclear weapons, lack of safeguards, and indications that uranium was transferred to Pakistan for use in its weapons program (believed to have substantial Libyan support). There are also reports of direct sales of uranium by Niger to Pakistan.

Table 4.4

Prospective Production Capacity

(MTU)

	1979	1980	1981	1982	1983	1984	1985	1986/1990
Arlit (Somair)	1,700	2,000	2,220	2,200	2,600	2,600	3,500	3,500
Akouta (Cominak)	1,600	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Arni (SMTT)	--	--	--	--	750	1,200	1,500	1,750
Abkorum (Azelik)	--	--	--	--	450	1,200	1,500	1,750
Imouraren	--	--	--	--	--	1,000	2,000	3,000
TOTAL	3,300	4,000	4,200	4,200	5,800	8,000	10,500	12,000

Allocation By Equity Shares

	1979	1980	1981	1982	1983	1984	1985	1986/1990
France	1,460	1,760	1,870	1,870	2,460	3,040	4,030	4,500
Japan	400	500	500	500	720	1,100	1,250	1,370
FRG	100	130	140	140	170	170	220	220
Spain	160	200	200	200	200	200	200	200
Italy	100	130	140	140	170	170	220	220
U.S.A.	--	--	--	--	--	350	700	1050
Niger	1,080	1,280	1,350	1,350	2,080	2,970	3,880	4,440

Source: Author's estimates, drawing on information from industry sources.

Footnotes to Chapter 4

1. "Ranger Uranium Environmental Inquiry--Second Report" (Commissiner: Mr. Justice R.W. Fox), Australian Government Purchasing Service, May 1977.

2. "Australia's Ailing Economy," *World Business Weekly*, Financial Times of London, October 1, 1979, p. 31.

3. "Ranger Uranium Environmental Inquiry--Second Report," *op. cit.*, Appendix V, National and Regional Economic Effects.

4. A. Fitzgibbons, "Mining and the Future Structure of the Australian Economy," *Australian Quarterly*, Vol. 45, June 1973, pp. 86-94.

5. R.K. Kindler, "Inflationary Implications of the Growth of the Mining Sector," *Australian Economic Papers*, University Relations Unit, Flinders University of South Australia, June 1978, pp. 37-50.

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10. M. Ross, *Trade Unions in Australia* (London: Penguin Books, 1975).

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12. "Final Report, Cluff Lake Board of Inquiry" (Chairman: Mr. Justice E. Banda) Saskatchewan Department of the Environment, Regina, Saskatchewan, May 1978.

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15. *Ibid.*, pp. 263, 264.

16. N.B. McLeod and J.J. Steyn, *Foreign Uranium Supply* (Palo Alto: Electric Power Research Institute, EA-725, 1978); prepared by NUS Corporation, Rockville, MD.

17. OECD-NEA/IAEA, *Uranium Resources, Production and Demand* (Paris, OECD, 1979).

18. *Nuclear Fuel*, May 28, 1979.

19. *Nuclear Fuel*, June 26, 1978.

V. MAJOR CONSUMERS

There are now 18 countries (outside the Centrally Planned Economies) operating power reactors with a total capacity of about 144 GWe. Of this total about 79 GWe is outside the United States: 54 GWe in Europe, 15 GWe in Japan and 6 GWe in Canada. Only about 4 GWe is operating outside of these industrialized areas. For this reason, most uranium market activity is conducted by a few large consumers, notably the United Kingdom, Japan, West Germany, France, Spain and Italy. Moreover, many countries with small nuclear programs still depend on reactor vendors or fuel fabricators to provide uranium for first cores or initial reloads. Only a few of these countries have had reactors operating long enough to need to procure uranium for operation beyond these first few years. For example, South Korea and Taiwan have only recently entered the world market: Korea now has two contracts (with Canada and Australia) and Taiwan has recently completed one with South Africa.

The identified total contractual commitments made by consumers in the international market through 1990 are shown in Table 5.1. These data are derived from the survey described at the beginning of Chapter 4. Over 320,000 MTU have been contracted. To the extent possible, procurements through middlemen--such as Rio Tinto Zinc and Uranex--are attributed directly to producers. There are about 10,000 MTU that appear to move through these agents over the period in question which we have not been able to trace directly from producer to consumer. This is not a large discrepancy. We have omitted the role of the United States in the international market, largely because at present there is only a weak coupling between the domestic U.S. market

Table 5.1

Contractual and Firm Equity Import Commitments* 1968-1990

(MTU)

Japan	120,030
France(1)	72,230
West Germany	56,530
United Kingdom(2)	20,300
Iran(3)	18,500
Spain	13,800
Italy	10,800
Belgium(4)	2,600
South Korea	3,400
Switzerland	1,600
Austria(5)	700
Sweden	700
Finland	720
TOTAL	321,910

* Commercial contracts with primary producers and explicit equity-based supply commitments (principally Niger) are included. Indirec+ supply arrangements through third parties and equity participations without explicit destination specification are not included.

(1) The figure for France is net imports; according to our estimates, actual imports are 93,580 MTU, but 21,350 MTU are exported. The figure also does not include France's domestic production, expected to be about 60,000 MTU over this period.

(2) United Kingdom contracts do not include pre-1973 deliveries under weapons-related procurements. However, at least some of the latter would be available for power generation purposes.

(3) Iran's commitments are from Namibia and South Africa, and may be underestimated due to the great secrecy involved. Iran appears to be trying to resell this material to other consumers and there are reports that material already delivered has been sold.

(4) The figure for Belgium does not include sales to that country by France, which we estimate to be about 7000 MTU.

(5) Some of the Austrian uranium, from South Africa, has been sold (in the United States) due to the deferral of operation of the Tullnerfeld reactor.

and the international market. On average, the U.S. imports about 2000 MTU annually (mostly to reactor vendors or fuel fabricators, rather than utilities) and generally on long-term contract. Historically, U.S. producers have exported comparable amounts, usually on a spot purchase basis, often in connection with other U.S. nuclear activities such as reactor sales, enrichment contracts with the U.S. government, or offset (Germany) or preproduction (Japan) sales. In terms of forward commitments, the United States appears to be a net importer, though this may simply be an artifact of the difference in the nature of import and export contracting; spot sales are not evident very far in advance.

Among the major consumers, procurement history and practices vary. Some consumers entered the market very early--in the late 1960s or early 1970s--for large quantities of uranium on long-term contracts. Others have domestic reserves or preferred access to uranium in former colonies, and thus delayed entry into the international market. And then some countries have simply purchased uranium as needed, using a combination of spot purchases and longer term contracts. Japan, France and West Germany provide examples of these three modes of operation. They also account for 77 percent of all identified international commitments over the period 1968-1990, and a description of their situations and behavior thus encompasses much of the activity in the international market. Below, we examine each of these countries in detail.

5.1 Japan

Japan's first uranium procurements were through the United States in connection with reactor sales by General Electric and Westinghouse. These vendors have constructed about 6.5 GWe of capacity in Japan, and imports to Japan from the United States for first cores and initial reloads total about 4000 MTU, virtually all delivered prior to 1980. In 1969 Japan began independent contracting for uranium, with domestic utilities or groups of utilities seeking uranium abroad, often with the assistance of Japanese trading companies.

Imports from Canada and South Africa began in 1969 but diversification did not occur until the mid-1970s. In 1974, Japan began to receive uranium from France (through Uranex, the marketing agency of the CEA) on a contract totalling about 9200 MTU and extending through 1985.* In 1977 imports began from Australia and, in 1978, from Niger. Japan also receives substantial amounts of uranium from Rio Tinto Zinc (London), from whom deliveries apparently began in 1977.**

Japan thus receives uranium from all major primary producers and through the two major independent supply channels--RTZ and Uranex. This supply pattern, and its behavior over time, is shown in Table 5.2. Total commitments, through 1990 including past deliveries, are about 120,000 MTU.***

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*These contracts were written prior to the halt of export contracting by France early in 1974. In the initial years, the uranium for Japan would have come from domestic French production or from Gabon or Niger. In the 1980s, some of the contracted uranium could be furnished from additional French supply sources in Namibia, South Africa or Canada.

**Some of this uranium might come from RTZ subsidiaries in Canada and Australia, but RTZ appears to be heavily dependent on Namibia to meet contract obligations.

*** Japan is purchasing uranium beyond its equity share in Cominak in Niger, reportedly 44 percent of output rather than the 25 percent equity share assumed in Table 5.2. If this continues, Japan may receive an additional 380 MTU/year or 3800 MTU over the decade.

Table 5.2

JAPAN
Contract and Equity Import Commitments
(MTU)

Year	Australia	Canada	Niger	South Africa	U.S.	France	RTZ	Total	Cumulative
1969		1190		100	240			1530	1530
1970		1150		100	90			1340	2870
1971		1250		100	90			1440	4310
1972		2080		100	560			2740	7050
1973		1150		500	200			1850	8900
1974		1150			200	300		1650	10,550
1975		1150		580	400	300		2430	12,980
1976		2390		1300	1000	300		4990	17,970
1977	690	2540		1150	700	900	600	6580	24,550
1978	460	2500	200	1200	500	900	950	6710	31,260
1979	740	2500	400	950	300	900	1950	7740	39,000
1980	730	1620	500	1030		900	2300	7080	46,080
1981	970	1690	500	720		900	3100	7880	53,960
1982	1500	1580	500	800		900	3100	8380	62,340
1983	1580	1900	720	740		900	3100	8940	71,280
1984	1300	3460	1100	610		900	3750	11,120	82,400
1985	1450	3540	1250	380		900	2900	10,420	92,820
1986	1160	1810	1370				1920	6260	99,080
1987	850	1730	1370				1550	5500	104,580
1988	850	1700	1370				1550	5470	110,050
1989	850	1700	1370				1150	5070	115,120
1990	850	1540	1370				1150	4910	120,030

Of this, about 34 percent comes from Canada, Japan's largest supplier. About 17.5 percent comes from RTZ, and of this, perhaps 11,500 MTU (or a minimum of 9.6 percent of total uranium supply) comes from Namibia. Some 8.6 percent comes from South Africa, 10 percent from Niger,* 7.4 percent from France, 11.6 percent from Australia and 3.6 percent from the United States.

Two trends are evident in Table 5.2. The first is a successful diversification in supply sources. Whereas in 1973 Japan received 90 percent of her uranium from only two sources (Canada and South Africa), no two primary producers account for more than 40 percent in 1980. This diversification clearly enhances Japan's energy supply security.** The second evident trend is the declining relative importance of South African supply. While South Africa provided up to one-third of Japan's uranium in the mid-1970's, this share declines to 15 percent by 1980; Japan's current contracts with South Africa decline to zero by 1986. This shift away from dependence on South African supply may be due to a perception of future insecurity of this supply channel or the international political sensitivity of dealing with South Africa, or both. The termination of Japan's dependence on France appears to be due simply to the cessation of French export contracting. In both cases, circumstances could change, creating new Japanese purchase opportunities. Given prospective excesses of capacity and production, Japan could contract for additional uranium from virtually all sources.

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*The Niger figures include only Japan's equity share in production in Niger. This is a lower bound on supplies from that country since it is known that Japan purchases part of the Niger government's share.

**Note, in this connection, that RTZ and Uranex--with their multiplicity of primary supply sources and ability to reallocate within their own systems--may provide a further buffer against disruptive events in producer countries.

But Japan's current supply and demand situation is such that this would not be necessary for quite some time. In Table 5.3, we show annual consumption requirements in the past, and for two future growth scenarios. The first scenario is based on plants operating, under construction and on order; the second is based on the INFCE "low" projection. Under present utility commitments, only about 20 GWe (including a present capacity of about 14.5 GWe) would be built. The INFCE projection envisions 45 GWe by 1990 and undoubtedly exaggerates Japan's nuclear growth potential by that date.

Japan's uranium supply commitments have greatly exceeded actual reactor requirements and will continue to do so over a wide range of nuclear futures. Our calculations indicate that Japanese reactor consumption of uranium to date has only been of order 13,000 MTU while known delivery commitments have been nearly 39,000 MTU. By this materials balance calculation,* current Japanese stocks--including material currently undergoing processing for fuel and that being held for Japan by producers and processors--may be as great as 25,000 MTU (ten year's supply at current consumption rates). Based on present utility commitments, this stock would grow to about 75,000 MTU by 1990, with contracts exceeding requirements in all years. If the INFCE growth projection were reached (which is virtually impossible), annual requirements would begin to exceed contracts in 1987 and pre-existing

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*Our calculation, as described in the appendix, computes uranium feed requirements for reactors as they come on line. We assume an enrichment tails array of 0.20 percent and 70 percent reactor capacity factor. In earlier years, reactor capacity factors in Japan were considerably below 70 percent but it is likely that significant amounts of fuel did not reach design burnup. Our calculation thus may overestimate consumption--and underestimate stocks--but probably not by much.

Table 5.3

JAPAN
Supply, Demand and Inventories

(MTU)

		Historical and Present Plans			INFCE Forecast		
Year	Import Commitments	Requirements	Annual Stock	Cumulative Stock	Requirements	Annual Stock	Cumulative Stock
1969	1530	190	1340	1340			
1970	1340	110	1230	2570			
1971	1440	290	1150	3720			
1972	2740	710	2030	5750			
1973	1850	1000	850	6600			
1974	1650	700	950	7550			
1975	2430	1950	480	8030			
1976	4990	2180	2810	10,840			
1977	6580	1050	5530	16,370			
1978	6710	1730	4980	21,350			
1979	7740	2580	5160	26,510			26,510
1980	7080	2560	4520	31,030	3070	4010	30,520
1981	7880	2760	5120	36,150	3170	4710	35,230
1982	8380	2290	6090	42,240	3710	4670	39,900
1983	8940	2500	6440	48,680	3880	5060	44,960
1984	11,120	2770	8350	57,030	4610	6510	51,470
1985	10,420	2770	7650	64,680	4660	5760	57,230
1986	6260	2770	3490	68,170	5760	500	57,730
1987	5500	2770	2730	70,900	5950	(450)	57,280
1988	5470	2770	2700	73,600	6360	(890)	56,390
1989	5070	2770	2300	75,900	7050	(1980)	54,410
1990	4910	2770	2140	78,040	7610	(2700)	51,710

stocks (about 57,000 MTU at the end of 1985) would begin to be run down. But stocks remaining at the end of 1990 would still exceed 51,000 MTU. These stocks do not include additional possible supply from non-equity purchases in Niger or any new contracting after late 1980.

Thus, Japan's uranium supply situation is secure over at least the next decade, with existing contracts in excess of the needs of even the most ambitious nuclear plans. Even the loss of a major supplier could easily be withstood (though this would cause reallocation problems for individual utilities and a disruption of supply logistics). Contract levels and stocks will be sufficient to allow leisure in making new uranium procurement decisions. In addition, the prospective global supply situation--as discussed above--is such that new procurement opportunities will be many. Current Japanese contracts decrease rapidly in the late 1980's, and no known contracts extend beyond 1996. But the volume in the late 1980's is still greater than would be needed for currently committed reactors. And the stock accumulated by 1990 would be enough to fuel the 20 or so GWe now committed for an additional 28 years. Japan can thus wait without danger for significant new reactor demand to materialize before committing to new uranium supplies.

The Japanese stock position is so strong that one must consider the question of whether some of Japan's uranium might re-enter the world market, on a sale or loan basis. While the cost of maintaining inventories of nuclear fuel is not as high as for other energy commodities, the carrying charges on a ten or twenty year forward inventory* are probably more than most utilities would bear voluntarily. The government policy toward stocks will thus have a major bearing on utility behavior and on the role of stocks in the world market. Government might encourage large stocks as part of a national energy security program or--if ways can be found to use the stocks as part of an international scheme--for international fuel assurance purposes. But given present trends in international uranium markets, both these security-related concerns should decline in importance since procurement possiblities are increasing, and real (and even nominal) prices are declining. If the market softens greatly, Japan would be in a good position to risk some of the higher-priced contracts it now holds by insisting upon downward renegotiation of prices--much as producers insisted upon upward price renegotiations in the tight market of the late 1970's. In this sense, at least, Japanese stocks overhang the market and may increase downward pressures on prices.

5.2 France

France's role in the uranium market is more complex, and less well documented, than for other major consumers. Unlike Japan or Germany, France has substantial domestic production of uranium; France also plays

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*Each year of forward supply of uranium adds about 0.5 mills/kilowatt-hour to current power costs, assuming that the annual carrying charge is 20 percent of procurement cost. If the stock is held as enriched uranium or fabricated fuel, the effect on the overall nuclear power cost may be double the above, or about one mill per kilowatt-hour. A ten-year forward supply of fuel might therefore cost utility customers five, ten, or more mills per kilowatt-hour, compared to perhaps thirty mills (currently) for actual generation. Such a large increase in nuclear power costs might be justified on national energy security grounds, depending on the premium attached to the latter. It would be difficult to justify in the more limited utility context, especially under conditions of a buyer's market.

a role as an exporter of uranium. France's procurement of uranium abroad is also more firmly under centralized government control, despite a multiplicity of organizations involved. And the dividing line between military and civilian uranium activities is ambiguous. Analysis of France's position in the uranium market is thus inherently difficult.

Prior to 1969, available data do not allow separation between domestic production and uranium procured from Gabon or other "affiliates." Annual supply through 1968 is given in the Appendix. The known total to that date from all sources was 16,800 MTU; how much of this was used in the French weapons program is not publicly known. Our calculations indicate that reactor requirements prior to 1969 totalled about 1300 MTU, so that the maximum known stock at the beginning of 1969 was about 15,500 MTU--a quantity that should be reduced by actual weapons-related consumption. In 1969, it is possible to begin tracking domestic production, and output from Gabon, France's sole import source at the time. In 1971, production began in Niger, with France receiving all output until 1976. Supplies from South Africa began in 1978 and contract deliveries from Namibia and Canada start in 1981.

