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COMMERCIAL NUCLEAR AND URANIUM MARKET FORECASTS FOR THE UNITED STATES AND THE WORLD OUTSIDE COMMUNIST AREAS

December 1979

All forecasts and analyses presented in this paper are conditional, based on clearly specified assumptions in areas of legitimate real world uncertainty. Reference to these forecasts out of context is inappropriate and may be misleading.

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PREFACE

This Analysis Report was prepared by the Energy Information Administration (EIA) to present its current forecasts of commercial nuclear power for the United States and the World Outside Communist Areas (WOCA). Included are comprehensive forecasts of uranium consumption requirements and, for the United States, associated ranges of potential price levels for uranium through the year 1995. The nuclear power forecasts for the United States update those which were previously published in the EIA Annual Report to Congress for 1978, released in July 1979. Major portions of this paper were originally prepared under the title "Uranium Market Forecasts" and were presented at the Uranium Industry Seminar in Grand Junction, Colorado, on October 16, 1979.

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EXECUTIVE SUMMARY

This report presents nuclear power forecasts prepared by the Energy Information Administration (EIA) of the United States Department of Energy. The domestic forecasts from the EIA Annual Report to Congress for 1978 (published in July 1979) are detailed for the two time frames considered in the EIA analytical hierarchy: the midterm, encompassing the 1985, 1990, and 1995 milestones and the long term, beyond 1995 to the year 2020. EIA nuclear forecasts for the balance of nations in the World Outside Communist Areas (WOCA) are also presented through the year 2000. In turn, an assessment is made of the uranium consumption requirements implied by both the domestic and WOCA nuclear power forecasts. This report includes a discussion of appropriate fuel cycle assumptions, sensitivities, and price projections.

Finally, an updated nuclear power forecast is presented for the midterm through the year 1995. This updated forecast incorporates utility-specific information accumulated since the assumptions for the EIA Annual Report were finalized in December 1978; therefore, this forecast is a better representation of the domestic political and economic climate following the reactor accident at the Three Mile Island generating station on March 28, 1979.

Forecasts through the year 2000 for the United States and WOCA prepared by the EIA and the International Nuclear Fuel Cycle Evaluation (INFCE) are chronologically summarized in the following table:

SUMMARY OF NUCLEAR POWER FORECASTS FOR WOCA

Source	Installed Nuclear Capacity At Year's End (GWe) 1985	1990	1995	2000
EIA 1977 Annual Report (5/78)				
Total WOCA	223-262	350-430	515-650	770-1,050
(U.S. Only)	(100-122)	(157-192)	(200-275)	(255-395)
INFCE (10/78)				
Total WOCA	245-274	373-462	550-770	850-1,200
(U.S. Only)	(100-122)	(157-192)	(200-275)	(255-395)
EIA 1978 Annual Report (7/79)				
Total WOCA	216-247	305-376	418-552	550-750
(U.S. Only)	(102-118)	(142-171)	(186-225)	(235-300)

In the domestic forecasts, a small reduction is reported for the 1985 milestone between the successive EIA Annual Reports. For the 1990 milestone, however, the 1978 Annual Report range of 142 to 171 GWe represents an approximate 10-percent reduction from the corresponding levels of 157 to 192 Gwe forecasted a year earlier. This reduction comes primarily as a result of declining demand growth, continuing delays in reactor programs and, for certain utilities, a deteriorating financial position.

Extension of the EIA midterm methodology to the year 1995, done for the first time in the 1978 EIA Annual Report, facilitated a continued, albeit more limited, evaluation of the pipeline of known domestic reactor projects. A range of 186 to 225 GWe for nuclear power was estimated for commercial operation in the year 1995, as compared to a range of 200 to 275 GWe reported in the 1977 Annual Report and submitted by the United States to the INFCE.

In the 1978 EIA Annual Report, a commensurate reduction is made in the projections for the year 2000, resulting in a current forecast range of 235 to 300 Gwe. This range represents a nuclear power potential that is 8 to 24 percent below the range of 255 to 395 GWe submitted by the United States to INFCE. In general, these reductions come as an indirect result of the forecast reductions in the midterm, although the narrowing of the forecast range is indicative of continuing improvements and confidence levels in the EIA forecasting methodologies and analytical techniques.

Beyond the year 2000, constraints represented by current nuclear uncertainties and lead times are less applicable, and nuclear power is assumed to remain an economically competitive option. Under these assumptions, EIA forecasts a vigorous deployment of new, nuclear power plants, with the total nuclear capacity reaching a level of approximately 670 GWe in the year 2020.

Based upon a methodology identical with that developed for the domestic analysis, individual forecasts are made for the other major industrial nations and developing countries with firm nuclear power programs. In aggregate, the forecasted level of 305 to 376 GWe for WOCA nuclear capacity in 1990 represents a 13-percent reduction from last year's EIA estimates and an 18-percent decrease from the INFCE totals. Reductions also occur for the other milestone years. Aside from the aforementioned decreases reported for the domestic program, reduced demand growth and similar delays in foreign WOCA construction programs account for the major portion of these reductions. For example, ambitious forecasts for Brazil, South Korea, and Taiwan have been reduced to more modest levels, while Iran's nuclear program has all but ceased to exist.