Niger is France's largest external supplier; equity participation alone should yield France about 4500 MTU annually by 1986--slightly exceeding expected domestic production--and France is buying at least part of the Niger government's share of production. Current commitments from Gabon, Namibia, South Africa and Canada are on the order of 1000 MTU annually each. The origins of France's uranium, to the extent they may be deduced from available sources, are shown in Table 5.4. Imports from Niger are based on equity shares in ventures there; as noted above

Table 5.4

FRANCE
Domestic and Foreign Supply

(MTU)

Year	Domestic	Gabon	Niger	Namibia	South Africa	Canada	Total	Cumulative
pre-1969 France + Affiliates							16,850	16,850
1969	1180	500					1680	18,530
1970	1250	400					1650	20,180
1971	1250	540	400				2190	22,370
1972	1540	210	870				2620	24,990
1973	1620	400	950				2970	27,960
1974	1670	440	1120				3230	31,190
1975	1740	800	1300				3840	35,030
1976	1870	850	1200				3920	38,950
1977	2100	1410	800				4310	43,260
1978	2180	1000	650		770		4600	47,860
1979	2600	1000	1460		770		5830	53,690
1980	3100	1000	1760		770		6630	60,320
1981	3300	1000	1870	110	770	520	7570	67,890
1982	3500	1300	1870	460	770	750	8650	76,540
1983	3600	1300	2460	850	770	750	9730	86,270
1984	3600	1300	3040	1380	770	750	10,840	97,110
1985	3600	1300	4030	1380	770	750	11,830	108,940
1986	4050	1300	4500	1380	770	750	12,750	121,690
1987	4050	1300	4500	1380	770	750	12,750	133,440
1988	4050	1300	4500	1380	0	750	11,980	145,420
1989	4050	1300	4500	1380	0	750	11,980	157,400
1990	4050	1300	4500	1380	0	750	11,980	169,380

this is a lower bound on supply. The evidence about the timing and quantities involved in commitments from Namibia is mixed. Some reports suggest that deliveries have already begun.

According to Table 5.4, which may underestimate supply, cumulative French access to domestic and foreign uranium stands at about 54,000 MTU (including some material used for weapons) as of the end of 1979. Annual supply in 1980 will be about 6600 MTU and forward commitments through 1990 probably approach 170,000 MTU. But not all of this uranium is available for domestic use. Prior to 1974, France actively sold uranium in the world market through the CEA-controlled marketing agent, Uranex. Deliveries under commitments made before 1974 appear to have begun in 1972 and continue until about 1985. There is evidence of about 21,000 MTU of such commitments, largely to Belgium and Japan, though other commitments may exist. Table 5.5 shows domestic production, and known imports and exports, allowing calculation of net annual and cumulative domestic supply. Our estimates show a cumulative net procurement of about 43,000 MTU by the end of 1979 and 149,000 MTU by the end of 1990.

In Table 5.6, we compare these net supply estimates with historical and prospective reactor requirements. At the end of 1979 stocks (from which weapons needs should be subtracted) stood at about 29,000 MTU. Under any reasonable growth rate, these stocks continue to grow over the next decade. Under the present plans scenario (current utility commitments), stocks would grow to nearly 76,000 MTU by 1990; assuming additional orders, as in the INFCE

Table 5.5

FRANCE

Net Domestic Supply

Year	Domestic Production	Imports	Exports	Net Domestic Supply	Cumulative
pre-1969	16,850				16,850
1969	1180	500	0	1680	18,530
1970	1250	400	0	1650	20,180
1971	1250	940	0	2190	22,370
1972	1540	1080	200	2430	24,800
1973	1620	1350	270	2700	27,500
1974	1670	1560	570	2660	30,160
1975	1740	2100	930	2910	33,070
1976	1870	2050	1250	2670	35,740
1977	2100	2210	1980	2330	38,070
1978	2180	2420	3050	1550	39,620
1979	2600	3230	2030	3800	43,420
1980	3100	3530	2030	4600	48,020
1981	3300	4270	1440	6130	54,150
1982	3500	5150	2000	6650	60,800
1983	3600	6130	2000	7730	68,530
1984	3600	7240	1800	9040	77,570
1985	3600	8230	1800	10,030	87,600
1986	4050	8700	0	12,750	100,350
1987	4050	8700	0	12,750	113,100
1988	4050	7930	0	11,980	125,080
1989	4050	7930	0	11,980	137,060
1990	4050	7930	0	11,980	149,040

Table 5.6

FRANCE
Supply, Demand and Inventories

(MTU)

		Historical and Present Plan			INFCE Forecast		
Year	Net Supply	Requirements	Annual Stock	Cumulative Stock	Requirements	Annual Stock	Cumulative Stock
pre-1969	16,850	1290		15,560			
1969	1680	450	1230	16,790			
1970	1650	200	1450	18,240			
1971	2190	270	1920	20,160			
1972	2430	340	2090	22,250			
1973	2700	340	2360	24,610			
1974	2660	660	2000	26,610			
1975	2910	660	2250	28,860			
1976	2670	2330	340	29,200			
1977	2330	2450	(120)	29,080			
1978	1550	2880	(1330)	27,750			
1979	3800	2640	1160	28,910			28,910
1980	4600	4000	600	29,510	4000	600	29,510
1981	6130	4540	1590	31,100	4540	1590	31,100
1982	6650	5790	860	31,960	5190	1460	32,560
1983	7730	4650	3080	35,040	5810	1920	34,480
1984	9040	4780	4260	39,300	5990	3050	37,530
1985	10,030	5670	4360	43,660	6500	3530	41,060
1986	12,750	5840	6910	50,570	6280	6470	47,530
1987	12,750	5840	6910	57,480	7920	4830	52,360
1988	11,980	5840	6140	63,620	7670	4310	56,670
1989	11,980	5840	6140	69,760	7810	4170	60,840
1990	11,980	5840	6140	75,919	8360	3620	64,460

projection,* stocks still climb to more than 64,000 MTU. Larger stocks are possible if France is able to purchase uranium in excess of equity shares in Niger, as expected (as much as 20,000 MTU might be involved). Thus, even though there may be uncertainty about early stock accumulations because of unknown weapons demand, the rate of growth of stocks is sufficient to overwhelm this uncertainty.

In absolute terms, anticipated French stocks are slightly greater than those of Japan. On the other hand, France envisions greater nuclear growth. France has 44 GWe presently planned by 1990 compared to 20 GWe for Japan; there are 86 GWe projected for France versus 45 GWe for Japan, according to the INFCE estimate. Thus the ratio of stocks to capacity is less than for Japan. If France builds 44 GWe by 1990, estimated stocks at that time would fuel these reactors for perhaps ten years. But France may be in a somewhat more vulnerable position than Japan in its extensive dependence on supply from Niger. Over the next decade, nearly half of France's imports come from Niger, and loss of that supply early in the decade would narrow France's supply-demand balance. Under the "present plans" growth scenario, stocks would be reduced to about 40,000 MTU in 1990 (or perhaps much less, depending on how much of past supply was used for weapons). Under the higher growth (INFCE) scenario, stocks would be reduced to about 28,000 MTU by the end of the decade without uranium from Niger. Thus unless there were also great difficulties with scheduled supplies from Gabon, South

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*Present plans and INFCE projections are in closer congruence for France than for most other countries due to the official character of nuclear power commitments.

Africa or Canada, France's options for expanded nuclear growth do not depend critically on the political stability and output performance of Niger. The sensitivity of this connection is declining further with the general increase in new contracting opportunities in other producer countries.

5.3 West Germany

In contrast to Japan, West Germany did not enter the market early for large quantities of uranium on long-term contracts and, in contrast to France, Germany did not have the opportunity to establish major equity shares in large production ventures until 1980, when it took a share in the Ranger development. Nor does the FRG have significant domestic resources. Perhaps because of a difference in procurement philosophy,* Germany contracted only for relatively small quantities in the tight market years of the late 1970s.

Total identifiable commitments (including a 49 percent equity share in Saskatchewan's Rabbit Lake deposit) from 1968 to 1990 are about 56,000 MTU. This might be compared with Japan's commitment to about 120,000 MTU over this same period. The Japanese and German nuclear programs are very similar in current and prospective size. Of this total commitment 39.2 percent comes from Canada (primarily the Uranerz-Gulf joint venture at Rabbit Lake and the Amok deposit at Cluff Lake), 21.2 percent from Australia, 14.5 percent from Namibia, 3.6 percent from Niger (based on equity shares--additional purchases

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*Buying smaller quantities over shorter terms is a reasonable and even preferable strategy under some market conditions. Except for the panic years of the mid- to late-1970's, utilities in the United States have generally bought in just this way.

are possible), 14.3 percent from South Africa,* 1.1 percent from France, and 6.2 percent from the United States. Prior to the mid-1970's, Germany's uranium came primarily from Canada, South Africa and the U.S.; and significant diversification has occurred only in the past few years.

Over the past decade, annual imports have generally exceeded needs, with spot purchases contributing significantly. German stocks have also grown in each year, albeit slowly, standing now at about 7000 MTU. About 2000 MTU of this (held as enriched uranium) resulted from the "Offset Agreement" of 1970 with the United States. Under this agreement the FRG agreed to purchase enrichment services from the United States government and uranium from U.S. producers as a way to balance U.S. expenditures for American troops stationed in Germany. Two increments have been delivered and a third (for about 850 MTU) has recently been negotiated. These known stocks provide a cushion for risks in procurement strategy.

The past approach of German utilities--which was to limit purchases to near-term needs and hold only small inventory--is now being augmented with efforts to establish positions in the market that improve access to supply. Uranerz, Urangesellshaft and RWE are active in exploration and joint development ventures in a number of producer countries. Recent commitments from Amok (Canada) and Ranger (Australia) represent a new emphasis on long-term supply commitments that ensure substantial stockbuilding through 1990. Under present contracts and reactor

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*There is some evidence--unconfirmed--for additional quantities from South Africa.

Table 5.7

West German Supply Arrangements

(MTU)

Year	Australia	Canada	Namibia	Niger	South Africa	U.S.	France	Total	Cumulative
1968		300						300	300
1969		70			30			100	400
1970		70			30	1360		1460	1860
1971		70			30			100	1960
1972		360			500			860	2820
1973		70			500			570	3390
1974		70			500	870		1440	4830
1975		460			500	650	360	1970	6800
1976		460	300		500	150	140	1550	8350
1977	260	460	600		500		140	1960	10,130
1978	310	1870	900		500			3580	13,890
1979	260	1600	900		500			3260	17,150
1980	260	710	500	130	500	450		2550	19,700
1981	50	1290	500	140	500			2480	22,180
1982	1230	1480	500	140	500			3850	26,030
1983	1230	1600	500	170	500			4000	30,030
1984	1220	1600	500	170	500			3990	34,020
1985	1190	1600	500	220	500			4010	38,030
1986	1190	1600	500	170	500			3960	41,990
1987	1190	1600	500	220	500			4010	46,000
1988	1190	1600	500	220				3510	49,510
1989	1190	1600	500	220				3510	53,020
1990	1190	1600	500	220				3510	56,530

Table 5.8

WEST GERMANY
Supply, Demand and Inventories

(MTU)

		Present Plans			INFCE Forecast		
Year	Import Commit-ments	Requirements	Annual Stock	Cumula-tive Stock	Require-ments	Annual Stock	Cumulative Stock
1968	300	70	230	230*			
1969	100	580	-480	-250			
1970	1460	120	1340	1090			
1971	100	120	-20	1070			
1972	860	710	150	1220			
1973	570	590	-20	1200			
1974	1440	1020	420	1620			
1975	1970	900	1070	2690			
1976	1550	1190	360	3050			
1977	1960	1300	660	3710			
1978	3580	1900	1680	5390			
1979	3260	1840	1420	6810			6810
1980	2550	3280	-730	6080	2020	530	7340
1981	2480	1760	720	6800	2120	360	7700
1982	3850	1970	1880	8680	2970	880	8580
1983	4000	2970	1030	9710	3590	410	8990
1984	3990	2680	1310	11,020	3360	630	9620
1985	4010	2680	1330	12,350	3430	580	10,200
1986	3960	2790	1170	13,520	4430	-470	9730
1987	4010	2790	1330	14,850	4630	-620	9110
1988	3510	2790	720	15,570	4690	-1180	7930
1989	3510	2790	720	16,290	5140	-1630	6300
1990	3510	2790	720	17,010	5530	-2020	4280

commitments, German stocks remain at four to five years times current consumption through the decade.

Germany's greatest vulnerability is in its dependence on Canada, simply because of the relatively large fraction of supply. However, this vulnerability does not appear to be a great threat to the German nuclear program. During the recent Canadian embargo, other deliveries to Germany were adequate to meet reactor requirements without dipping into stocks. And in the future, stocks would be adequate to make up for a loss of Canadian supply for at least a few years. But the most reassuring fact is that there will be very substantial opportunities to buy more uranium, from primary producers or, perhaps, even from other consumers. And prices are likely to be lower than in the recent past. Given past and current market trends, it is difficult to fault Germany's approach to uranium procurement.

VI. THE URANIUM MARKET

6.1 Introduction

In Chapters 2 and 3, we reviewed the prospects for aggregate supply and demand for world uranium. Based on reactor prospects and IAEA estimates of uranium development plans it was evident that there is likely to be a soft market in uranium for the next decade or more. The detailed look at uranium producers in Chapter 4, and the review of the three largest consumers in Chapter 5, reinforce this conclusion. These country studies also provide data that can be used to construct a disaggregated picture of how this excess supply situation may occur, and of its implications for the market.

In this chapter, we begin with a look at trade patterns for a selected set of producers and consumers. As will be seen, the data cover most but not all international uranium trade; and contracts and plans can change in the future. Still, even an approximate picture of these trade flows will provide useful insight into the market and its likely future evolution. Also, based on these detailed trade data, it is possible to return to the types of forecasts shown in Section 3.4 to add more detail as to where the points of stress (such as undesired stock accumulation or shortage) are likely to appear. We can then estimate how uranium prices, and market structure, are likely to respond as the system works through an era of excess supply.

6.2 Trade Patterns

As noted at the outset, we have carried out this analysis assuming that the linkage between the U.S. and the rest of the world uranium market will be weak in the future, as it has been in the past. In the analysis below there are strong indications that this situation may change: falling world prices, in the face of relatively high U.S. uranium production costs, may lead to a larger entry of U.S. purchasers into the world market. But as of the early 1980's, and for the next decade (as reflected by contract commitments) the U.S. remains only weakly coupled to the rest of the world.

Therefore, in looking at trade patterns, we concentrate on the suppliers discussed in Chapter 3, Australia, Canada, South Africa, Namibia, and Niger. As of 1980, they represent virtually all of world uranium trade outside the U.S. and the Centrally Planned Economies. Though new sources are being developed--in Spain, Brazil, and elsewhere--it is unlikely that they will contribute a significant fraction of export trade over the next decade or so. Where the consumer sector is disaggregated, we break out the three nations discussed in Chapter 5. To achieve a materials balance, we need to take some account of the U.S., so it is shown as a net buyer. As noted earlier, the U.S. tends to buy on long-term contract and sell abroad on spot. For future years there is no indicator of spot sales, so the figures will tend to overstate the role of the U.S. as a net importer.

Figure 6.1 shows the nation-to-nation trade patterns for 1980. It is constructed using estimates of production plans, presently planned reactor installations, and data on uranium contracts and firm equity commitments. On the left-hand margin are the five largest exporters--Canada, Namibia, Australia, South Africa, and Niger. On the right-hand margin are the consumers--the FRG, Japan, and "other." France--which is simultaneously a domestic producer, importer and exporter--is shown in the middle of the diagram. Note that the figure

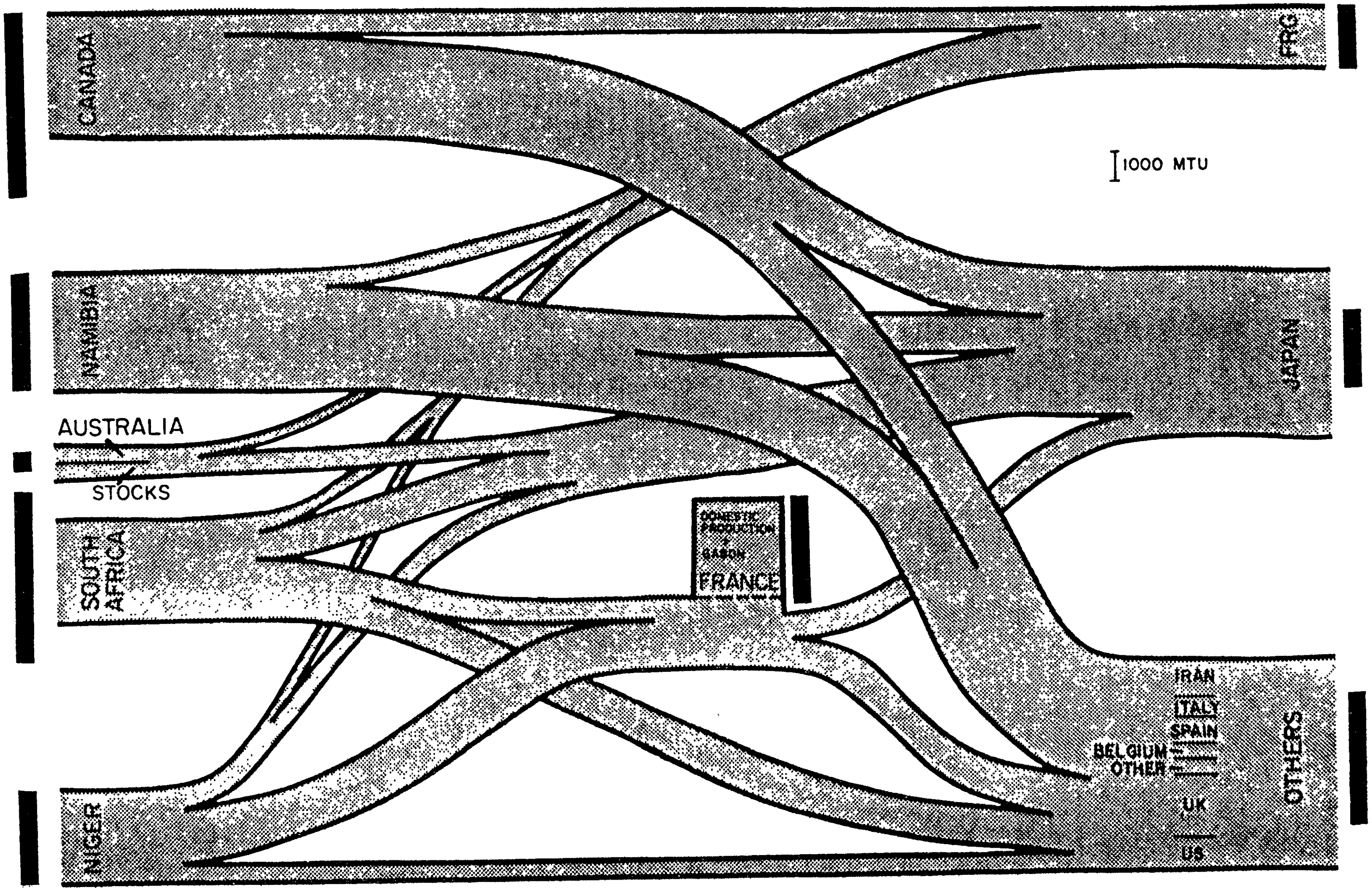

Figure 6.1 1980 URANIUM FLOWS

Width of channel indicates quantity. Bars at left indicate production capacity (less domestic consumption for Canada). Bars on right indicate reactor requirements.

takes account of the fact that France receives the total output of Gabon, a volume here combined with domestic production. The width of the flow channels on the figure indicates the relative volumes of uranium that will move from country to country during calendar year 1980.

Net inventory changes are shown on the figure. For Canada, South Africa, and Niger, 1980 contract commitments are smaller than planned production, so these producers are shown as adding to inventory in that year. (Note that the figure also indicates that in 1980 Australia is drawing down inventories in order to meet current contract commitments.) Similarly, for the FRG, Japan and the "other" group, contracted supplies exceed reactor needs--resulting in a net addition to consumer inventories. For France, any net inventory buildup is shown as consumer's stock.

Several interesting aspects of uranium trade emerge from Figure 6.1. First, the FRG and Japan are seen to be very well diversified in their uranium sources, whereas France depends heavily on sources from her former African colonies (Gabon and Niger) and South Africa. Second, France plays an important part in the overall market--because the total volume handled is large, and because France has commerical connections with several nations on both the supply and consumer sides. In effect, the French network almost represents a separate submarket, though French export commitments were made prior to 1974. Finally, a significant fraction--about 40 percent or about 10,500 MTU--of expected total production (including small producers not shown) will go into inventories somewhere in the system. Of this about 6,000 MTU, under current contracts, will show up as consumer stocks; the remaining 4500 MTU would be held by producers.

Between 1980 and 1985, this pattern changes in several ways, as shown in Figure 6.2. Under current contracts and equity arrangements, exports by Canada, Niger and Australia increase greatly (though Australia's recent sales to Japan the FRG, Finland and the U.S. do not appear in the figure), while those of South Africa and Namibia do not. Imports by Japan, France and West Germany increase significantly in volume while those of other consumers do not. That is, the increase in committed exports by Canada and Niger goes primarily to Japan and France. But French exports to other consumers do not increase. Also notable in Figure 6.2 is the extent to which planned production capacity exceeds export commitments for all major producers save Namibia. Planned production capacity (for the five primary producers) exceeds export commitments by a factor of about 1.6 or about 14,000 MTU. On the consumer side, import commitments exceed reactor requirements for Japan and France and, collectively, for the "other" group; as noted in Chapter 5, the FRG has only recently made arrangements to cover all anticipated reactor requirements. Overall, production under present plans would exceed present plans requirements by more than 100 percent, or about 24,000 MTU. Under current contracts, about 14,000 MTU of this would be added to consumer stocks.

Beyond the mid-1980's, it is not as useful to draw such flow diagrams since uncertainties about uranium production and reactor requirements increase. Moreover, current contracts begin to expire by the late 1980's and the supply arrangements that will result in maps like those in Figures 6.1 and 6.2 are yet to be made. Indeed it is likely that nearer-term trade patterns will be redrawn somewhat as the market is rebalanced: as discussed below, changing expectations about nuclear power growth, increasing inventories, and changing uranium market conditions will result in a termination and revision of some contracts and the initiation of new

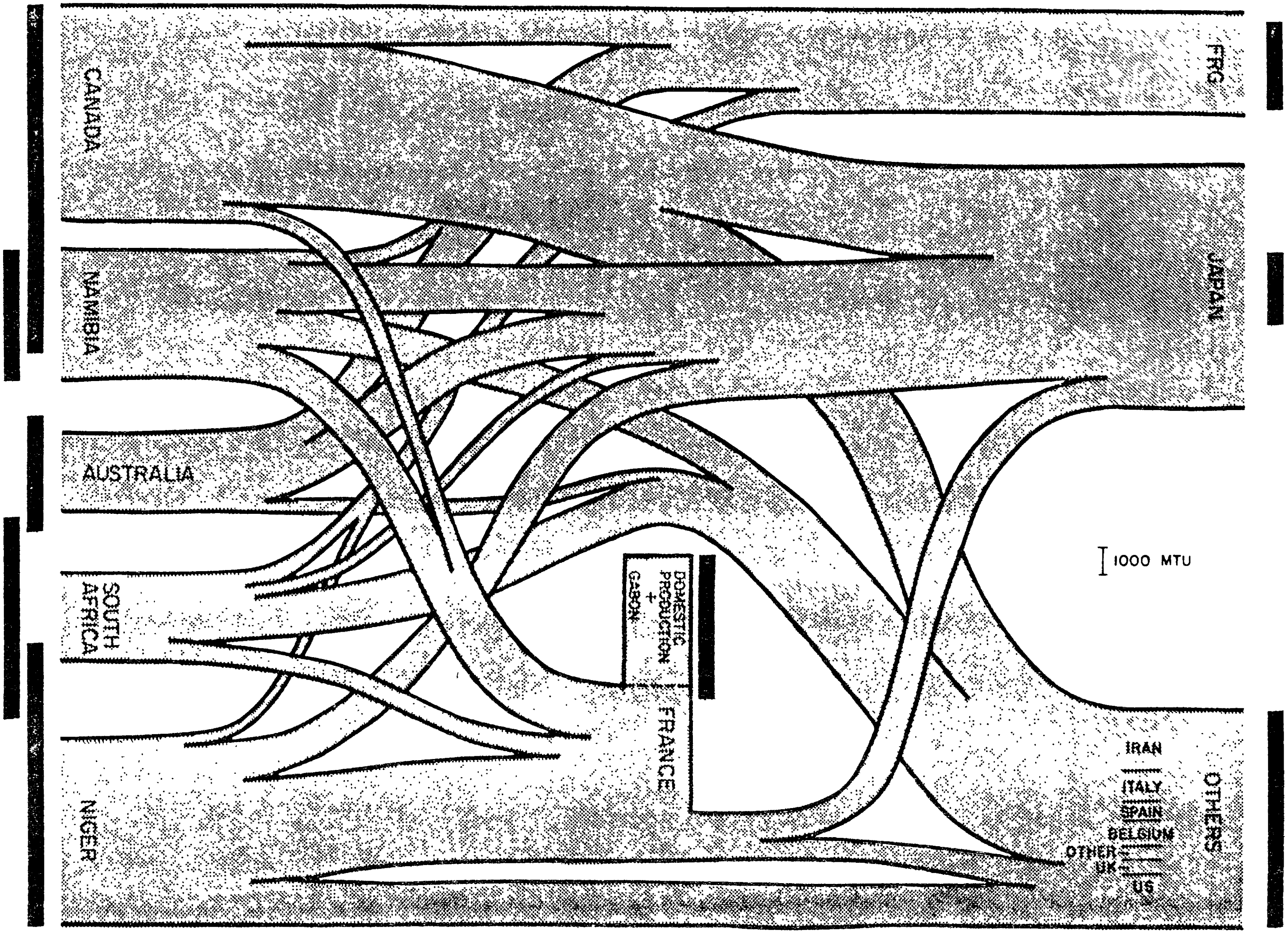

Figure 6.2 1985 URANIUM FLOWS

Width of channel indicates quantity. Bars at left indicate planned production capacity (less domestic consumption for Canada and South Africa). Those on right indicate reactor requirements.

contract arrangements and spot market sales. However, it is also evident that these transactions will primarily involve reallocation; any tightening of the market will depend heavily on revitalization of nuclear power growth expectations.

Thus the snapshots of Figures 6.1 and 6.2 show the implications of existing plans and contracts as best we understand them. As such, they give an approximate picture of how world trade will evolve over the next few years. More importantly, however, they lead to a set of questions of the form, "If these data are approximately correct, are these plans and commitments likely to be carried out as these data show; and if not, how is the market likely to adjust " In Section 6.3.2 below, we consider the trends lying beneath these snapshots, and suggest some of our own answers to these questions.

6.3 Market Trends

To look at trends, we essentially take snapshots of the type presented above, and string them together to make a movie. Since the data quickly multiply if many details are presented, the forecast is based on a few key aggregates--planned production, likely reactor demand, overall contract commitments, and stocks.

6.3.1 Commitments, Plans, and Stocks

Except for one brief period, the history of the international uranium industry has been one of overcapacity and overproduction. In Figure 3.8 we considered aggregate data for production plans and reactor operation, and drew conclusions about the potential softness of the uranium market over the next few years. Now, based on the data developed in Chapters 4 and 5 it is possible to consider this outlook in more detail, taking account of the five major exporters studied in Chapter 4 (Australia, Canada, South Africa, Namibia and Niger). As Figure 6.3 shows, exports by these five countries were generally much below production levels until mid-1975 when a sudden upsurge in demand* allowed producers to sell not only their current production but also some inventory. Also notable in Figure 6.3 is the rate at which production expanded, with output rising by a factor of 2.7 from 1975 to 1979.

But there are now strong indications that this period of great prosperity was but a brief moment in the experience of the industry, unlikely to occur for at least another decade, if then. By late 1979, export levels again fell below production, in part because of a leveling off of demand due to lower reactor needs, and in part because production capacity responded so vigorously to rising demand expectations and exploding prices (discussed below). If production goes forward as presently planned, either large inventories are going to accumulate in the producer countries, or significant quantities of material are going to be put on world markets, perhaps to be purchased and added to consumer inventories.

To construct an estimate of the potential effect of these developments on uranium markets, we consider the excess of planned production over and above contract commitments. The totals for Canada,

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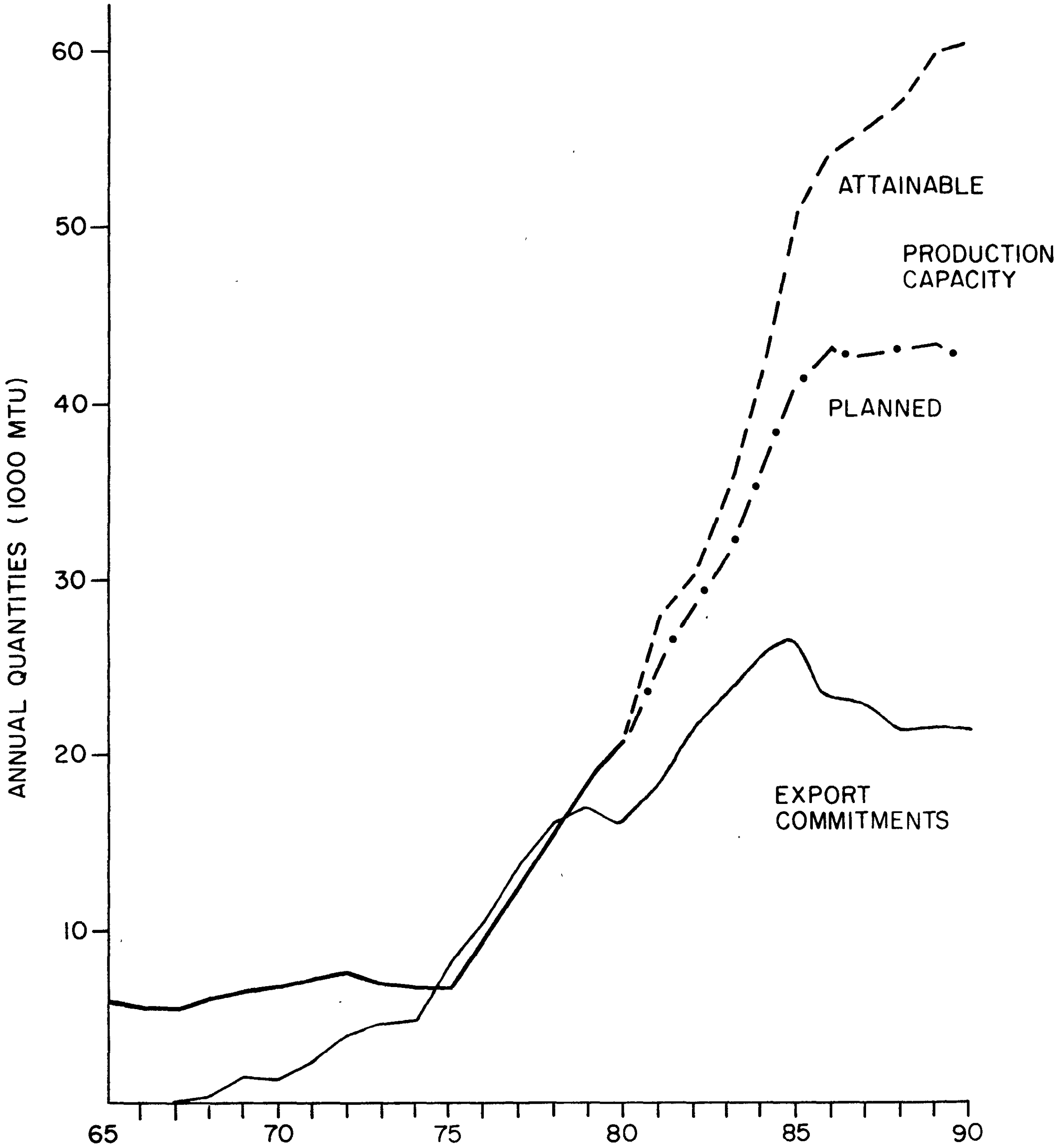
*Due to several factors--including the introduction of new enrichment contracting policies by the U.S. See T.L. Neff and H.D. Jacoby, "Nuclear Fuel Assurance: Origins, Trends and Policy Issues," Cambridge, M.I.T. Energy Laboratory Report MIT-EL-79-003, 1979 and "Supply Assurance in the Nuclear Fuel Cycle", Annual Review of Energy, 1979..



SOURCE: TABLE A-28, APPENDIX

Figure 6.3

IDENTIFIABLE PRIMARY EXPORTER COMMITMENTS
(AUSTRALIA, CANADA, NAMIBIA, NIGER, SOUTH AFRICA)

Australia, Niger and South Africa are shown in figure 6.4.* This is material which--if produced--will either be added to the stockpile of these producers, or somehow offered for sale. Admittedly, this is a mechanical forecast, assuming that plans will be realized; shortly we will consider the forces that lend momentum to these plans or may lead them to be changed. But still, this simple calculation indicates the volumes are very large; by the end of the decade, cumulative new sales, plus total inventories, would amount to about 170,000 MTU. This is nearly eight years forward supply for (non-U.S.) reactors now built, under construction, or ordered as of 1980.

The natural question is, how much of this material will consumers want to buy A partial answer to this question can be had by observing that consumers, like producers, seem to have had falsely high expectations for nuclear power growth, and some seem to have overcompensated for uncertainties about uranium supply. In Figure 6.5, we show the total supply of uranium available to consumers (non-U.S. WOCA) historically and prospectively. Total supply is the sum of imports and domestic production.** Over the entire history of commercial nuclear power, total supply to consumers has exceeded requirements. Even during the tight market years of the late 1970s, procurements exceeded reactor requirements and inventories increased.

For the future, total supply exceeds reactor requirements under the

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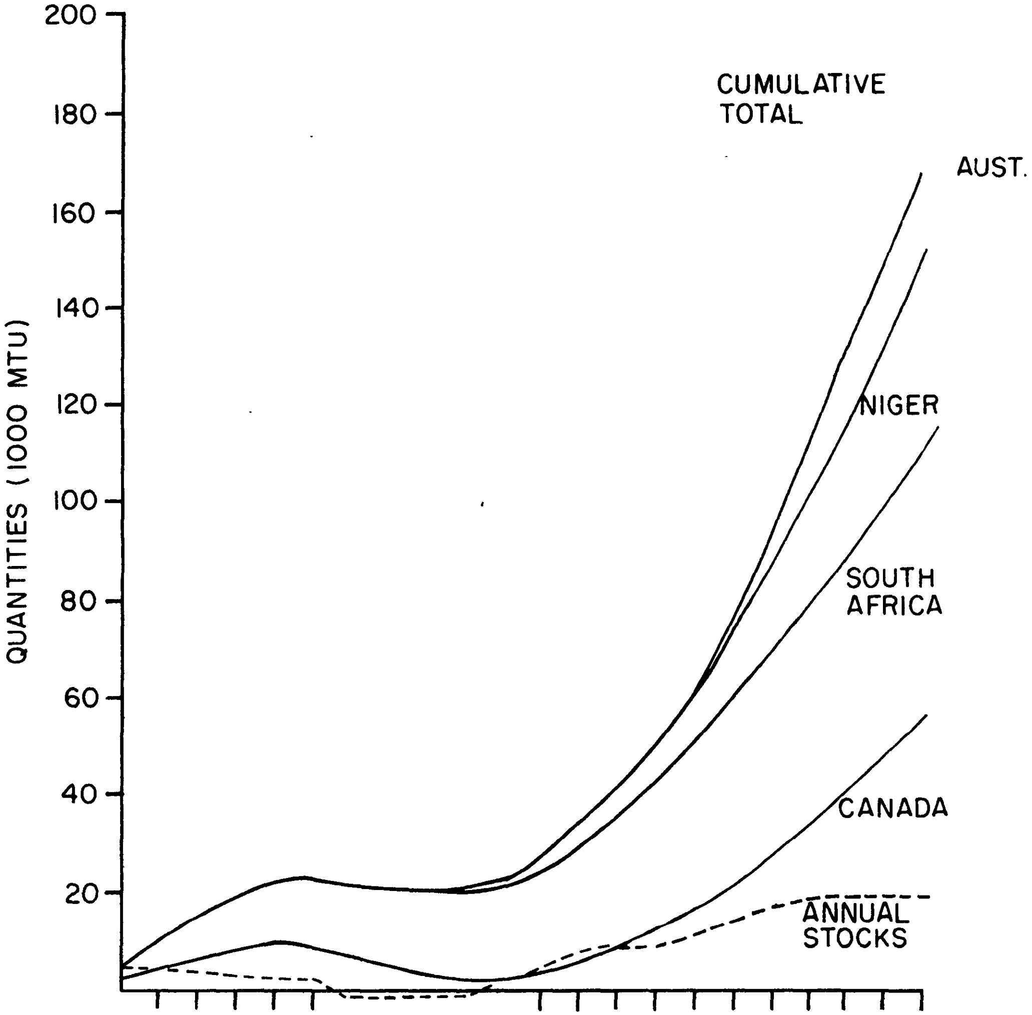
*Namibia is assumed to accumulate no stocks since RTZ, the principal agent involved, has contract commitments greater than any excess that might be available from Namibia.