EIA forecast ranges for foreign nations in the year 2000 assume a relatively vigorous growth in electricity demand after 1995, a continous displacement of fossil-fueled capacity in baseload service, and a mitigation of political and technical problems that currently plague many foreign nuclear programs. For the year 2000, the current forecast range of 550 to 750 GWe represents about a 28-percent reduction from last year's EIA figures of 770 to 1,050 GWe and between 35 to 38 percent reduction from the range of 850 to 1,200 developed by the INFCE exercise.

The uranium market forecasts associated with these power forecasts are developed for both the United States and WOCA in aggregate. A reference case of domestic uranium market activity is based upon the EIA midcase nuclear power forecast through the year 2020. A universe of light water reactor (LWR) technologies is assumed to characterize the entire forecast period. The reference case of foreign uranium consumption requirements is also based upon the midcase power forecast, but only through the year 1995. This foreign case is characterized by a basic mix of reactor technologies prescribed by the participating nations during the INFCE exercise. Historic fuel utilization efficiencies are assumed to continue into the future, and enrichment services are assumed to be conducted at 0.2-percent tails assay throughout the period for the reference case.

For the United States, uranium requirements are forecast to increase from approximately 17,500 short tons during 1978 to about 40,000 short tons per year by 1995. By the year 2000, these annual requirements would rise to about 55,000 tons and, due to the rapid introduction of LWR's after the year 2000, an annual requirement of 128,000 tons would be generated for the year 2020. Prior to 1995, foreign uranium requirements would generally lag behind those calculated for the United States alone but, for the year 1995, foreign WOCA requirements of about 43,000 tons slightly exceed domestic requirements of 40,000 tons.

Uncertainties and sensitivities in various fuel cycle assumptions can obviously affect total uranium requirements for the future. Parametric analyses of fuel performance, for example, indicate that achievement of current industry design levels could decrease uranium requirements by nearly 10 percent for 1990 and that introduction of improved fuel technologies could add an additional savings of nearly 10 percent by 1995. Operation of enrichment plants at 0.25 percent tails assay, on the other hand, could increase uranium requirements by as much as 10 percent during that period. Steady-state capacity factors of 55 pecent would reduce uranium demand by over 12 percent, while operation at a 75-percent capacity factor would increase requirements by nearly the same amount. The reference case assumes a steady-state capacity factor of 65 percent.

The EIA price forecasts indicate that, in constant 1978 dollars, new-contract base prices for uranium may rise from current levels of approximately 43 dollars per pound to between 60 and 85 dollars per pound by 1995. Average delivered prices are forecast to rise from about 20 dollars per pound today to between 58 and 70 dollars per pound by the end of the midterm time frame.

Parametric analyses indicate that, in the early forecast years, market psychology and installed nuclear power capacity uncertainties generate the largest variance in the predicted path of uranium market prices. By 1995, however, mine and mill construction costs and drilling discovery rates become as important as these other two factors. Without question, however, the greatest price sensitivity in 1995 is to the uncertainty about the size of the domestic uranium resource base.

The assumptions for the most recent EIA Annual Report were finalized in December 1978. Since that date, recent events have not been particularly supportive of the Nation's nuclear power program. Demand forecasts have continued to decline, construction and financial constraints have worsened for many utilities, and, without a doubt, the accident at the Three Mile Island station on March 28, 1979, has eroded the general confidence of the utility industry, the investment community, and the public. These and other trends have prompted EIA to make a major reevaluation of the nuclear forecasts published in its Annual Report.

Overall, the EIA reevaluation indicates that a more likely forecast range in 1985 is 95 to 113 GWe or a reduction of between 5 and 8 GWe compared to the 1978 EIA Annual Report range for the same year. Because the momentum in the existing

construction pipeline is substantial, the updated forecast for 1985 has been affected less significantly than forecasts for the ensuing milestone years. For example, the updated forcast range of 129 to 155 GWe for 1990 implies that 13 to 16 GWe of generating capacity will be delayed as a result of recent events. By 1995 the impacts become even more significant, as the updated forecast range of 156 to 196 GWe for that year represents a full 30-GWe reduction from the range published in the 1978 EIA Annual Report.

1. INTRODUCTION

A proper admonition about any forecasting effort might well be that "there are no facts about the future." While this statement is certainly true, it might be worthwhile to elaborate on its scope. For example, the evolution of nuclear power starkly illustrates not only that we are uncertain about the course of future events, but that we are not even able to grasp the array of possible paths for these future events. The acccident sequence at Three Mile Island (TMI) developed in a manner not unforeseen by nuclear safety experts, but it is doubtful that these experts had sufficient appreciation of the tendency for errors to compound throughout the events of March 28, 1979.

Furthermore, the technical consequences of the accident at TMI are dwarfed by the social and institutional impacts. The accident has brought to the forefront such issues as the proper roles of equity holders versus ratepayers in assuming the cost of replacement power due to extended plant outages and the adequacy of private and public financial compensation. Even the Nuclear Regulatory Commission (NRC) may not survive in its present form if some of the "Kemeny Commission" recommendations are implemented. This discussion underscores what has by now become a fact of life for the nuclear industry. Uncertainty about the future has become a double-edged sword, and the industry has been feeling the blows from both edges. One edge is the continuing lack of resolution of issues at the heart of nuclear power.

issues such as the ultimate disposition of radioactive nuclear waste. The other edge is the introduction (or resurfacing) of new issues, such as those prompted by TMI and the Carter Administration's nonproliferation policies.