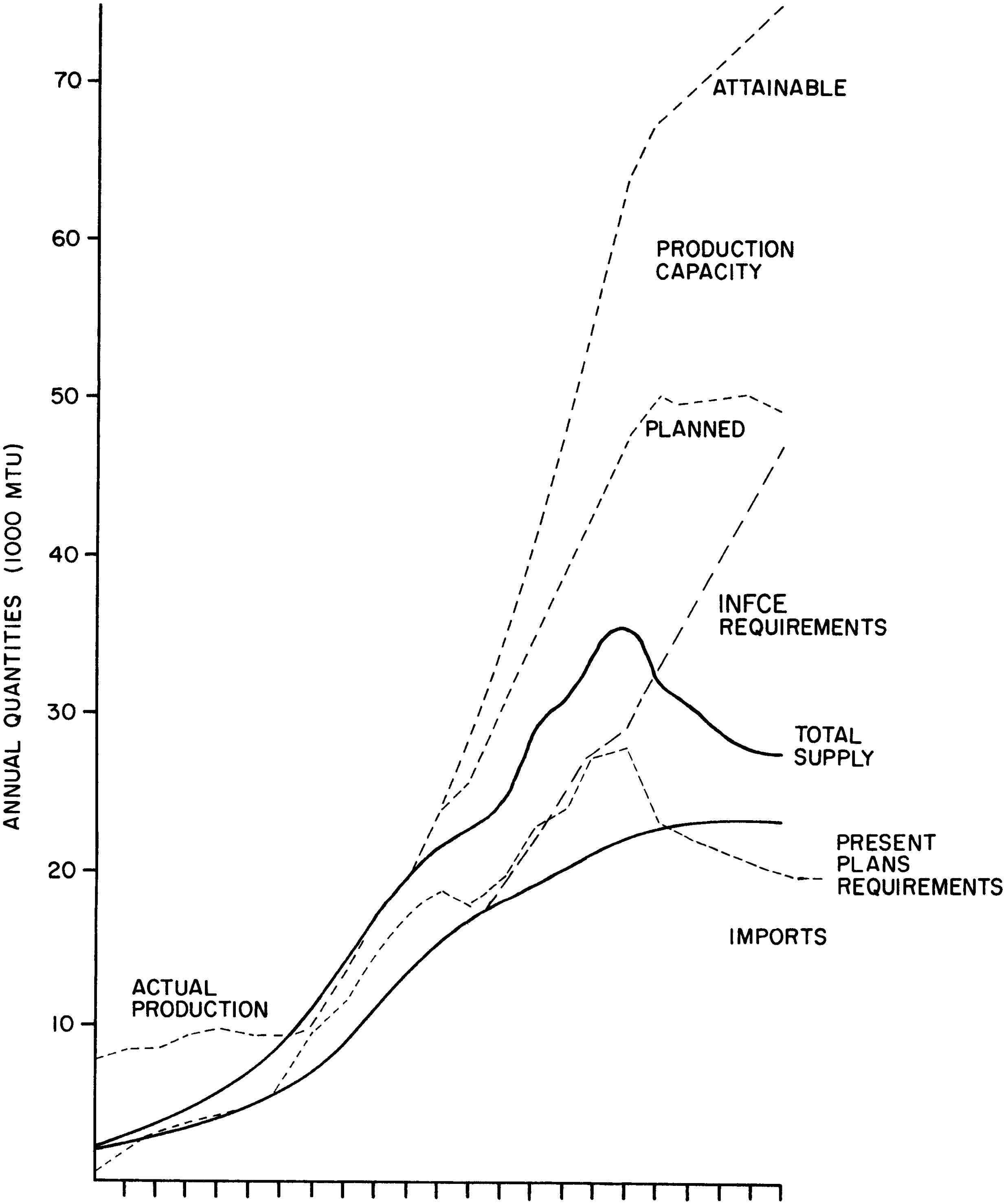
**Most domestic consumer production is in France, though Argentina, Brazil, Mexico, Portugal and Spain will also produce significant amounts of uranium over the next decade.



SOURCE: TABLE A-29, APPENDIX

Figure 6.4

ANNUAL AND CUMULATIVE PRODUCER INVENTORIES--
CURRENT EXPORT COMMITMENTS AND PRODUCTION PLANS



SOURCE: TABLE A-30, APPENDIX

Figure 6.5

CONSUMER SUPPLY AND DEMAND
(non-U.S. WOCA)

"present plans" scenario and even exceeds the (unrealistic) INFCE scenario until 1985 (and even then, large inventories would delay need for new procurements until about 1990). Consumers have contracted for more uranium than they can realistically use over the next decade.* Reactors ordered even today cannot result in uranium demand significantly greater than that shown in Figure 6.5; indeed it is more likely that some of the demand shown there will disappear or be delayed, due to reactor cancellations and delays.

The result of excess procurement is inventory. Figure 6.6 shows annual and cumulative consumer stocks assuming current import commitments and the "present plans" nuclear growth scenario. Today, (non-U.S.) stocks are nearly 50,000 MTU, nearly three years forward supply for all present reactors. By 1985, inventories would total 107,000 MTU--on average, 5 times the annual consumption rate in that year--and by 1990 they are 145,000 MTU or 6.8 times annual consumption. As the figure also shows, under the INFCE forecast, there would be a need for new uranium contracts as of 1985 or so, else inventories would be rapidly drawn down (as the figure shows). Since the INFCE forecast is significantly above current expectations for reactor growth over this period, there is a strong possibility that a high level of consumer stocks would be maintained over the decade, even if no additional uranium above existing contracts were purchased. Of course, the amount of uranium that may be available from producers would be extremely large in relation to any conceivable reactor need, as Figure 6.4 shows.

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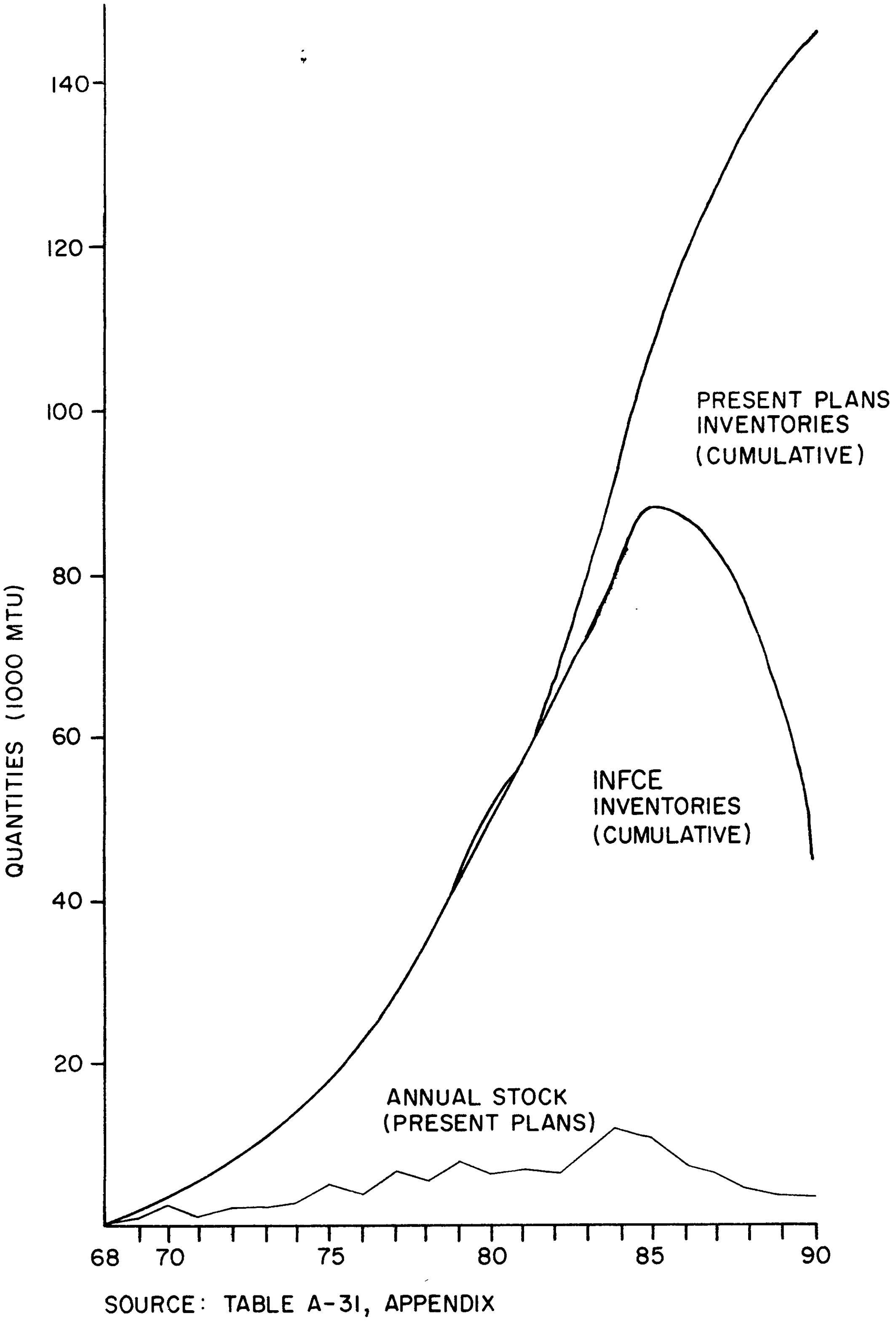
*Note that if our research has failed to identify all import commitments, it simply means that this conclusion is strengthened.



SOURCE: TABLE A-31, APPENDIX

Figure 6.6

POTENTIAL CONSUMER INVENTORIES

Note that these observations concern the aggregate of all consumers; in fact, different consumers are in very different positions with regard to uranium procurement, as we have seen in Chapter 5. There are uncovered requirements in Western Europe (outside France and the U.K.) where about 20,000 MTU--in addition to current delivery commitments--would be needed through 1990, according to present utility plans. (The deficit under INFCE growth assumptions would be about 48,000 MTU.) In the OECD "rest of the world" group, which includes South Korea, Taiwan, Brazil and other developing countries (but excludes Iran and South Africa), new procurements through 1990 of about 8,000 MTU would have to be made, under present plans. (Under INFCE assumptions this would increase to 21,000 MTU.)*

A more detailed review of supply positions indicates that under present plans, countries with prospective deficits might have to find at most an additional 29,000 MTU through 1990 (including some stock building). Where might this uranium be found? Obviously, as we have seen, producers would easily be able to supply this quantity; indeed, it is likely that one of several producers alone (Canada, Australia or South Africa) could supply all the uranium needed through 1990. For the developing countries--with their smaller individual needs--there are many possibilities among suppliers.

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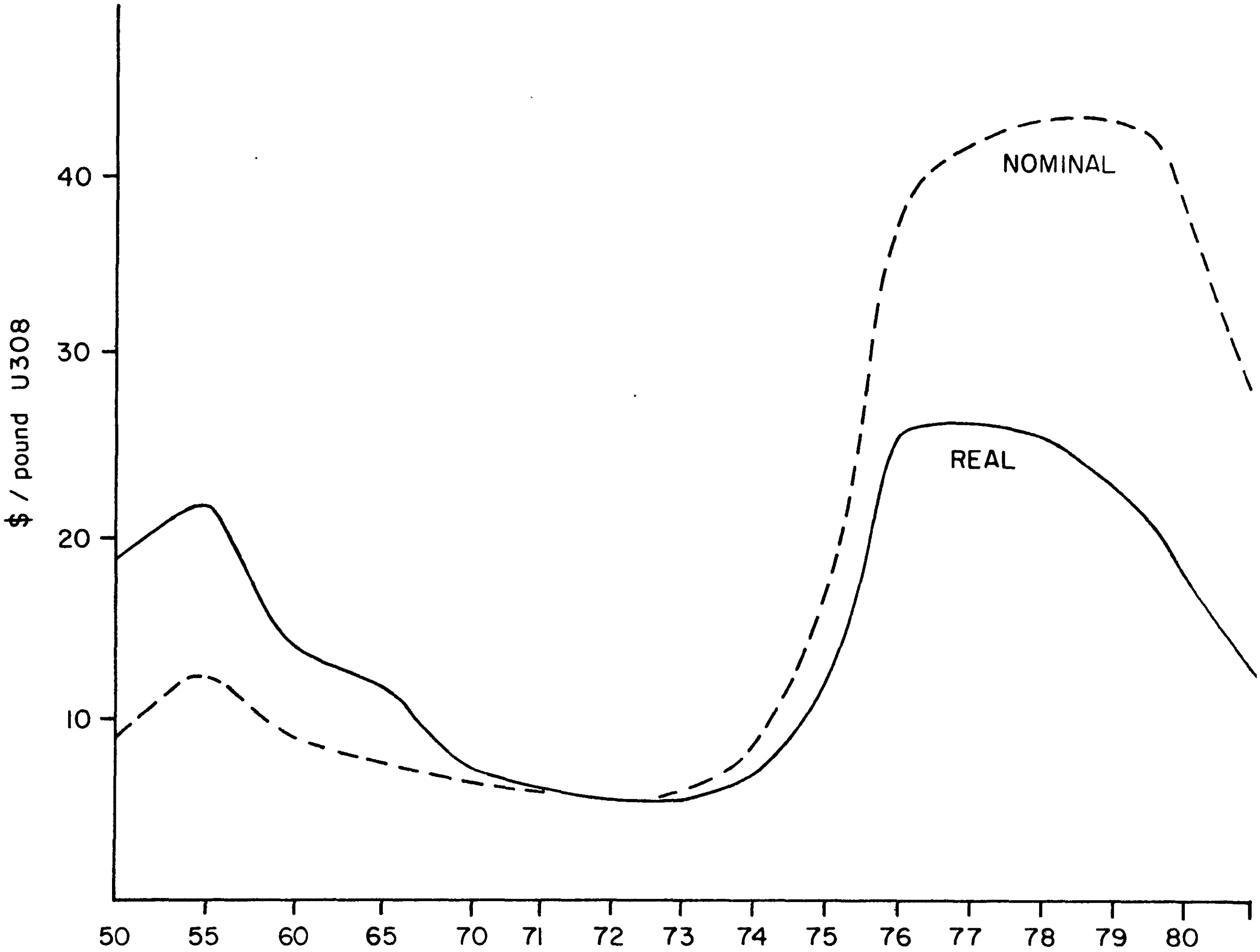
*This demand is for those countries without indigenous supplies of uranium in excess of reactor requirements. In fact, some of the LDCs with domestic production will have sufficient excess supplies that the present plans needs of the "other" group, taken as a whole, could be more than covered by this production plus current contracts. Under present plans, an overall stock of about 8000 MTU would accumulate. Under the INFCE growth scenario, there would be a shortfall of about 6000 MTU. Given the difficulties and rising costs of nuclear power construction in many LDCs, we suspect that these numbers--especially those associated with the INFCE projection--overstate uranium requirements.

6.3.2 Prices

Prices will be a major influence on the degree to which uranium development plans are realized, and on the level of stocks that various entities will desire to hold. Much of the recent and planned expansion of uranium capacity has been influenced by the rapid price rise in the mid 1970s. The tight market conditions of this period can be seen in Figure 6.2, which shows export commitments slightly exceeding production for several years. The associated price jump is plotted in Figure 6.7, in nominal and in constant 1972 dollars. Over this period, a classic seller's market prevailed: joint ventures expanded with purchasers taking a larger portion of the front-end capital risk, and price provisions often were very favorable to exporters (e.g., escalating price floor or spot market price, whichever was higher).

As of the late 1970s, the picture has changed drastically as Figure 6.5 makes clear. Nominal prices are falling--from the mid-$40 range in 1978 to the upper $20 range now. The drop in real prices has been striking: the real price for U_3O_8 is down to its level in early 1975, near the start of the great price upsurge.

How far can prices fall? In part this depends on how producers react. One might expect that there will be a postponement of some planned expansion in supply over the early 1980s (see Figures 6.2 and 6.5). Surely some projects will be delayed, if not canceled, if prices continue to fall. On the other hand, it is evident from our review of the major producers in Chapter 5 that there is considerable momentum toward increased capacity and production. Major investments--economic and political--have been made. In many cases, consumers have already made the front-end investments in mines, mills and infrastructure--often



SOURCE: TABLE A-32, APPENDIX

Figure 6.7

NOMINAL AND REAL URANIUM PRICES
(1972 constant dollars)

through zero-interest loans to be repaid out of production. For much of this production, variable costs are low. For example, expenditures have already been made for roads, mines and mills to exploit high-grade, easily mined deposits in Saskatchewan, Australia's Northern Territory and in Niger. Consumers who put up the capital may be entitled to half the output, subject only to taxes and other royalties. But a host government or company may be entitled to sell the other half, and its unit variable costs may be very small. In South Africa, facilities for recovering uranium from the ore mined to recover gold are already paid for, and the cost of recovering uranium may be lower than the present value of reprocessing slimes at a later date if they are simply dumped. There are thus economic incentives to sell such uranium even at relatively low prices. In sum, as prices fall, the short-term elasticity of supply may be very low.

A second major factor, of course, is the pace of reactor orders. If they should pick up in the next 2 or 3 years--say, to levels close to that implied by the INFCE forecast--then some of the downward price pressure may be reduced. However, if (as is likely in our view) reactor growth continues on a path closer to the present plans and commitments, then there will be continuing downward pressure on prices over the next decade.

The third key factor, of course, is inventories. As we have seen, a few consumer countries are rebuilding huge inventories--quantities that will be very costly to hold. For example, under present procurement schedules, Japan and France together could hold as much as 150,000 MTU by 1990.* That will be very costly to hold. Perhaps these nations and

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*Indeed, Japan and France are in danger of holding of order of 10 to 25 years forward supply for all reactors operating by the late 1980s; if inventory costs are internalized, the increase in the cost of nuclear power could be as much as 50-100 percent.

their utilities will be willing to carry these stocks for a decade or more, in the interests of fuel security and stability of long-term planning. Such a development cannot be ruled out, for we know very little about the stock-holding policies of these nations. Indeed many of them may just now be realizing the magnitude of the unexpected inventories, and may not yet have decided how to manage them.

But there are preliminary indications that significant quantities of these stocks will come onto the market from the consumer side and there could develop a major pattern of sales, loans or other agreements among consumers--with material flowing from those in excess to those in need. As our global stock calculations show, if efficient mechanisms of this type should develop (and there is no reason why they should not if excess-holders are willing to part with some of their material) then there are circumstances where growing forward stocks could be maintained for most consumers with no further purchases to 1990, beyond current contract commitments.

Whatever the level of this exchange of stocks among consumers, it surely could rise to a level high enough to accommodate the purchases required by the developing countries--under present plans, the 8000 MTU figure above. Fuel assurance for any of these countries, or all of them, could be provided by any single large producer or consumer, or by any combination desired. For the countries of Western Europe that are in a deficit position regarding future needs, these needs could also be met by consumers with large stocks, though some mixture of consumer inventory and producer sales is more likely.

The clear implication of our analysis is that the market for uranium will be soft for quite some time. Producers are unlikely to make significant new commitments for exports--at anywhere near the level of planned capacity--for deliveries much before the end of the decade. And when current contracts begin to expire in the late 1980's it is unlikely that demand will exceed the level of those contracts, unless many new reactors are ordered soon. In fact the current ordering rate is negative, due to cancellations. The demand seen by producers over the next decade will be higher if consumers are unable to rationalize their stock positions, but even if they are unable to redistribute stocks, uncovered requirements are not large on the scale of anticipated or potential industry expansion. Moreover, even if Japan, France and other consumers decide to carry large inventories, these stocks will overhang the market, depressing prices. Uncertainties for producers are thus very high and strongly biased on the downside.

All of the factors we have identified:

- producer momentum toward expansion of production and the inability to retard this momentum,
- low variable costs and large sunk costs (often financed by consumers),
- large producer and consumer inventories overhanging the market, and
- a lack of new demand

imply that uranium prices in the world market are likely to decline further--and probably significantly--over the decade. While some in the industry believe that this is a temporary phenomenon and that prices will rise again in a year or so, there appears to be little reason for this optimism. Rather, it is possible to see constant dollar prices declining to the depressed levels of the early 1970's.

In the short run at least--for the next decade or perhaps two--the international market situation we have described will be good for consumers. There wil be many prospective sources of supply, allowing the possibility of diversification, stock-building and other responses to security of supply concerns. And prices will be relatively low. But in the longer run, consumers may be concerned that exploration and investment activity may be dampened so much by reduced expectations that uranium will not be available if more nuclear plants are later deployed. This fear appears to us to be without basis. The historical evidence is that the uranium industry--even when in a depressed state--has consistently <u>over</u>-responded to demand perceptions, with reserves and production capacity well in excess of needs. Moreover, it has been able to respond rapidly to changes in demand levels as Figure 6.3 shows for the period 1975-79.* Finally, consumers have been willing to underwrite producer risks in expanding production (e.g., with zero-interest loans for mines and mills), thus making possible larger commitments to capacity at an earlier date. (Indeed, one could argue that consumers are largely responsible for the looming excess capacity in producer countries.)

For the future, there is no reason to expect a change in industry behavior. Resource horizons are still expanding and the uranium industry is diversifying to other countries and geologic environments.

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*Though for the brief period of 1975-79, consumers bought more than they needed, and somewhat in excess of production, because of security of supply concerns.

But even more importantly, the time horizon for new demand--the time it takes to order and build significant new reactor capacity--is comparable to that for resource development. As we observed earlier, the industry is well able to respond to real demand (it even appears to respond to dreams and ambitions). But even those who doubt this view should be reassured by other factors. First, inventories on both sides of the market will remain high. Second, there will be considerable unused but operable capacity whenever new demand arises. Third, production levels at many deposits are below what is economically and technically feasible; expansion is usually possible. Finally, consumer investment and other involvement (as in exploration) are always possible and seem effective in accelerating industry expansion. Countries with particular concerns about supply and its security will probably find a welcome reception in just about any traditional or prospective producer country over the next decade and more.

VII. ISSUES AND IMPLICATIONS

The results of our analyses have implications for a number of issues beyond those directly related to the international uranium market. In this section, we identify these connections, leaving more extensive analysis to future research.

7.1 Technological Change

The prospective long-term trends in the market identified here--excess capacity, stock buildup and declining prices--tend to undermine the rationale for rapid changes in nuclear technology. Breeder reactors will have higher capital costs than LWRs, a disadvantage that is overcome only if uranium is much higher in price or lower in security of access than it is now. Neither condition seems likely for some decades and the point where the breeder becomes economically competitive will most likely be delayed further.

A similar argument applies to plutonium recycle, which would be economically doubtful even at uranium prices above those we are likely to see over the next decade. To the extent that lasers are of interest to strip enrichment tails or enrich to lower tails assay, their attractiveness may decline due to availability of lower cost natural feed. Of course, to the extent that lasers reduce overall enrichment costs they will be of considerable value.

Finally, there seems to be less urgency for changes in reactor design or operation to conserve uranium, especially where there may be reductions in overall efficiency or capacity factor, or significant increases in costs. It should be noted, on the other hand, that uranium is but one factor in decisions concerning these technologies, and that wise policy for the longer term favors the creation and maintenance of technological options.

7.2 Fuel Assurance

As shown above, uranium supply conditions are becoming more favorable. But securing an assured supply of nuclear fuel can still be a complicated matter, especially for developing countries. In addition to uranium, a consumer must arrange for conversion, enrichment and fabrication services. As a result there are a number of opportunities in the supply chain for breakdowns or the imposition of political or other conditions on supply. The important question for consumers is whether concerns about these problems can be reduced to an acceptable level by exploiting new flexibilities in the uranium market.* This is a question in need of further investigation, though it is evident that for at least some countries, supply assurance is improving greatly.

7.3 Enrichment Markets and Nonproliferation

In the past there has been a strong linkage between the uranium and enrichment markets. For many years the U.S. enjoyed an enrichment monopoly; because of its downstream influence, the U.S. could affect the demand for uranium (through enrichment contracting terms) and set terms for supply (such as safeguards). In the 1970's the U.S. enrichment monopoly yielded to the entry of the U.S.S.R., Eurodif and Urenco. At the same time new nonproliferation concerns arose, most dramatically in Canada in response to the Indian nuclear test.

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*This question should be seen in the light of the corresponding increase in flexibility in enrichment procurements; see [1].

The fact that enrichment supply was becoming less a source of potential leverage, and the active involvement of Canada in non-proliferation actions, suggested to many in the late 1970's that uranium supply could become the new focus of nonproliferation leverage. On the positive side, assured supply could reward acceptance of a more vigorous and comprehensive nonproliferation regime and encourage countries to defer proliferation sensitive technologies. Or, the implicit or explicit threat of withholding supply could compel behavior. Our analysis indicates that the use of uranium supply as a tool of persuasion will be increasingly limited at best, and counterproductive at worst. Major consumers have strong market positions, and most have large inventories (the exception being West Germany); they would thus be able to withstand disruptions for the few years that would be needed to arrange new sources of supply. Smaller nations--notably several of the developing countries of primary nonproliferation interest--probably have even greater flexibility than the industrial countries because of the great number of different arrangements that might be made for small amounts of material in today's market.

But these observations reopen the enrichment question. Through a combination of uranium and enrichment supply there may still be sources of influence through the fuel cycle. It is evident that enrichment and uranium markets are still coupled, though this linkage is declining in importance. Efforts might be made to strengthen this linkage, or at least retard its demise, in ways that advance fuel assurance goals, as well as the interests of uranium producer countries. There is interest outside the U.S. in this approach, interest strong enough to overcome the economic and other problems associated with an oversupply of enrichment. Several countries (Japan, France and the U.S.) are now engaged in discussions with Australia concerning construction of a facility to enrich that country's uranium. Australia's interest is in the value added and in the uranium marketing opportunities involved; the consumer's interest is evidently in the forging of greater security of supply simultaneously for uranium and enrichment services. Vertical integration of these markets with explicit consumer and producer involvement could provide greater security. Japan is also contemplating a domestic enrichment plant; given Japan's strong position in the uranium market, enrichment may now be perceived as the most insecure step in the fuel cycle.

Strengthening the connections between uranium and enrichment could also have important nonproliferation implications. The key problem will be in reconciling nonproliferation goals with the economic and security concerns of producers and consumers. If efforts are made to develop linkages that increase the potential for coercive action by producers or others, then supply security and other interests may be undermined. But such linkages may have positive benefits for nonproliferation, especially if their coercive potential can be reduced or at least left unexercised: they both draw key actors together into a sphere of common interest and, by increasing supply security, they may help delay proliferation-sensitive technological commitments. Thus, the carrot approach may be better than the stick.*

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*For an exploration of this issue in the context of U.S. policy, see [2].

The potential benefits for the economic interests of producers, the energy security interests of consumers, and this particular side of nonproliferation strategy must be weighed against the risks associated with the wider spread of enrichment technology. This is indeed a difficult problem and one in need of close analysis in a detailed fuel market context.

7.4 U.S. and Foreign Markets

The domestic U.S. uranium market has long been essentially separate from that of the rest of the world. U.S. uranium exports have usually been of relatively small volume and generally associated with other export trade: first cores and reloads for reactors sold by U.S. vendors or as feed for enrichment contracts with the U.S. Similarly, U.S. imports--historically comparable in magnitude to exports--have generally come to reactor vendors or fuel fabricators, rather than to U.S. utilities. Thus, U.S. involvement in the international uranium market has been minimal and usually the result of its sales of technology and fuel processing services.

However, this situation threatens to change. The U.S. uranium industry faces increasingly high costs--due to the nature of the U.S. resource base and its advanced stage of exploitation, and due to U.S. labor, regulatory and other costs. In contrast, foreign ventures often work with higher grade, larger and more easily exploited deposits, which have inherently lower fixed and variable costs. Moreover, as discussed above, many of the fixed costs associated with these ventures have been underwritten by others or by co-produced products (such as gold in South Africa or, prospectively, copper at Roxby Downs in Australia). Thus, at least some U.S. producers will be at a cost disadvantage relative to foreign producers, who may enter the U.S. market with sales to domestic utilities. While there may be a natural reluctance on the part of U.S. utilities to buy abroad, even the threat of low-cost foreign competition may restrain U.S. domestic industry investments in exploration and development and thus threaten the long-term viability of the U.S. uranium industry. The parallel with the earlier increase in U.S. dependence on cheaper foreign oil at the expense of the domestic industry is evident.

This problem is extremely difficult, involving not only domestic energy security but also the linkages to nonproliferation, relations with other producers, enrichment policy, and the potential for cartelization of the international market. When U.S. producers were threatened in the 1960's and early 1970's by excess capacity abroad, the U.S. instituted an embargo on the enrichment of foreign uranium for domestic use (at that time, U.S. utilities constituted most of the market for fuel). This embargo was a source of much antipathy toward the U.S. among other producers, especially Canada, and probably helped create the conditions for cartelization abroad. Similar unilateral action today would undoubtedly strain relations even further, at a time when the U.S. needs the support of other producers in achieving its nonproliferation goals.

U.S. producers would also like more than just protection in the home market. With the decline in expectations for domestic nuclear growth, some producers are looking for sales abroad. In some cases--as in the recent UNC sale to the FRG under the Offset Agreement--they are achieving them with government assistance. Potential trade competition and conflict thus extends outside the U.S.

The evident locus for protectionist measures, as in the past, is the U.S. policy on enrichment. Virtually all U.S. consumers depend on U.S. enrichment supply, and so too do many foreign buyers. Restrictions on use of foreign feed, or lower prices for enrichment of uranium of domestic origin, would benefit U.S. uranium producers and might be justified on the grounds of maintaining diverse competitive sources of supply for energy security and nonproliferation reasons. The difficulties, of course, are the implicit subsidy involved--with the U.S. having made a commitment to competitive enrichment pricing--and the fact that other uranium producers might still see the measure as targeted against their interests.

What foreign and domestic producers would probably prefer to do would be to keep world uranium prices close to U.S. long-run marginal cost. In this way all producers would have the same relative advantage in the market, but low-cost producers would simply make more profit on what they sold (careful calculation would be necessary to show that pricing based on U.S. costs would yield enough return to make up for whatever sales volume they would lose to U.S. producers). But to implement such "orderly marketing" arrangements would involve formal or informal cartelization and, probably, considerable government involvement.

There are two key issues here: the potential for successful cartelization and the effects on nonproliferation and other international policy matters. While there is a clear congruence of interest between producers--including the U.S.--it is questionable whether cartelization could proceed successfully. Not only are economic tensions between producers likely to be high, but political disparities may be great, especially between the U.S., Canada and Australia on the one hand, and the African producers on the other. This disparity is particularly large on the issue of whether strict conditions (e.g., full-scope safeguards or reprocessing veto rights) should be attached to uranium supply. Nonproliferation concerns might help draw together the U.S., Canada and Australia, but might separate these producers from others in the market. There is also a question whether individual producers would be able to exercise sufficient discipline over internal industry activities to prevent price competition or implement market-sharing arrangements. Not only are there competing private interests involved, but there is a need to reconcile federal and provincial (or state or territorial) interests in some countries. Finally, foreign governments and companies (often motivated more by security than economic concerns) are active in several producer countries and it would be difficult to avoid potentially high foreign policy costs in any effort to impose restraints on these interests. In at least some countries, domestic firms, foreign participants and local political interests would be in alliance against national attempts to restrict freedom of action. It is difficult to see how all of these differing interests can be reconciled in a cartel.

Finally, any effort to cartelize would be seen by consumers as a threat to fuel assurance and would, therefore, undermine current nonproliferation efforts. The U.S., especially, is thus at the center of a host of conflicting interests involving nonproliferation strategy, fuel assurances, enrichment policy and position in the world market, the viability of the domestic uranium industry, and others. The full exploration of these issues and the trade-offs involved are subjects for further research and analysis.

References, Chapter VII

1. T.L. Neff and H.D. Jacoby, "Supply Assurance in the nuclear Fuel Cycle," Annual Review of Energy, Vol. 4 (Palo Alto, CA: Annual Reviews, Inc., 1979), pp. 259-311.

2. T.L. Neff and H.D. Jacoby, "Nonproliferation Strategy in a Changing Nuclear Fuel Market," Foreign Affairs, Vol. 57, No. 5 (Summer 1979).

APPENDIX

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Calculational Basis

Chapter 2

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Table A-1

REACTOR FUEL REQUIREMENTS

Reactor Type	LWR (no recycle)	HWR	HTR	GG	AGR
Initial Core					
Natural Uranium (MTU/GWe)	363	145	236	918	458
Separative Work (MTSWU/GWe)	243	--	310	--	252
Reloads[1]					
Natural Uranium (MTU/GWe)	138	119	57	214	131
Separative Work (MTSWU/GWe)	111	--	75	--	89

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1. Assumes 70% capacity factor, 0.20% tails assay where enrichment is required.

Table A-2

FUEL CYCLE LEAD TIMES

All but HWR	First Core	Reloads
Enrichment	2 years	Same calendar year
Natural Uranium	3 years	1 year
HWR		
Natural Uranium	2 years	1 year

CALCULATIONAL BASIS

As discussed in chapter 2, historic uranium requirements are estimated on a reactor-by-reactor basis, computing first core and makeup needs as required according to startup and refueling schedule. Variations in reactor type were taken into account, though an average 70% capacity factor is assumed (rather than using actual factors for each reactor). Where enrichment was required, tails assay was assumed to be 0.20%. Quantities required and lead times are summarized in Table A-1 and A-2. Because reactors have generally not reached 70% capacity factors, these calculations may overestimate uranium requirements somewhat, though the premature failure of some early fuel provides a partially compensating effect. Fuel cycle assumptions are shown in Tables A-1 and A-2. Reactor capacities and startup dates were taken from the _Nuclear News_ list of August 1979, as shown in Table A-9.

For the future, two different nuclear growth scenarios are employed: a "present plans" scenario and the INFCE "low" growth scenario. The present plans projection is just the sum of reactors in operation, under construction, or on order (letter of intent) as reported in the _Nuclear News_ utility survey of 1979 (August, 1979). In the near term this projection appears generally optimistic, with delays in reactor completion and operation likely. In the longer term--say toward the end of the decade--the "present plans" scenario may understate the potential of nuclear power. The most evident projection for this potential is the INFCE "low" scenario (higher growth INFCE scenarios are now commonly recognized as being unrealistic, at least over the next decade or two). It envisions the ordering and completion of 94 GWe beyond reactors already ordered (as indicated by the _Nuclear News_

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* Fuel requirements are very closely proportional to reactor capacity; fuel requirements were thus proportioned linearly with capacity.

survey) by 1990 and 484 Gwe by 2000. We believe this expectation to be unrealistically high, especially for the next decade, but use it to illustrate uranium market conditions under high demand levels. The INFCE projection is probably best thought of as an upper bound, at least until well after 1990. The two growth scenarios are summarized in Tables A-4 through A-8. The corresponding uranium requirements are shown in Tables A-10 through A-12.