The objective of this report is to contribute as much as possible to an understanding of how events in the past year have affected the outlook for nuclear power growth and, by implication, the future of the uranium market. In order to lend perspective to the report, it might be useful to outline briefly the functions of the Energy Information Administration, or "EIA" as it is popularly called. EIA was explicitly established in the Department of Energy's (DOE) authorizing legislation as the branch of DOE responsible for carrying out essential energy data collection and analysis activities. Congressional intent in establishing EIA was to maintain a separation between what are considered basically data collection and analysis activities and policy formulation and advocacy activities. Furthermore, the DOE Act gives the EIA Administrator the authority to publish any statistical or analysis report without requiring prior approval from other DOE officials. There is a price for this independence, however. EIA is not allowed to engage directly in any energy policy design or advocacy activities. EIA does perform energy policy analysis, but this analysis is done at the request of other parts of DOE or the Congress, and any policies to be analyzed are specified by the requesting client.

EIA is required by its authorizing legislation to submit an annual report to the Congress--a report that documents its activities over the previous year, presents historical data series on energy market activity, and projects energy market activities into the future, "under various sets of conditions." EIA resolves the policy advocacy dilemma in its independent projections of energy markets by considering only those laws and regulations in force at the time of the analysis. However, these independent projections do consider variations in non-policy parameters, such as geologic endowment of energy resources or the level of national economic activity.

EIA's forecast report to Congress (Volume Three of its Annual Report) was released in July 1979, although most of the analysis was completed by the end of February 1979. In general, these latest forecast results update those of a year earlier, published as EIA's first report to Congress. Some important differences in their respective assumptions and results are summarized in Figure 1. Within the context of the "current law and regulation" constraint, variations were made in gross sets of input assumptions, as shown in Figure 2, in an attempt to bracket the range of most probable energy futures. The Scenarios A through E in Figure 2

Figure 1

COMPARISON OF EIA'S 1977 AND 1978 ANNUAL REPORTS TO CONGRESS (ARC)

Assumptions

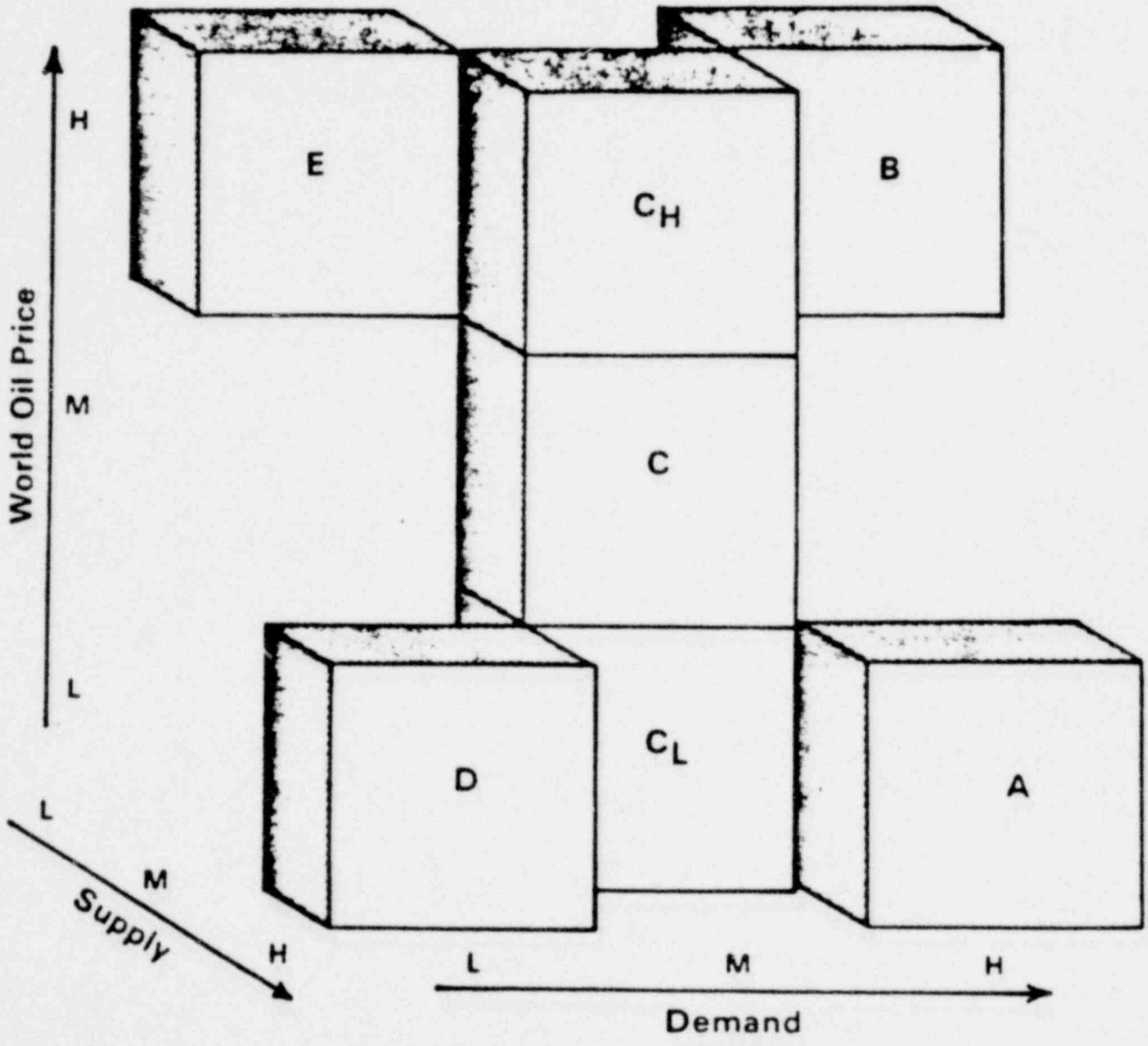
1. World Oil Price Levels are explicitly modeled in ARC 1978, rather than assumed as in ARC 1977.
2. New engineering/process demand models used for ARC 1978, rather than pure econometric demand models of ARC 1977.
3. Underlying data base updated to include such things as nuclear cancellations and the new United Mine Workers contract.
4. Policy assumptions updated to reflect the National Energy Act legislation.

Results

1. World Oil Price Levels considerably higher in ARC 1978 than ARC 1977.
2. Total demand for energy lower in ARC 1978, although electricity demand levels comparable to ARC 1977.
3. Post-1985 nuclear power projections diminished.

Figure 2

EIA PROJECTION SERIES FOR THE 1978 ANNUAL REPORT TO CONGRESS

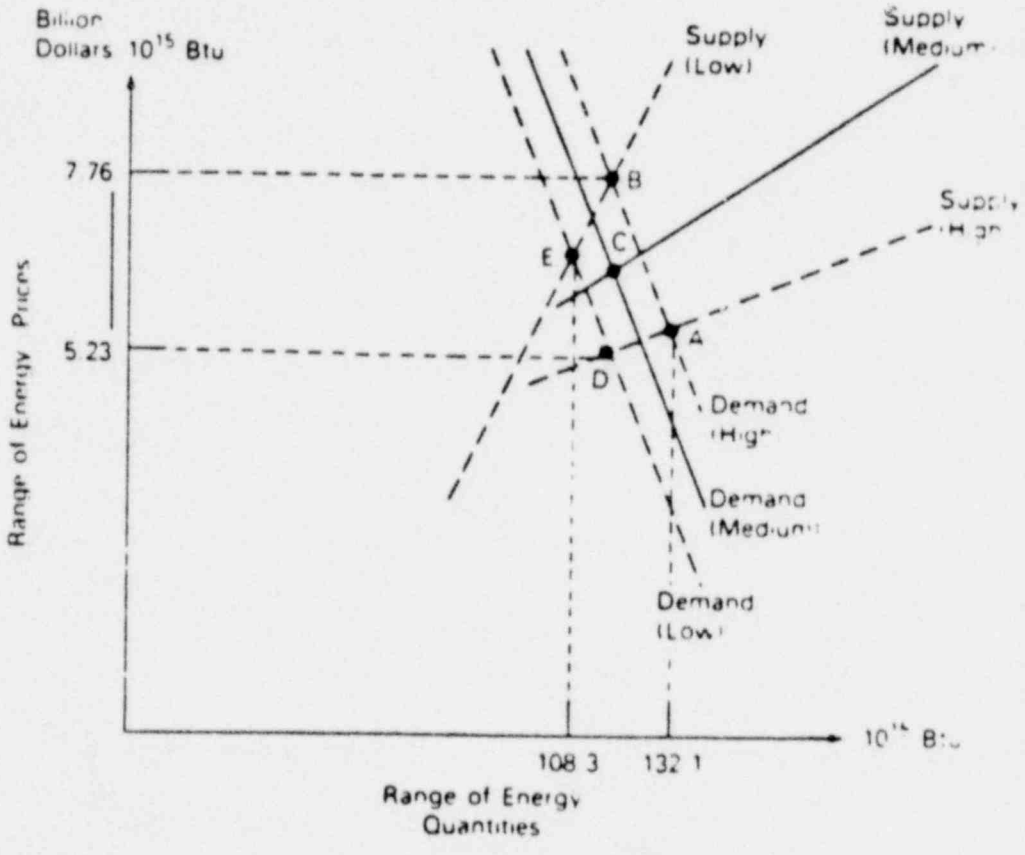


combine various permutations of three domestic "demand" curves (low, medium, and high economic activity), three domestic "supply" curves (low, medium, and high availability at a given price), and three levels of world oil prices. The Projection Series C, which incorporates the medium demand, supply, and world oil price assumptions, is usually the point of reference, although one should not associate the term "most probable" with the Series C results. The Projection Series A and E result in the extremes of energy quantities, whereas the Series B and D exhibit the widest coverage of energy prices, as illustrated in Figure 3.

In retrospect, it would appear that the Series E assumptions are most consistent with such factors as the oil supply disruption in Iran (which was not incorporated into the analysis), the present path of world economic activity, and the accident at TMI (which also was not explicitly factored into the analysis).