Table A-3

OECD/IAEA
HISTORIC NUCLEAR GROWTH PROJECTIONS
(GWe)

Year Of Projection	Projection For Year					
	1970	1975	1980	1985	1990	2000
1969	25.6	101-125	234-328	-	-	-
1970	18	118	300	610	-	-
1973	14	94	264	567	1068	-
1975	14	69	194	530	1004	2480
1977	14	69	146	278-368	504-700	1000-1890
1978	14	69	144-159	243-272	374-460	833-1200

* Estimates do not include Eastern Europe, USSR nor China.

▨ Actual capacity

Sources:

OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Production and Short-Term Demand. Paris, 1969.

OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Resources, Production and Demand. Paris. 1970, 1973, 1976, 1977, 1979.

Table A-4

PRESENT PLANS AND INFCE NON-U.S. WOCA NUCLEAR GROWTH PROJECTIONS (MWe)

Year	INFCE	Present Plans
1980	82,120	78,870
1981	96,420	98,920
1982	105,620	114,880
1983	121,281	135,070
1984	136,910	146,700
1985	156,510	158,830
1986	178,210	164,350
1987	200,810	166,580
1988	224,310	168,390
1989	249,610	169,270
1990	274,210	171,080
1991	301,270	171,080
1992	328,340	172,010
1993	355,410	172,010
1994	384,480	172,010
1995	414,550	172,010
1996	446,270	172,010
1997	477,990	172,010
1998	516,745	172,010
1999	542,630	172,010
2000	574,950	172,010

Table A-5

INFCE REACTOR GROWTH PROJECTIONS[1]

(MWe)

Year	Europe	Pacific (Japan)	Rest of World[2]	Canada	U.S.	Total
1980	54,020	17,000	5,000	6,100	62,300	144,420
1981	64,720	18,000	7,000	6,700	66,300	162,720
1982	69,320	19,000	9,000	8,300	71,300	176,920
1983	78,680	21,000	12,000	9,600	78,300	199,580
1984	88,510	23,000	15,000	10,400	84,300	221,210
1985	99,510	26,000	19,000	12,000	100,300	256,810
1986	112,610	29,000	23,000	13,600	110,300	288,510
1987	125,310	33,000	28,000	14,500	123,300	324,110
1988	139,510	36,000	33,000	15,800	134,300	358,610
1989	153,310	41,000	39,000	16,300	147,300	396,910
1990	164,210	45,000	45,000	20,000	157,300	431,510
1991	175,670	49,000	54,000	22,600	165,900	467,170
1992	187,140	53,000	63,000	25,200	174,500	502,840
1993	198,610	57,000	72,000	27,800	183,100	538,510
1994	210,080	63,000	81,000	30,400	191,700	576,180
1995	221,550	70,000	90,000	33,000	200,300	614,850
1996	231,590	75,880	102,000	36,800	211,300	657,570
1997	241,630	81,760	114,000	40,600	222,300	700,290
1998	258,500	87,840	126,000	44,400	233,300	750,040
1999	262,510	93,920	138,000	48,200	244,300	786,930
2000	272,950	100,000	150,000	52,000	255,300	830,250

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[1] "Low" estimate OECD Redbook 1979 and INFCE Final Report, Working Group Three.

[2] Does not include countries with centrally planned economies.

Table A-6

PRESENT PLANS REACTOR GROWTH PROJECTIONS[1] (MWe)

Year	Europe	Pacific (Japan)	Rest of World[2]	Canada	U.S.	Total
1980	53,320	14,490	4,930	6,130	65,870	144,740
1981	69,450	15,020	7,680	6,770	79,000	177,920
1982	78,780	16,630	11,670	7,800	92,685	207,560
1983	93,240	18,190	14,060	9,580	106,470	241,540
1984	99,890	20,400	16,080	10,330	121,550	268,250
1985	107,720	20,400	20,380	10,330	128,640	287,470
1986	112,490	20,400	20,380	11,080	140,050	304,400
1987	112,490	20,400	20,980	12,710	146,840	313,420
1988	113,420	20,400	20,980	13,590	155,960	324,350
1989	113,420	20,400	20,980	14,470	161,530	330,800
1990	114,350	20,400	20,980	15,350	168,390	339,470
1991	114,350	20,400	29,980	15,350	171,630	342,710
1992	115,280	20,400	20,980	15,350	175,360	347,370
1993	115,280	20,400	20,980	15,350	175,360	347,370
1994	115,280	20,400	20,980	15,350	175,360	347,370
1995	115,280	20,400	20,980	15,350	175,360	347,370
1996	115,280	20,400	20,980	15,350	175,360	347,370
1997	115,280	20,400	20,980	15,350	175,360	347,370
1998	115,280	20,400	20,980	15,350	175,360	347,370
1999	115,280	20,400	20,980	15,350	175,360	347,370
2000	115,280	20,400	20,980	15,350	175,360	347,370

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[1] Based on the utility survey as reported in *Nuclear News*, August 1979, Volume 22, No. 10.

[2] Does not include countries with centrally planned economies.

Table A-7a
INFCE REACTOR GROWTH PROJECTION
(GWe)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-
Austria	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
Belgium	2.6	3.5	3.5	4.5	5.5	5.5	5.5	5.5	6.8	6.8	6.8	8.1	9.4
Canada	6.1	6.7	8.3	9.6	10.4	12.0	13.6	14.5	15.8	16.3	20.0	33.0	52.0
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-
Finland	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	3.2	4.2
France	17.5	22.9	24.6	30.3	34.2	39.0	44.0	48.0	53.0	55.0	59.0	73.0	86.0
Germany, FR	11.2	13.0	15.0	16.6	17.6	20.2	24.0	26.8	26.8	32.1	35.9	49.1	53.8
Greece	-	-	-	-	-	-	-	.6	.6	.6	1.2	2.2	3.2
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-
Italy	1.4	1.4	1.4	1.4	2.4	5.4	8.4	11.4	15.9	20.3	25.9	32.0	43.0
Japan	17.0	18.0	19.0	21.0	23.0	26.0	29.0	33.0	36.0	41.0	45.0	70.0	100.0
Luxembourg	-	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
New Zealand	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-
Portugal	-	-	-	-	-	-	-	.9	.9	1.8	1.8	3.6	5.4
Spain	4.9	5.8	6.7	7.7	9.8	9.8	9.8	10.5	11.9	14.2	15.8	28.0	38.0
Sweden	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	0	0	0
Switzerland	1.9	1.9	1.9	1.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Turkey	-	-	-	-	-	.6	.6	.6	.6	.6	.6	.6	.6
United Kingdom	7.4	9.4	9.4	9.4	9.4	9.4	10.7	11.4	11.4	12.3	12.3	19.7	27.6
United States	62.3	66.3	71.9	78.3	84.3	100.3	110.3	123.3	134.3	147.3	157.3	200.3	253.3
Rest of World	5.0	7.0	9.0	12.0	15.0	19.0	23.0	28.0	33.0	39.0	45.0	90.0	150.0
TOTAL	144.5	163.1	177.9	199.9	221.6	257.2	288.9	324.5	357.0	397.3	432.8	616.8	830.5

Notes:
1. From *Nuclear News*, August 1979, Volume 22, No. 10
2. From *Uranium Resources, Production and Demand*, OECD-NEA/IAEA, Paris 1979.
3. Data were not included for Eastern Europe, USSR nor China.

Table A-7b
PRESENT PLANS REACTOR GROWTH PROJECTION
(GWe)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-
Austria												.7	.7
Belgium	1.6	3.5	3.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Canada	6.1	6.8	7.8	9.6	10.3	10.3	11.1	12.7	13.6	14.5	15.4	15.4	15.4
Denmark	-	-	-	-	-	-	-	-	-	-	-	-	-
Finland	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
France	15.5	21.9	25.4	31.9	36.2	42.6	43.9	43.9	43.9	43.9	43.9	43.9	43.9
Germany, FR	10.3	12.8	14.3	19.4	19.7	19.7	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Greece	-	-	-	-	-	-	-	-	-	-	-	-	-
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-
Italy	1.4	1.4	1.4	1.4	2.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Japan	14.5	15.0	16.6	18.2	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Luxembourg	-	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
New Zealand	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-
Portugal	-	-	-	-	-	-	-	-	.9	.9	1.9	2.8	2.8
Spain	3.8	6.6	9.5	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Sweden	7.3	7.3	7.3	7.3	8.4	8.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Switzerland	1.9	2.9	2.9	2.9	2.9	2.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Turkey	-	-	-	-	-	.4	.4	.4	.4	.4	.4	.4	.4
United Kingdom	8.7	10.5	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
United States	66.1	79.3	93.0	106.7	121.8	128.9	140.3	147.1	156.2	161.8	168.7	175.6	175.6
Rest of World	4.9	7.7	11.7	14.1	16.1	20.4	20.4	21.0	21.0	21.0	21.0	21.0	21.0
TOTAL	144.8	178.4	207.9	241.9	268.6	287.8	304.0	313.0	323.9	330.4	339.2	347.7	347.7

Notes:
1. From Nuclear News, August 1979, Volume 22, No. 10
2. From Uranium Resources, Production and Demand, OECD-NEA/IAEA, Paris 1979.
3. Data were not included for Eastern Europe, USSR nor China.

Table A-8

REST OF WORLD PRESENT PLANS NUCLEAR GROWTH ESTIMATES[1] (GWe)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000
Argentina	.34	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94
Brazil	.62	.62	.62	.62	.62	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Egypt	-	-	-	-	-	-	-	.62	.62	.62	.62	.62	.62
India	1.0	1.0	1.2	1.5	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Iran	1.2	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Korea	.56	.56	1.2	1.8	2.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Mexico	-	-	.65	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Philippines	-	-	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
South Africa	-	-	.92	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Taiwan	1.2	2.2	3.1	3.1	4.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
TOTAL	4.9	7.7	11.7	14.1	16.1	20.4	20.4	21.0	21.0	21.0	21.0	21.0	21.0
INFCE Total	5.0	7.0	9.0	12.0	15.0	19.0	23.0	28.0	33.0	39.0	45.0	90.0	150.0

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[1] From Nuclear News, August 1979, Volume 22, No. 10.

Table A-9

HISTORIC[1] NUCLEAR CAPACITY GROWTH[2] (GWe)

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Australia																							
Austria																							
Belgium																			1.7	1.7	1.7	1.7	1.7
Canada												.2	.2	.2	1.3	2.0	2.5	2.5	2.5	2.5	4.0	4.8	5.5
Denmark																							
Finland																					.4	.4	1.5
France			.04	.1	.1	.1	.1	.1	.3	.3	1.1	1.1	1.5	1.5	2.0	2.6	2.8	2.8	2.8	2.8	3.7	4.6	10.1
Germany, FR						.1	.1	.1	.1	.1	.3	.5	.9	.9	.9	2.1	2.1	2.1	3.3	4.1	6.1	7.3	9.1
Greece																							
Iceland																							
Ireland																							
Italy								.3	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	1.4	1.4
Japan										.2	.2	.2	.2	.8	1.3	1.7	1.7	3.7	5.0	7.1	7.6	11.2	14.5
Luxembourg																							
Netherlands													.1	.1	.1	.1	.5	.5	.5	.5	.5	.5	.5
New Zealand																							
Norway																							
Portugal																							
Spain													.2	.2	.6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2.0
Sweden																.5	.5	1.0	2.4	3.1	3.7	3.7	5.5
Switzerland													.4	.4	.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.9
Turkey																							
United Kingdom	.2	.4	.4	.4	.4	1.0	1.0	1.3	2.9	3.5	3.5	4.2	4.2	4.2	4.7	5.3	5.3	5.3	5.3	6.8	8.1	8.1	8.1
United States				.2	.4	.7	.8	.8	.8	1.6	1.6	2.6	3.9	6.4	9.1	14.6	19.4	29.2	36.3	40.3	46.4	49.3	55.2
Rest of World[2]													.4	.4	.4	.5	.7	1.1	1.1	1.1	1.1	2.2	3.0
TOTAL	.2	.4	.4	.4	.9	1.9	2.0	2.6	4.7	6.3	7.3	9.4	12.6	15.7	21.4	32.1	38.2	50.9	63.6	72.7	86.0	97.3	120.0

Notes: 1. From Nuclear News, August 1979, Volume 22, No. 10.

2. Data were not included for Eastern Europe, USSR, nor China.

Table A-10

TOTAL NON-U.S. WOCA ANNUAL URANIUM REQUIREMENTS PRESENT PLANS AND INFCE NUCLEAR GROWTH PROJECTIONS

(MTU)

Year	Present Plans	INFCE Low
1980	17,320	15,920
1981	17,550	19,990
1982	20,320	21,490
1983	20,340	24,730
1984	20,470	27,560
1985	22,900	28,940
1986	22,560	22,140
1987	23,170	36,230
1988	22,940	40,030
1989	23,380	43,300
1990	23,280	46,650
1991	23,620	50,490
1992	23,410	54,190
1993	23,440	57,870
1994	23,540	61,660
1995	23,540	65,580
1996	23,540	69,540
1997	23,540	73,520
1998	23,540	79,820
1999	23,540	83,350
2000	23,540	92,040

Table A-11

INFCE URANIUM REQUIREMENTS[1]
(MTU)

Year	Europe	Pacific (Japan)	Rest of World[2]	Canada	U.S.	Total
1980	10,390	3,070	1,550	910	11,100	27,020
1981	12,780	3,170	2,130	910	11,290	31,280
1982	13,890	3,710	2,670	1,220	15,610	37,100
1983	16,380	3,880	3,100	1,370	14,390	39,120
1984	17,720	4,610	3,860	1,370	16,310	43,870
1985	18,390	4,660	4,270	1,620	17,790	46,730
1986	20,310	5,760	5,380	1,690	19,900	53,040
1987	22,130	5,950	5,900	2,260	20,610	56,840
1988	23,670	6,360	7,740	2,260	21,610	61,040
1989	25,360	7,050	8,570	2,320	23,410	66,710
1990	26,900	7,610	9,380	2,760	24,790	71,440
1991	28,370	8,450	10,610	3,060	25,980	76,470
1992	29,840	9,140	11,830	3,375	27,150	81,340
1993	30,540	9,680	13,790	3,860	29,220	87,090
1994	32,010	10,470	15,020	4,170	30,420	92,080
1995	33,480	11,380	16,240	4,480	31,590	97,170
1996	34,710	12,170	17,740	4,930	33,120	102,660
1997	35,940	12,960	19,240	5,380	34,630	108,150
1998	37,910	14,080	21,170	6,660	36,150	115,970
1999	38,710	14,870	22,660	7,110	37,660	121,010
2000	41,630	16,500	25,820	8,090	40,700	132,740

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[1] INFCE Working Group 1 on Availability of Nuclear Fuel and Heavy Water. Final Report. Draft. Vienna, Austria. June 11, 1979.

[2] Does not include countries with centrally planned economies.

Table A-12

PRESENT PLANS URANIUM REQUIREMENTS[1]
(MTU)

Year	Europe	Pacific (Japan)	Rest of World[2]	Canada	U.S.	Total
1980	12,280	2,560	1,480	990	13,400	30,720
1981	12,140	2,760	1,720	920	15,680	33,280
1982	14,060	2,290	3,040	930	14,680	35,000
1983	14,780	2,510	1,810	1,250	18,160	38,500
1984	13,920	2,770	2,310	1,470	18,550	39,020
1985	16,090	2,770	2,680	1,360	20,380	43,280
1986	15,660	2,770	2,680	1,450	20,660	43,220
1987	16,000	2,770	2,760	1,640	22,070	45,240
1988	15,790	2,770	2,760	1,620	22,010	44,950
1989	16,130	2,770	2,760	1,730	22,970	46,350
1990	15,920	2,770	2,760	1,830	22,550	45,830
1991	16,260	2,770	2,760	1,830	23,450	47,070
1992	16,050	2,770	2,760	1,830	23,520	46,930
1993	16,050	2,770	2,760	1,830	23,490	46,930
1994	16,170	2,770	2,760	1,830	23,680	47,220
1995	16,170	2,770	2,760	1,830	23,680	47,220
1996	16,170	2,770	2,760	1,830	23,680	47,220
1997	16,170	2,770	2,760	1,830	23,680	47,220
1998	16,170	2,770	2,760	1,830	23,680	47,220
1999	16,170	2,770	2,760	1,830	23,680	47,220
2000	16,170	2,770	2,760	1,830	23,680	47,220

[1] INFCE groupings.

[2] Does not incude countries with centrally planned economies.

Table A-13

HISTORICAL RESERVE AND RESOURCE ESTIMATES(1)

COUNTRY	1967		1970		1973		1975		1977		1980	
	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.
Algeria	-	-	-	-	-	-	28	-	28	50	28	0
	-	-	-	-	-	-	-	-	0	0	0	5
Argentina	7	16	8	17	9	14	9	15	18	0	23	9
	9	25	9	25	8	23	11	24	24	0	5	5
Australia	8	2	17	5	71	79	243	80	289	44	292	46
	2	1	7	5	30	29	-	-	7	5	8	8
Austria	-	-	-	-	-	-	-	-	2	0	2	0
	-	-	-	-	-	-	-	-	0	0	0	0
Bolivia	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	-	-	0	1	0	1
Brazil	-	-	1	1	-	3	10	9	18	8	74	100
	-	-	-	-	1	-	1	-	0	0	0	0
Canada	154	223	178	177	185	190	144	324	167	392	215	369
	100	131	100	131	122	219	22	95	15	264	19	358
Central African Empire	-	-	8	8	8	8	8	8	8	8	18	8
	-	-	-	-	-	-	-	-	0	0	0	0
Chile	-	-	-	-	-	-	-	-	0	5	0	5
	-	-	-	-	-	-	-	-	0	0	0	0
Denmark (Greenland)	-	4	-	-	6	10	-	-	0	0	0	0
	-	-	4	-	-	-	6	10	6	9	27	16
Finland	-	-	-	-	-	-	-	-	1	0	0	0
	-	-	-	-	1	-	2	-	2	0	3	0
France	35	15	35	19	37	24	37	25	37	24	39	26
	4	8	7	12	20	25	18	15	15	20	16	20
Gabon	3	3	10	5	20	5	20	5	20	5	20	5
	-	-	-	5	-	5	-	5	0	5	0	5

Note: The first row of entries for each country is for the lower cost category of reserves and resources while the second is for the higher. See text discussion, Chapter 3.

Table 13-A (con't.)