Figure 3

THE PROJECTION SERIES: QUANTITIES FOR 1995



2. NUCLEAR POWER GROWTH

Methodology

Although the EIA methodology for projecting nuclear power (for both the domestic and foreign regions) is presented in the EIA Annual Report for 1978, some important principles are worth restating. In summary, the analysis begins with data assembling on the current status of each known nuclear reactor project. Such data includes reported construction completion, current and projected licensing activities, and measures of the "momentum" of each project. The measure of momentum incorporates such things as recent progess, or lack thereof, in licensing or construction, as evidenced by increases in the reported percent completion of construction or by recent announcements of delays.

Once this "snapshot" of each project's current status has been made, institutional factors are then introduced, where appropriate, to determine approximate relative priorities for likely completion of these projects. For example, all projects for one utility company generally have a preferred sequence of startup, as indicated by the utility's announced plans. Also, relative priorities can be determined in geographical regions for which there is a great deal of joint ownership of the individual projects. The preference

ranking of individual projects, coupled with their most recent (or pending) activities and with empirically determined estimates of the required time durations for the licensing and construction tasks, are used to generate estimates of startup dates for each project. Thus, each startup date reflects the various technical and institutional constraints on nuclear power construction in general, especially since a great deal of effort is spent on those projects closest to completion for which particular problems or progress can be identified. If delays are indicated for these lead projects, these delays must often be propagated to the schedules for trailing projects.

Two further factors must introduced--financial constraints and the demand for new generating capacity on the national electricity grid. The former category can be handled by computing the utility's generating-unit construction expenditure stream (including of course planned fossil or hydroelectric projects) and comparing this projected expenditure stream with the utility's recent history. Where large increases in construction expenditures are indicated, and where the utility would likely have difficulty raising the scheduled capital, the construction schedule is adjusted (slipped) to ameliorate the projected financial strain.

The demand for power is introduced at the last stage of the analysis. The costs of supplying nuclear energy are estimated as a function of the quantity to be supplied. The "supply curves" so estimated, along with analogous ones for the other energy sources, are incorporated into large energy/economic models. These models equilibrate supply and demand quantities by determining the most efficient set of energy prices to clear the market.

Because of the long lead times for nuclear power planning, deployment of the current inventory of nuclear power projects sets an upper limit on the amount of nuclear power capacity available well into the future--at least through the year 1990. The nuclear supply curves described above include these restrictions. Beyond the year 1990, the possibility remains that yet unknown nuclear generating units could be ordered and brought online. (Of course, the determination of the conditions remains under which these orders would occur, as disscussed below.) For the long-term (post-1995) period, the EIA analysis assumes the removal, or at least the advent of predictability, of major institutional constraints on nuclear energy supplies, so that the growth of nuclear power is assumed to reflect only the projected demand for baseload electrical generating capacity and the projected cost of nuclear power relative to other types of energy sources.

Results for Domestic Nuclear Power

The results for the domestic "Series C" (midcase) projection, as published in the EIA Annual Report for 1978, are shown in Table 1. In general, the Series C results point to a future "electrical world." Electricity is projected to grow at about double the growth rate of total energy. Furthermore, nuclear power continues to grow at a rate that approximately doubles that of electricity, albeit from a relatively lower base. In absolute terms, about 8.5 gigawatts (GWe) of nuclear power capacity would be added in an average year between 1978 and 1990, rising to about 10 GWe per year in the following decade, and then doubling to about 20 GWe per year for the first two decades of the Twenty-First Century.

The growth of electricity and nuclear power is further illustrated in Figure 4. Nuclear and coal contribute about equal shares to electricity growth through the end of the Twentieth Century, but in the Twenty-First Century, nuclear carries the whole burden of electricity growth because of the increasing demand for coal, both in the industrial sector and in synthetic fuel production, and because of the projected cost advantage of nuclear power for electricity production. If relatively low-cost uranium supplies are not forthcoming or if nuclear power construction costs increase faster than coal-fired construction costs (in contrast to the assumptions of Series C), part

Table 1

EIA DOMESTIC PROJECTION SERIES C

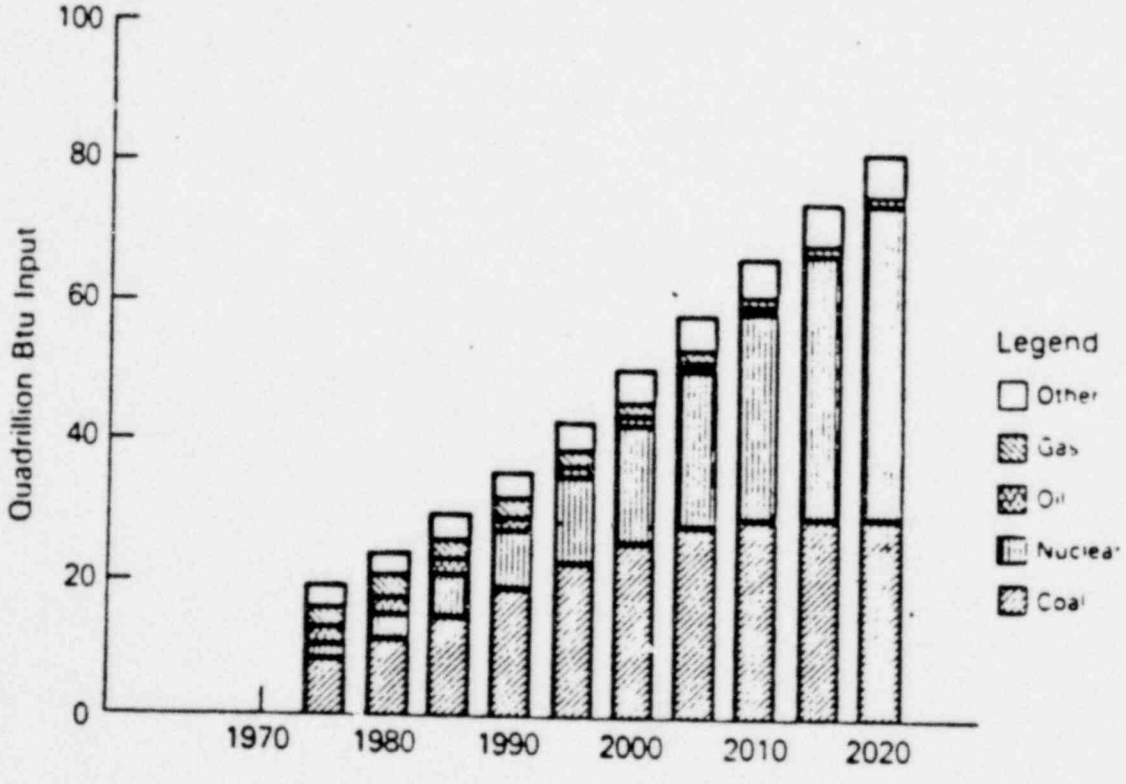
Activity*	Activity Level for Year					Average Annual Growth Rate (%)			
	1977	1985	1990	1995	2020	1977-1985	1985-1990	1990-1995	1995-2020
Real GNP (trillion dollars)	2.02	2.70	3.15	3.64	6.60	3.7	3.0	2.9	2.4
World crude oil price (dollars per barrel)	15.00	15.00	18.50	23.50	30.00	0	4.3	5.0	.**
End Use Energy Consumption (Quads)	60.5	68	74	83	104	1.3	2.0	2.2	0.9
Primary Energy Supply (Quads)	79.8	92	104	117	169	1.8	2.5	2.5	1.5
Total Electricity Production (Billion kwh)	2,125	3,050	3,710	4,460	8,120	4.6	4.0	3.7	2.4
Percent of Electricity from Nuclear	11.8	19	22	25	49	-	-	-	-
Installed Nuclear Power Capacity (GWe)	47	114	152	208	670	11.7	5.9	6.5	4.8

* All monetary figures are in constant (1978) dollars

** Rises to 30 dollars per barrel in the year 2000 and remains constant thereafter in constant (1978) dollars

Figure 4

COAL AND NUCLEAR DOMINATE ELECTRICITY GENERATION



of the nuclear growth after the year 2000 could be displaced by coal-fired generation. Thus, a great deal of caution is advised when considering the nuclear aspects of this long-term projection. Nuclear power growth is spurred by a combination of the indicated high degree of electrification and the cost advantage projected for nuclear power, primarily due to the assumed abundance of low-cost uranium resources. Thus, it is unlikely that higher levels of nuclear power could be realized for this set of energy and economic assumptions, although one could easily postulate conditions leading to lower levels of nuclear power use in the long term.

Unfortunately, time constraints and the relative infancy of EIA's long-term analysis program did not allow the development of a full array of projection series, as was done for the midterm. Thus, the consequences of various assumptions about such factors as the cost and size of the domestic uranium resource base and regional siting constraints were not investigated. Alternative scenarios were developed for the midterm period--scenarios designed to test the sensitivity of the energy price/quantity results to various supply and demand assumptions. These were addressed in the previous section and the Projection Series A through E in Figure 2.

The assumptions on low nuclear energy supply (used for the Series B and E) reflect more pessimistic construction and licensing schedules and continuing cancellations and deferrals

of nuclear power projects. The high nuclear supply assumptions (Series A and D) reflect more optimistic considerations for nuclear power, including a resumption of nuclear plant ordering. Very little further adjustment was required to accommodate variations in the demand assumptions of Figure 2. There is projected to be ample demand for nuclear generating capacity, at least in the "demand for power" sense.

The resulting range of domestic nuclear power forecasted for the midterm is shown in Table 2. Also shown are the results of various other studies, including EIA's previous report to Congress for 1977. The EIA results for nuclear power capacity in 1985 are essentially the same for both Annual Reports. For the year 1990, the range has slipped downward in the past year. There are various reasons for this slippage. The estimates for the technical limits of construction and licensing time did not change appreciably, even though the supporting data for making the estimates were updated by a year. Two other factors are important, however. The first is that many projects that appeared to have institutional momentum in 1977 did not maintain momentum during 1978. Examples are the projects in the State of New York and several others for which the NRC reported anticipating license applications. The second factor is the evaporation of construction momentum for numerous projects, especially the second or successive units at some sites for which contruction activity was reported during 1977, but not maintained during 1978.