COUNTRY	1967		1970		1973		1975		1977		1980	
	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.
Germany	-	-	-	-	-	-	1	1	2	3	4	3
	-	-	-	-	-	-	1	3	1	1	0	1
India	-	-	-	-	-	-	3	1	30	24	30	0
	2	1	2	1	2	1	26	23	0	0	0	24
Italy	1	-	1	-	1	-	-	-	1	1	0	1
	-	-	-	-	-	-	1	1	0	0	2	0
Japan	-	-	2	-	3	-	1	-	8	0	8	0
	3	-	4	-	4	-	7	-	0	0	0	0
Korea	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	2	-	3	0	3	0
Madagascar	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	-	-	0	2	0	2
Mexico	-	-	1	-	1	-	5	-	5	2	7	34
	-	-	1	-	1	-	1	-	0	0	0	0
Namibia	-	-	-	-	-	-	-	-	-	-	117	30
	-	-	-	-	-	-	-	-	-	-	16	23
Niger	9	10	20	29	40	20	40	20	160	53	162	53
	10	-	10	10	10	10	10	10	0	0	0	0
Philippines	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	-	-	0	0	0	0
Portugal	7	5	7	6	6	6	7	-	7	1	7	2
	-	9	-	12	1	10	-	-	2	0	1	1
Somalia	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	-	-	6	3	5	2
South Africa	158	12	154	12	202	8	186	6	306	34	246	54
	50	27	50	27	62	26	90	68	42	38	145	85

Table 13-A (con't.)

COUNTRY	1967		1970		1973		1975		1977		1980	
	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.	R.A.	E.A.
Spain	9	-	9	-	9	-	10	9	7	9	10	9
	3	23	8	-	8	-	94	98	0	0	0	0
Sweden	-	-	-	-	-	-	-	-	1	3	1	0
	269	38	269	-	270	40	300	-	300	0	299	3
Turkey	-	-	-	-	2	-	7	-	4	0	2	0
	-	-	-	-	1	-	1	-	0	0	2	0
United Kingdom	-	-	-	-	-	-	-	-	0	0	0	0
	-	-	-	-	-	-	2	4	0	7	0	8
United States	139	250	192	390	259	538	320	500	523	838	531	777
	77	154	108	231	141	231	134	312	120	215	177	381
Yugoslavia	-	-	-	-	6	10	4	-	5	5	5	5
	-	-	-	-	-	-	2	15	2	16	2	16
Zaire	5	-	-	-	2	2	2	2	2	2	2	2
	-	-	-	-	-	-	-	-	0	0	0	0
TOTALS	535	540	643	669	867	917	1,085	1,005	1,649	1,511	1,843	1,538
	529	417	579	459	682	619	731	683	545	586	730	964
	1,064	957	1,222	1,128	1,549	1,536	1,816	1,688	2,194	2,097	2,573	2,502

Sources:

OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Resources. Paris, 1967.
OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Production and Short-Term Demand. Paris, 1969.
OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Resources, Production and Demand. Paris, 1970, 1973, 1976, 1977, 1979.

Table A-14

HISTORICAL WORLD URANIUM PRODUCTION
(MTU)

YEAR	U.S.	Canada	Niger	France(1)	Gabon	S. Africa	Namibia	Belgian Congo(2)	Australia	Others(3)	Total	Cumulative
1948	200	100						1,300			1,600	1,600
1949	365	100		75				1,400			1,940	3,540
1950	420	200		100				2,040			2,760	6,300
1951	690	200		100				1,600			2,590	8,890
1952	770	430		100		100		1,070			2,470	11,360
1953	1,500	800		100		780		970			4,150	15,510
1954	2,700	970		100		1,290		970	100		6,130	21,640
1955	3,100	970		180		2,153		970	180		7,553	29,193
1956	6,200	1,730		200		3,445		1,000	220		12,795	41,988
1957	7,567	5,075		369		4,383		1,200	321		18,915	60,903
1958	10,766	10,305		807		4,806		1,822	466		28,972	89,875
1959	13,381	12,227		896		4,960		1,784	859		34,107	123,982
1960	14,457	9,786		1,038		4,922		915	934		32,052	156,034
1961	14,226	7,382		1,450		4,206		123	1,197		28,584	184,618
1962	13,150	6,459		1,523		3,876			1,047		26,055	210,673
1963	11,304	6,459		1,584		3,460			917		23,724	234,397
1964	10,689	5,614		1,580		3,422			282		21,587	255,984
1965	8,151	3,384		1,611		2,261			260		15,667	271,661
1966	7,536	2,999		1,622		2,522			260		14,939	286,600
1967	8,228	2,845		1,692		2,476			260		15,501	302,101
1968	9,300	3,014		1,720		3,050			260		17,344	319,445
1969	8,900	3,430		1,180	500	3,080			254	250	17,594	337,039
1970	9,900	3,530		1,250	400	3,167			254	110	18,611	355,650
1971	9,470	3,830	430	1,250	540	3,220			0	194	18,934	374,584
1972	9,900	4,000	867	1,545	210	3,197			0	168	19,887	394,471
1973	10,200	3,710	948	1,616	402	2,735			0	162	19,773	414,244
1974	8,900	3,420	1,117	1,673	436	2,711			0	215	18,472	432,716
1975	8,900	3,510	1,306	1,742	800	2,488			0	334	19,080	451,796
1976	9,800	4,850	1,460	1,871	850	2,758	650		360	348	22,947	474,743
1977	11,460	5,790	1,609	2,097	1,408	3,360	2,340		360	413	28,837	503,580
1978	14,400	6,600	2,200	2,183	1,000	3,960	2,700		516	472	34,031	537,611
1979	14,800	7,000	3,300	2,180	1,000	5,200	3,690		600	712	38,482	576,093

(1) Before 1969 French production includes that from Gabon and other "affiliates."

(2) The Belgian Congo is now Zaire.

(3) Other includes: Argentina, Japan, West Germany, Mexico, Portugal, Spain, Sweden, and Brazil.

SOURCES FOR TABLE A-14

Data through 1956 are from U.S. Geological Survey Professional Paper 820, 1973.

Data through 1957-1976 are from Uranium Resources, Production and Demand, OECD Nuclear Energy Agency and the International Atomic Energy Agency, Paris, 1970, 1973, 1976, 1977, 1979.

Data from 1977-1979 are taken from The Balance of Supply and Demand 1978-1990, Supply and Demand Committee of the Uranium Institute, Mining Journal Books Ltd., London, 1979; and International Nuclear Fuel Cycle Evaluation, Working Group 1 on Availability of Nuclear Fuel and Heavy Water, Final Report, Draft, Vienna, Austria, June 11, 1979.

Table A-15

HISTORIC URANIUM PRODUCTION AND REACTOR REQUIREMENTS
NON-U.S. WOCA
(MTU)

Year	Uranium Production	Uranium Requirements
1948	1,400	
1949	1,575	
1950	2,340	
1951	1,900	
1952	1,700	
1953	2,650	90
1954	3,430	0
1955	4,453	90
1956	6,595	40
1957	11,348	40
1958	18,206	50
1959	20,726	320
1960	17,595	90
1961	14,358	320
1962	12,905	990
1963	12,420	460
1964	10,898	620
1965	7,516	1,590
1966	7,403	1,210
1967	7,273	970
1968	8,044	1,880
1969	8,694	3,060
1970	8,711	1,470
1971	9,464	2,570
1972	9,987	4,280
1973	9,573	4,900
1974	9,572	5,800
1975	10,180	6,460
1976	13,147	10,250
1977	17,377	10,750
1978	19,631	14,590
1979	23,682	14,740

Table A-16

HISTORIC U.S. URANIUM PRODUCTION AND REACTOR REQUIREMENTS
(MTU)

Year	Uranium Production	Uranium Requirements
1948	200	
1949	365	
1950	420	
1951	690	
1952	770	
1953	1,500	
1954	2,700	
1955	3,100	
1956	6,200	
1957	7,567	70
1958	10,766	60
1959	13,381	120
1960	14,457	50
1961	14,226	50
1962	13,150	100
1963	11,304	420
1964	10,689	100
1965	8,151	470
1966	7,536	690
1967	8,228	1,110
1968	9,300	1,360
1969	8,900	740
1970	9,900	2,630
1971	9,470	4,810
1972	9,900	3,910
1973	10,200	3,440
1974	8,900	5,580
1975	8,900	5,390
1976	9,800	6,690
1977	11,460	9,610
1978	14,400	10,890
1979	14,800	11,900

Table A-17

ATTAINABLE PRODUCTION CAPACITIES
(MTU)

Year	Australia	Canada	France	S. Africa	Namibia	Niger	Other	U.S.	Gabon	Total
1979	600	6,900	2,950	5,240	3,700	3,300	1,170	16,300	1,000	41,160
1980	600	7,200	3,450	6,500	4,100	4,300	2,020	20,900	1,000	50,070
1981	2,300	9,000	3,650	7,300	4,400	4,500	2,810	24,300	1,000	59,260
1982	3,800	9,900	3,870	8,600	4,550	4,500	4,210	27,100	1,500	68,030
1983	5,000	11,000	4,020	9,900	5,000	5,400	5,070	30,900	1,500	77,790
1984	6,500	13,500	4,020	10,400	5,000	8,000	5,320	33,000	1,500	87,240
1985	12,000	14,400	4,020	10,600	5,000	10,500	5,870	34,100	1,500	97,990
1986	13,600	14,500	4,520	10,700	5,000	12,000	5,870	35,000	1,500	102,690
1987	15,200	14,500	4,520	10,700	5,000	12,000	5,940	38,400	1,500	107,760
1988	16,800	14,700	4,520	10,600	5,000	12,000	6,000	40,800	1,500	111,920
1989	18,400	15,400	4,520	10,600	5,000	12,000	6,070	42,600	1,500	116,090
1990	20,000	15,500	4,520	10,400	5,000	12,000	6,130	44,200	1,500	119,250

Source: OECD Nuclear Energy Agency and the International Atomic Energy Agency.
Uranium Resources, Production and Demand, Paris, 1979.

Table A-18

PLANNED PRODUCTION CAPACITY
(MTU)

Year	Australia	Canada*	France	Gabon	Niger	S. Africa	Namibia	Other	Total
1980	600	6,210	3,100	1,000	4,300	5,780	4,080	740	25,810
1981	2,300	8,080	3,300	1,000	4,500	6,370	4,400	970	30,920
1982	3,800	8,970	3,500	1,300	4,500	6,900	4,550	1,380	34,900
1983	3,800	9,750	3,600	1,300	5,400	7,500	5,020	1,990	38,360
1984	3,800	12,030	3,600	1,300	8,000	7,870	5,020	1,780	43,400
1985	4,700	13,040	3,600	1,300	10,500	7,700	5,020	1,850	47,710
1986	5,500	13,050	4,050	1,300	12,000	7,530	5,020	1,650	50,100
1987	5,500	12,860	4,050	1,300	12,000	7,510	5,020	1,060	49,300
1988	5,500	13,080	4,050	1,300	12,000	7,430	5,020	1,730	50,110
1989	5,500	13,670	4,050	1,300	12,000	7,370	5,020	1,330	50,240
1990	4,700	13,670	4,050	1,300	12,000	7,230	5,020	1,580	49,550

* This represents Canadian production available for export -- production minus domestic requirements.

Source: OECD Nuclear Energy Agency and the International Atomic Energy Agency. *Uranium Resources, Production and Demand*, Paris, 1979.

Table A-19

NON-U.S. WOCA URANIUM PRODUCTION AND REACTOR REQUIREMENTS[1]
(MTU)

Year	Present Plans Uranium Requirements	INFCE Low Uranium Requirements	Planned Uranium Production	Attainable Uranium Production
1967	970		7,273	
1968	1,880		8,044	
1969	3,060		8,694	
1970	1,470		8,711	
1971	2,570		9,464	
1972	4,280		9,987	
1973	4,900		9,573	
1974	5,800		9,572	
1975	6,460		10,180	
1976	10,250		13,147	
1977	10,750		17,377	
1978	14,590		19,631	
1979	14,740		23,682	
1980	17,320	15,920	25,810	29,170
1981	17,550	19,990	30,920	34,960
1982	20,320	21,490	34,900	40,930
1983	20,340	24,730	38,360	46,890
1984	20,470	27,560	43,400	54,240
1985	22,900	28,940	47,710	63,890
1986	22,560	33,140	50,100	67,690
1987	23,170	36,230	49,300	69,360
1988	22,940	40,030	50,110	71,120
1989	23,380	43,300	50,240	73,490
1990	23,280	46,650	49,550	75,050

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[1] Does not include enrichment plant feed in excess of actual reactor requirements.

Table A-20

AUSTRALIAN EXPORT COMMITMENTS
(MTU)

YEAR	DESTINATION					TOTAL	PRODUCTION AND PLANNED CAPACITY	POTENTIAL CAPACITY
	FRG	JAPAN	U.S.	SOUTH KOREA	FINLAND			
1977	260	690	200	-	-	1150	360	-
1978	310	460	180	-	-	950	520	-
1979	260	740	180	-	-	1180	600	-
1980	260	730	180	-	-	1170	600	600
1981	50	970	180	-	80	1280	2300	2300
1982	1230	1500	190	-	80	3000	3800	3800
1983	1230	1580	190	190	80	3270	3800	5000
1984	1220	1300	190	190	80	2980	3800	6500
1985	1190	1450	190	190	80	3100	4700	12000
1986	1190	1160	190	190	80	2810	5500	13600
1987	1190	850	190	190	80	2500	5500	15200
1988	1190	850	190	190	80	2500	5500	16800
1989	1190	850	190	190	80	2500	5500	18400
1990	1190	850	190	190	-	2420	4700	20000
1991	1190	850	-	190	-	2230	-	-
1992	1190	850	-	190	-	2230	-	-
1993	1190	850	-	-	-	2040	-	-
1994	1190	850	-	-	-	2040	-	-
1995	1190	850	-	-	-	2040	-	-
1996	1190	850	-	-	-	2040	-	-

Table A-21

CANADIAN COMMERCIAL EXPORT COMMITMENTS[1]
(MTU)

YEAR	DESTINATION								
	Japan	U.K.	U.S.	France	Spain	FRG	Italy	Other[2]	TOTAL
1967	-	-	30	-	-	-	-	-	30
1968	-	-	30	-	-	300	-	-	330
1969	1190	-	30	-	-	70	-	-	1290
1970	1150	-	30	-	-	70	-	-	1250
1971	1250	-	-	-	-	70	-	-	1320
1972	2080	-	-	-	-	360	-	-	2440
1973	1150	960	-	-	-	70	-	-	2180
1974	1150	960	-	-	850	70	-	-	3030
1975	1150	960	580	-	1810	460	-	690	5650
1976	2390	960	190	-	1420	460	320	230	5970
1977	2540	960	90	-	1420	460	320	350	6140
1978	2500	960	200	-	1010	1870	300	270	7110
1979	2500	960	290	-	650	1600	310	400	6710
1980	1620	960	170	-	270	710	310	160	4200
1981	1690	-	820	520	270	1280	310	730	5620
1982	1580	770	960	750	270	1480	310	650	6770
1983	1900	770	1220	750	190	1600	310	320	7060
1984	3460	770	1220	750	190	1600	310	240	8540
1985	3540	770	1070	750	190	1600	310	240	8470
1986	1810	770	1070	750	-	1600	-	160	6160
1987	1730	770	1070	750	-	1600	-	160	6080
1988	1700	770	1070	750	-	1600	-	160	6050
1989	1700	770	1070	750	-	1600	-	160	6050
1990	1540	770	1070	750	-	1600	-	160	5890
1991	1540	770	40	-	-	850	-	-	3200
1992	1540	390	40	-	-	850	-	-	2820
1993	1540	390	40	-	-	850	-	-	2820
1994	-	390	40	-	-	850	-	-	1280
1995	-	390	40	-	-	850	-	-	1280
1996	-	-	40	-	-	-	-	-	40
1997	-	-	40	-	-	-	-	-	40
1998	-	-	40	-	-	-	-	-	40
1999	-	-	40	-	-	-	-	-	40

[1] Both contracts and equity commitments are included; the latter are involved in supply to France, Italy and the FRG.

[2] "Other" includes Belgium, Finland, South Korea, Sweden and Switzerland.

Table A-22

CANADIAN EXPORTS COMPARED WITH PRODUCTION
(MTU)

Year	Domestic Requirements	Exports	Production and Planned Capacity	Excess or (Deficit)
1967	2	30	2845	2810
1968	180	330	3014	2500
1969	190	1290	3430	1950
1970	100	1250	3530	2180
1971	150	1320	3830	2360
1972	240	2440	4000	1320
1973	310	2180	3710	1220
1974	520	3030	3420	(130)
1975	410	5650	3510	(2550)
1976	410	5970	4850	(1530)
1977	570	6140	5790	(920)
1978	660	7110	6600	(1170)
1979	810	6710	7000	(520)
1980	990	4200	7200	2010
1981	920	5620	9000	2460
1982	930	6770	9900	2200
1983	1250	7060	11000	2690
1984	1470	8540	13500	3490
1985	1360	8470	14400	4570
1986	1450	6160	14500	6890
1987	1640	6080	14500	6780
1988	1620	6050	14700	7030
1989	1730	6050	15400	7620
1990	1830	5890	15500	7780
1991	1830	3200	15500	10470
1992	1830	2820	15500	10850
1993	1830	2820	15400	10750
1994	1830	1280	15400	12290
1995	1830	1280	15400	12290

Source: OECD Nuclear Energy Agency and the International Atomic Energy Agency. Uranium Resources, Production and Demand. Paris, 1979.