Table 2

MIDTERM NUCLEAR POWER CAPACITY IN COMMERCIAL OPERATION COMPARISON OF FORECASTS, 1985-1995 (GWe)

Source	1985	1990	1995
1978 Annual Report	102-118	142-171	186-225
1977 Annual Report	100-122	157-192	—
DOE Utility Survey (January 1979)	139	181	—
U.S NRC (September 1978)[a]	113	—	—
U.S Department of Commerce (November 1978)	141	—	—
Data Resources, Inc. (April 1979)	116	147	205
National Electric Reliability Council (August 1978)	138	—	—
Electrical World Magazine Survey (January 1979)	137	170	—
Westinghouse Corporation (December 1978)	111	173	246
Babcock and Wilcox Co (March 1979)	123	165	200

Comparison of the EIA projections with other sources, especially for the year 1985, indicates that studies based primarily on surveys of the electric utility industry yield much higher nuclear growth estimates than those obtained by other sources. The difference between utility announcements and independent projections is probably that the independent projections reflect average experienced lead times, whereas the utility estimates are really planning targets, in most cases.

Results For Foreign Nuclear Power

Foreign nuclear power forecasts through 1995 are also prepared as part of EIA's normal analysis activities. The techniques used are analogous to those used for domestic nuclear projections, although the supporting data base on foreign nuclear power programs is not a extensive as that for the domestic programs.

The latest EIA estimates of foreign nuclear power capacities are shown in Table 3. In many instances, broad numerical ranges are given that reflect the large uncertainties associated with many national programs and particularly the issues of rising construction costs, reactor safety, and radioactive waste management that are no longer exclusive to the domestic program and public debate. In the nations of the Organization for Economic Cooperation and Development

Table 3

FOREIGN NUCLEAR GENERATING CAPACITY: ACTUAL AND POTENTIAL, 1978-1995[a]

	1978	1985	1990	1995
OECD[b]				
Australia/N.Z.	—	—	—	0–1.0
Austria/Switz	1.0	1.9–2.6	2.9–3.8	3.8–4.9
Benelux/Denmark	2.3	5.0–6.0	6.0–6.9	8.2–9.6
Canada	4.8	9.8–10.3	14.2–16.2	17.2–22.1
France	6.5	24.4–28.2	35.8–41.8	48.3–54.5
Germany	9.1	15.9–18.4	20.1–28.1	28.1–36.7
Greece/Turkey	—	—	—	0.6–1.8
Italy	0.6	1.4	3.4–6.4	6.4–10.4
Japan	10.9	16.9–19.7	26.8–32.7	41.4–50.0
Scandinavia	5.9	9.5	9.5–12.7	12.7–15.8
Spain/Portugal	1.1	5.8–7.4	8.3–11.2	10.8–15.2
U.K./Ireland	5.9	9.3	12.4	18.3–20.7
Subtotal	48.1	100–113	139–172	196–243
Non-OECD				
Argentina	0.3	0.9	2.1–2.7	3.3–4.5
Brazil	—	1.8	1.8–3.1	3.1–5.7
India	1.0	1.2–1.5	1.9–2.2	2.9–3.3
South Korea	0.6	1.8–2.7	5.5–7.4	9.3–13.5
Iran	—	1.2–2.4	2.4	2.4–3.6
Mexico	—	1.3	1.9–2.6	2.6–4.1
Pakistan	0.1	0.1	0.1–0.7	0.7–1.9
Phillipines	—	0.6	0.6	0.6–1.8
South Africa	—	0.9	1.8–3.6	3.6–5.4
Taiwan	0.6	3.1–4.0	4.9–6.7	6.7–8.7
Yugoslavia	—	0.6	0.6–1.2	1.2–1.8
Subtotal	2.6	14–16	24–33	36–54
Total OECD and Non-OECD	50.7	114–129	163–205	232–297

[a]Gigawatts of capacity in commercial operation at the end of each forecast year

[b]National and regional groupings as modeled in the EIA International Energy Evaluation System (IEES)

(OECD), growth in electricity demand has generally declined in recent years and, as a result, official program delays have been frequent. In unusual cases, public referenda have been exercised to determine nuclear policy. Although most Asian and European nuclear programs are affected by these political, economic, and environmental uncertainties, nuclear power is still projected to increase significantly its contribution to energy supplies during the midterm.

Because of reduced growth rates in projected electricity demand, the nuclear capacities forecasted for most countries in Projection Series A through E are toward the lower end of the ranges of potential capacity, given in Table 3. However, the EIA forecasts indicate that nuclear power will provide between 26 and 30 percent of the foreign OECD's electricity in 1995, compared to 8 percent in 1976. Led by an ambitious French light water reactor (LWR) program, European utilization of nuclear energy is forecasted to be even greater, rising to between 34 and 40 percent of total European electricity production by 1995.

More modest nuclear programs are anticipated for most non-OCED developing nations. Several ambitious nuclear power program targets have been reduced during the last year. The defacto demise and decline of the Iranian and Brazilian programs, for example, are now well-publicized. Currently, a limited number of non-OECD nuclear plants are

under construction, and poorer nations are particularly hard-pressed to finance nuclear projects in the face of rising oil prices and social and agricultural programs with higher priorities. While programs evolving in South Korea and Taiwan could be quite significant in the future, EIA forecasts that nuclear power will more generally contribute only on the order of 10-15 percent of total electricity generated in the non-OECD countries by 1995.