Table A-23

IDENTIFIABLE SOUTH AFRICAN EXPORT COMMITMENTS

Year	Destination								Total
	Japan	U.S.	FRG	Switzerland	France	Taiwan	Other[1]	Iran[2]	
1969	100	-	30	-	-	-	-	-	130
1970	100	-	30	-	-	-	-	-	130
1971	100	500	30	-	-	-	-	-	630
1972	100	-	500	-	-	-	-	-	600
1973	500	500	500	70	-	-	-	-	1570
1974	-	130	500	70	-	-	-	-	700
1975	580	190	500	70	-	-	190	-	1530
1976	1300	380	500	70	-	-	40	-	2290
1977	1150	480	500	320	-	-	70	300	2820
1978	1200	480	500	200	770	-	140	750	4040
1979	950	380	500	300	770	-	50	750	3700
1980	1030	380	500	140	770	-	140	750	3710
1981	720	380	500	100	770	-	120	900	3490
1982	800	380	500	100	770	-	120	1080	3570
1983	740	380	500	-	770	190	120	1080	3780
1984	610	380	500	-	770	300	210	1080	3850
1985	380	-	500	-	770	400	210	1080	3340
1986	-	-	-	-	770	500	210	770	2250
1987	-	-	-	-	770	500	170	770	2210
1988	-	-	-	-	-	500	170	770	1440
1989	-	-	-	-	-	500	170	770	1440
1990	-	-	-	-	-	500	170	770	1440
1991	-	-	-	-	-	-	170	770	940
1992	-	-	-	-	-	-	-	770	770

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1 Other includes Austria and Belgium.

2 Current status of Iranian contracts uncertain.

Table A-24

SOUTH AFRICAN EXPORTS COMPARED WITH PRODUCTION

(MTU)

Year	Export Commitments	Production and Planned Capacity	Potential Production Capacity
1969	130	3080	
1970	130	3167	
1971	630	3220	
1972	600	3197	
1973	1570	2735	
1974	700	2711	
1975	1530	2488	
1976	2290	2758	
1977	2820	3360	
1978	4040	3960	
1979	3700	5200	
1980	3710	5780	6500
1981	3490	6370	7300
1982	3570	6900	8600
1983	3780	7500	9900
1984	3850	7870	10400
1985	3340	7700	10600
1986	2250	7530	10700
1987	2210	7510	10700
1988	1440	7430	10600
1989	1440	7370	10600
1990	1440	7230	10400
1991	940		
1992	770		

Table A-25

JAPAN

NUCLEAR CAPACITY AND URANIUM REQUIREMENTS

(MWe and MTU)

	Reactors on Line or Ordered			INFCE Projection		
		U Requirements			U Requirements	
Year	Capacity (MWe)	Annual	Cumulative	Capacity (MWe)	Annual	Cumulative
1961	0	0	0			
1962	0	0	0			
1963	0	70	70			
1964	0	0	70			
1965	0	0	70			
1966	150	20	90			
1967	150	260	350			
1968	150	180	530			
1969	150	190	720			
1970	810	110	830			
1971	1,250	890	1,720			
1972	1,720	710	2,430			
1973	1,720	990	3,420			
1974	3,690	700	4,120			
1975	5,000	1,950	6,070			
1976	7,070	2,180	8,250			
1977	7,610	1,050	9,300			
1978	11,180	1,730	11,030			11,030
1979	14,490	2,580	13,610	15,000	2,430	13,460
1980	14,490	2,560	16,170	17,000	3,070	16,530
1981	15,020	2,760	18,930	18,000	3,170	19,700
1982	16,630	2,290	21,220	19,000	3,710	23,410
1983	18,190	2,510	23,730	21,000	3,880	27,290
1984	20,040	1,770	26,500	23,000	4,610	31,900
1985	20,040	2,770	29,270	26,000	4,660	36,560
1986	20,040	2,770	32,040	29,000	5,760	42,320
1987	20,040	2,770	34,810	33,000	5,950	48,270
1988	20,040	2,770	37,580	36,000	6,360	54,630
1989	20,040	2,770	40,350	41,000	7,050	61,680
1990	20,040	2,770	43,120	45,000	7,610	69,290
1991	20,040	2,770	45,890	50,000	8,450	77,740
1992	20,040	2,770	48,660	55,000	9,140	86,880
1993	20,040	2,770	51,430	60,000	9,680	96,560
1994	20,040	2,770	54,200	65,000	10,470	107,030
1995	20,040	2,770	56,970	70,000	11,380	118,410
1996	20,040	2,770	59,740	76,000	12,170	130,580
1997	20,040	2,770	62,510	82,000	12,960	143,540
1998	20,040	2,770	65,280	88,000	14,080	157,620
1999	20,040	2,770	68,050	94,000	14,870	172,490
2000	20,040	2,770	70,820	100,000	16,500	188,990

Table A-26
FRANCE
NUCLEAR CAPACITY AND URANIUM REQUIREMENTS
(MWe and MTU)

	Reactors on Line or Ordered			INFCE Projection		
Year	Capacity (MWe)	U Requirements		Capacity (MWe)	U Requirements	
		Annual	Cumulative		Annual	Cumulative
1956	0	20	20			
1957	0	20	40			
1658	0	0	40			
1959	40	10	50			
1960	80	10	60			
1961	80	10	70			
1962	80	110	180			
1963	80	10	190			
1964	80	310	500			
1965	280	40	540			
1966	280	250	790			
1967	1,060	140	930			
1968	1,060	380	1,310			
1969	1,520	450	1,760			
1970	1,520	200	1,960			
1971	2,030	270	2,230			
1972	2,570	340	2,570			
1973	2,800	340	2,910			
1974	2,800	660	3,570			
1975	2,800	660	4,230			
1976	4,090	2,330	6,560			
1977	3,690	2,450	9,010			
1978	4,580	2,880	11,890			11,890
1979	10,060	2,640	14,530	12,000	2,260	14,150
1980	15,540	4,000	18,530	17,500	4,000	18,150
1981	21,860	4,540	23,070	22,900	4,540	22,690
1982	25,450	5,790	28,860	24,600	5,190	27,880
1983	31,900	4,650	33,510	30,300	5,810	33,690
1984	36,230	4,780	38,290	34,200	5,990	39,680
1985	42,640	5,670	43,960	39,000	6,500	46,180
1986	43,910	5,840	49,800	44,000	6,280	52,460
1987	43,910	5,840	55,640	48,000	7,920	60,380
1988	43,910	5,840	61,480	53,000	7,670	68,050
1989	43,910	5,840	67,320	55,000	7,810	75,860
1990	43,910	5,840	73,160	59,000	8,360	84,220
1991	43,910	5,840	79,000	61,800	8,630	92,850
1992	43,910	5,840	84,840	64,600	8,910	101,760
1993	43,910	5,840	90,680	67,400	9,040	110,800
1994	43,910	5,840	96,520	70,200	9,320	120,120
1995	43,910	5,840	102,360	73,000	9,590	129,710
1996	43,910	5,840	108,200	75,600	9,810	139,520
1997	43,910	5,840	114,040	78,200	10,030	149,550
1998	43,910	5,840	119,880	80,800	9,670	159,200
1999	43,910	5,840	125,720	83,400	9,890	169,110
2000	43,910	5,840	131,560	86,000	10,110	179,220

Table A-27
WEST GERMANY
NUCLEAR CAPACITY AND URANIUM REQUIREMENTS
(MWe and MTU)

	Reactors on Line or Ordered			INFCE Projection		
Year	Capacity (MWe)	U Requirements		Capacity (MWe)	U Requirements	
		Annual	Cumulative		Annual	Cumulative
1961	0	0	0			
1962	50	10	10			
1963	50	10	20			
1964	50	90	110			
1965	50	100	210			
1966	50	120	330			
1967	287	40	370			
1968	542	70	440			
1969	870	580	1,020			
1970	870	120	1,140			
1971	870	120	1,260			
1972	2,140	710	1,970			
1973	2,140	590	2,560			
1974	2,140	1,020	3,580			
1975	3,280	900	4,480			
1976	4,090	1,190	5,670			
1977	6,100	1,300	6,970			
1978	7,330	1,900	8,870			8,870
1979	9,060	1,840	10,710	9,600	2,050	10,920
1980	10,320	3,280	13,990	11,200	2,020	12,940
1981	12,770	1,760	15,750	13,000	2,120	15,060
1982	14,320	1,970	17,720	15,000	2,970	18,030
1983	19,430	2,970	20,690	16,600	3,590	21,620
1984	19,720	2,680	23,370	17,600	3,360	24,980
1985	19,720	2,680	26,050	20,200	3,430	28,410
1986	20,530	2,790	28,840	24,000	4,430	32,840
1987	20,530	2,790	31,630	26,800	4,630	37,470
1988	20,530	2,790	34,420	28,800	4,690	42,160
1989	20,530	2,790	37,210	32,100	5,140	47,300
1990	20,530	2,790	40,000	35,900	5,530	52,830
1991	20,530	2,790	42,790	38,540	5,840	58,670
1992	20,530	2,790	45,580	41,180	6,140	64,810
1993	20,530	2,790	48,370	43,820	6,480	71,290
1994	20,530	2,790	51,160	46,460	6,780	78,070
1995	20,530	2,790	53,950	49,100	7,090	85,160
1996	20,530	2,790	56,740	50,040	7,400	92,560
1997	20,530	2,790	59,530	50,980	7,720	100,280
1998	20,530	2,790	62,320	51,920	7,200	107,480
1999	20,530	2,790	65,110	52,860	7,520	115,000
2000	20,530	2,790	67,900	53,800	7,840	122,840

Table A-28

IDENTIFIABLE PRIMARY EXPORTER COMMITMENTS
(MTU)

YEAR	EXPORTS						PRODUCTION	
	Australia	Canada	Namibia	Niger	South Africa	Total	Actual or Planned	Attainable
1967	-	30	-	-	-	30	5,579	
1968	-	330	-	-	-	330	6,147	
1969	-	1,290	-	-	130	1,420	6,572	
1970	-	1,250	-	-	130	1,380	6,849	
1971	-	1,320	-	400	630	2,350	7,330	
1972	-	2,440	-	870	600	3,910	7,819	
1973	-	2,180	-	950	1,570	4,700	7,087	
1974	-	3,030	-	1,120	700	4,850	6,727	
1975	-	5,650	-	1,300	1,530	8,480	6,890	
1976	-	5,970	650	1,450	2,290	10,360	9,664	
1977	1,150	6,140	2,340	1,350	2,820	13,800	12,885	
1978	950	7,110	2,670	1,290	4,040	16,060	15,313	
1979	1,180	6,710	3,110	2,520	3,700	17,220	18,982	
1980	1,170	4,200	3,760	3,090	3,710	15,930	20,960	21,110
1981	1,280	5,620	4,370	3,290	3,490	18,050	25,660	27,860
1982	3,000	6,770	4,680	3,290	3,570	21,310	28,720	30,050
1983	3,270	7,060	4,980	4,200	3,780	23,290	31,460	34,690
1984	2,980	8,540	4,960	5,240	3,850	25,570	36,711	41,570
1985	3,100	8,470	4,970	6,500	3,340	26,380	40,950	50,780
1986	2,810	6,160	4,870	7,090	2,250	23,180	43,090	53,990
1987	2,500	6,080	5,110	7,090	2,210	22,990	42,880	55,400
1988	2,500	6,050	5,110	6,510	1,440	21,610	43,020	57,120
1989	2,500	6,050	5,110	6,510	1,440	21,610	43,560	59,250
1990	2,420	5,890	5,110	6,510	1,440	21,370	42,610	60,710

Table A-29

ANNUAL AND CUMULATIVE PRODUCER INVENTORIES[1] -- CURRENT EXPORT COMMITMENTS AND PRODUCTION PLANS

Year	Australia		Canada		Niger		South Africa		Total	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1969	250	250	1,950	1,950			2,950	2,950	5,150	5,150
1970	250	500	2,180	4,130			3,140	6,090	5,570	10,720
1971	0	500	2,360	6,490			2,590	8,680	4,950	15,670
1972	0	500	1,320	7,810			2,600	11,280	3,920	19,590
1973	0	500	1,220	9,030			1,160	12,440	2,380	21,970
1974	0	500	(130)	8,900			2,010	14,450	1,880	23,850
1975	0	500	(2,550)	6,350			960	15,410	(1,590)	22,260
1976	360	860	(1,530)	4,820			470	15,880	(700)	21,560
1977	(790)	70	(920)	3,900	260	260	540	16,420	(910)	20,650
1978	(430)	(360)	(1,170)	2,730	910	1,170	80	16,500	(610)	20,040
1979	(580)	(940)	(520)	2,210	780	1,950	1,500	18,000	1,180	21,220
1980	(570)	(1,510)	2,010	4,220	1,210	3,160	2,070	20,070	4,720	25,940
1981	1,020	(490)	2,460	6,680	1,210	4,370	2,880	22,950	7,570	33,510
1982	800	310	2,200	8,880	1,210	5,580	3,330	26,280	7,540	41,050
1983	530	840	2,690	11,570	1,200	6,780	3,720	30,000	8,140	49,190
1984	820	1,660	3,490	15,060	2,760	9,540	4,020	34,020	11,090	60,280
1985	1,600	3,260	4,570	19,630	4,000	13,540	4,360	38,380	14,530	74,810
1986	2,690	5,950	6,890	26,520	4,910	18,450	2,760	41,140	17,250	92,060
1987	3,000	8,950	6,780	33,300	4,910	23,360	2,800	43,940	17,490	109,550
1988	3,000	11,950	7,030	40,330	5,490	28,850	3,580	47,520	19,100	128,650
1989	3,000	14,950	7,620	47,950	5,490	34,340	3,580	51,100	19,690	148,340
1990	2,280	17,230	7,780	55,730	5,490	39,830	3,580	54,680	19,130	167,470

Notes: 1. Inventories accumulated prior to 1969 are not included here. The precise quantities involved depend upon sales for weapons purposes. Numbers in () are deficits.

Table A-30
CONSUMER SUPPLY AND REQUIREMENTS
(Non-U.S. WOCA)
(MTU)

Year	Imports	Domestic Production	Total Supply	Requirements Present Plans	Requirements INFCE	Production* Actual and Planned	Production* Attainable
1968	800	1,200	2,020	1,880		8,044	
1969	2,130	1,340	3,470	3,060		8,694	
1970	3,200	1,360	4,560	1,470		8,711	
1971	2,480	1,440	3,920	2,570		9,464	
1972	4,680	1,710	6,390	4,280		9,987	
1973	4,900	1,780	6,680	4,900		9,573	
1974	6,230	2,060	8,290	5,800		9,572	
1975	9,560	2,070	11,630	6,460		10,180	
1976	11,440	2,210	13,650	10,250		13,147	
1977	14,860	2,490	17,350	10,750		17,377	
1978	17,120	2,640	19,760	14,590		19,631	
1979	18,920	3,080	22,000	14,740		23,682	
1980	17,680	4,800	22,480	17,320	15,920	25,810	29,170
1981	19,130	5,140	24,270	17,550	19,990	30,920	34,960
1982	22,880	5,740	28,620	20,320	21,490	34,900	40,930
1983	23,840	6,700	30,540	20,340	24,730	38,360	46,890
1984	27,320	6,750	34,070	20,470	27,560	43,400	54,240
1985	27,800	7,520	35,320	22,900	28,940	47,710	63,890
1986	23,340	7,960	31,310	22,560	33,140	50,100	67,690
1987	22,540	7,960	30,500	23,170	36,230	49,300	69,360
1988	20,160	7,960	28,120	22,940	40,030	50,110	71,120
1989	19,760	7,960	27,720	23,380	43,300	50,240	73,490
1990	19,520	7,960	27,480	23,280	46,650	49,550	75,050

*Canadian production is net of requirements.

Table A-31

ACTUAL AND PROSPECTIVE CONSUMER INVENTORIES

(Non U.S. WOCA[1])

(MTU)

		Present Plans			INFCE "Low"		
Year	Total Supply	Requirements	Annual Stock	Cumulative Stock	Requirements	Annual Stock	Cumulative Stock
1968	2,020	1,700	320	320			
1969	3,470	2,870	600	920			
1970	4,560	1,370	3,190	4,110			
1971	3,920	3,420	1,500	5,610			
1972	6,390	4,040	2,350	7,960			
1973	6,680	4,600	2,080	10,040			
1974	8,290	5,280	3,010	13,050			
1975	11,630	6,040	5,590	18,640			
1976	13,650	9,840	3,810	22,450			
1977	17,350	10,170	7,180	29,630			
1978	19,760	13,930	5,830	35,460			
1979	22,000	13,930	8,070	43,530			43,530
1980	22,480	16,330	6,150	49,680	15,010	7,470	51,000
1981	24,270	16,630	7,640	57,320	19,080	5,190	56,190
1982	28,620	19,390	9,230	66,550	20,270	8,350	64,540
1983	30,540	19,090	11,450	78,000	23,360	7,180	71,720
1984	34,070	19,000	15,070	93,070	26,190	7,880	79,600
1985	35,320	21,540	13,780	106,850	27,320	8,000	87,600
1986	31,310	21,110	10,200	117,050	31,450	-140	87,460
1987	30,500	21,530	8,970	126,020	33,970	-3,470	83,990
1988	28,120	21,320	6,800	132,820	37,770	-9,650	74,340
1989	27,720	21,660	6,060	138,880	40,980	-13,260	61,080
1990	27,480	21,450	6,030	144,910	43,890	-16,410	44,670

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[1] Excludes Canada, whose requirements are covered by domestic production.

Table A-32

HISTORIC NOMINAL AND REAL PRICE OF URANIUM[1]

($/pound U_3O_8)

Year	Nominal Price	Real Price[2]
1950	9.20	18.90
1955	12.50	22.00
1960	8.80	13.90
1965	8.00	12.10
1970	6.20	7.00
6/73	6.50	6.10
12/73	7.00	6.30
6/74	10.50	8.40
12/74	15.00	10.80
5/75	21.00	14.60
8/75	26.00	17.80
12/75	35.00	23.80
4/76	40.00	26.85
12/76	41.00	26.45
6/77	42.25	26.25
12/77	43.20	26.20
6/78	43.40	25.30
12/78	43.25	23.85
6/79	43.00	22.75
9/79	42.20	21.60
12/79	40.75	20.35
3/80	38.00	18.50
4/80	35.00	16.90
8/80	31.50	14.75
10/80	28.50	13.25
12/80	28.00	12.90

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1. 1950-1967 from USACE purchases, ERDA, Statistical Summary of the Uranium Industry (1976); 1968-1980 from NUEXCO Spot Market Price

2. Deflated by the GNP implicit Price Index for Fixed Investment Non-Residential Structures (1972=100). Index after 8/80 is estimated.