Comparison of Forecasts for WOCA

Aggregate forecasts for the World Outside Communist Areas (WOCA) are illustrated in Table 4. Compared to EIA forecasts presented in the 1977 Annual Report, the current forecasts through the year 2000 represent about a 20-percent reduction in nuclear capacity in 1995 and nearly a 30-percent reduction for the year 2000. Compared to the final forecasts ranges provided by the International Nuclear Fuel Cycle Evaluation (INFCE), the current EIA forecasts imply an even greater reduction, between 24 and 32 percent by 1995 and 35 to 38 percent by the year 2000. Because they are highly motivated by political goals, the INFCE forecasts for the post-1990 period are recognized as very optimistic; they portend a near trebling of capacity in only 10 years. The current EIA forecasts, in and of themselves, imply a doubling of capacity during the same period but, as previously described, are evaluated in a much more rigorous analytical framework than was possible during the INFCE exercise.

Table 4

NUCLEAR POWER FORECASTS FOR WORLD OUTSIDE COMMUNIST AREAS (WOCA)

SOURCE	1985	1990	1995	2000
INFCE	245-274	373-462	550-770	850-1200
EIA 1977 Annual Report				
U.S.	100-122	157-192	200-275	255-395
Other WOCA	123-140	193-238	315-375	515-655
Total WOCA	223-262	350-430	515-650	770-1050
EIA 1978 Annual Report				
U.S.	102-118	142-171	186-225	235-300
Other WOCA	114-129	163-205	232-297	315-450
Total WOCA	216-247	305-376	418-522	550-750

3. URANIUM REQUIREMENTS

From nuclear power forecasts, it is possible to derive the associated natural uranium requirements. Since a variation in installed nuclear capacity is only one of several possible sources of variation in fuel requirements, the initial focus will be on a "reference case" for fuel requirements--a case not necessarily considered the most probable but one that does provide a convenient point of reference for later discussion. Following discussion of the reference case, uncertainties in the input parameters and the corresponding sensitivity of the fuel requirements to these uncertainties will be addressed.

A point of caution is imperative at this point. The nuclear fuel requirements presented here have precise meaning--they are the physical quantities minimally required to maintain the assumed nuclear power programs. These requirements are not meant to be synonymous with "market demand" for fuel--a demand that would additionally reflect procurement and inventory practices of buyers and sellers and the degree of buyer foresight.

Reference Uranium Requirements

The basic assumptions for the "reference" case are shown in Table 5. These assumptions are addressed elsewhere but are summarized here:

Table 5

URANIUM REQUIREMENTS "REFERENCE" CASE PARAMETERS

Parameter Description	Parameter Value	
	Domestic	Foreign
Nuclear Power Growth	EIA Mid Case	EIA Mid Case
Reactor Mix	LWR	INFCE Weightings
Power Plant Capacity Factor	65% Plateau (57% lifetime average)	
Fuel Utilization Efficiency	Past Industry Experience	
Recycle Option	No Reprocessing	Planned Reprocessing
Enrichment Plant Tails Assay	0.20%	0.20%

1. The EIA, midcase, nuclear growth forecast is discussed earlier as the "Series C" estimate from the EIA's 1978 Annual Report. Only light water reactors are considered for the United States, whereas the assumed foreign reactor mix reflects the same weights as the INFCE nuclear power forecasts.

2. The powerplant capacity factor (ratio of actual electrical output to maximum design capability) is represented by a profile which begins at 40 percent during six months of initial operation and is followed by a plateau at 65 percent until the 15th year of operation. Between the 15th and 30th (last) year of operation, the capacity factor declines by two percentage points per year, but it never falls below 40 percent. This startup and 65-percent plateau roughly approximate the historical pattern of performance for light water reactors.

3. The fuel utilization efficiency, obtained from historical LWR performance, is a combination of expected heat production in the fuel elements and the nuclear plant thermal efficiency. These efficiency parameters are discussed in more detail in a previous presentation, where they are described as the "empirical" fuel cycle plans.

4. Reprocessing and recycling of uranium and plutonium in LWR's is assumed to be deferred beyond the year 2020 for domestic nuclear power plants. Outside the United States,

the schedule of available reprocessing capacity reflects currently known plans.

5. All enrichment contracts are assumed to be serviced at 0.20-percent U-235 tails assay.

The resulting reference uranium requirements are shown in Figure 5 for both foreign and domestic cases through 1995. In addition, the long-term domestic outlook is addressed in Figure 6. In the midterm reference case (Figure 5), domestic uranium requirements generally match or slightly exceed the foreign requirements until the end of the period. The assumed use of plutonium and uranium recycle just offsets the greater foreign nuclear power capacity in producing this balance of foreign and domestic requirements for uranium.

The domestic long-term reference case, labeled EIA "Series C Current Once-thru Cycle" in Figure 6, exhibits a sharply increasing trend after the year 2000--a reflection of the Series C long-term growth of nuclear power. The reference case requirements increase from about 55 thousand short tons in the year 2000 to about 128 thousand short tons in the year 2020. The curve in Figure 6 labeled "Firm" Nuclear Power Capacity shows the requirements for the 118 GWe of "firm" domestic nuclear power capacity that is currently either in operation or well into construction. By inference, the uranium requirements above this line are contingent on favorable decisions for installing additional nuclear power capacity beyond the relatively assured 118 GWe. The third line of Figure 6 will be discussed in the next section.

Figure 5

DOMESTIC AND FOREIGN URANIUM CONSUMPTION HISTORY AND EIA SERIES C, 1965-1995

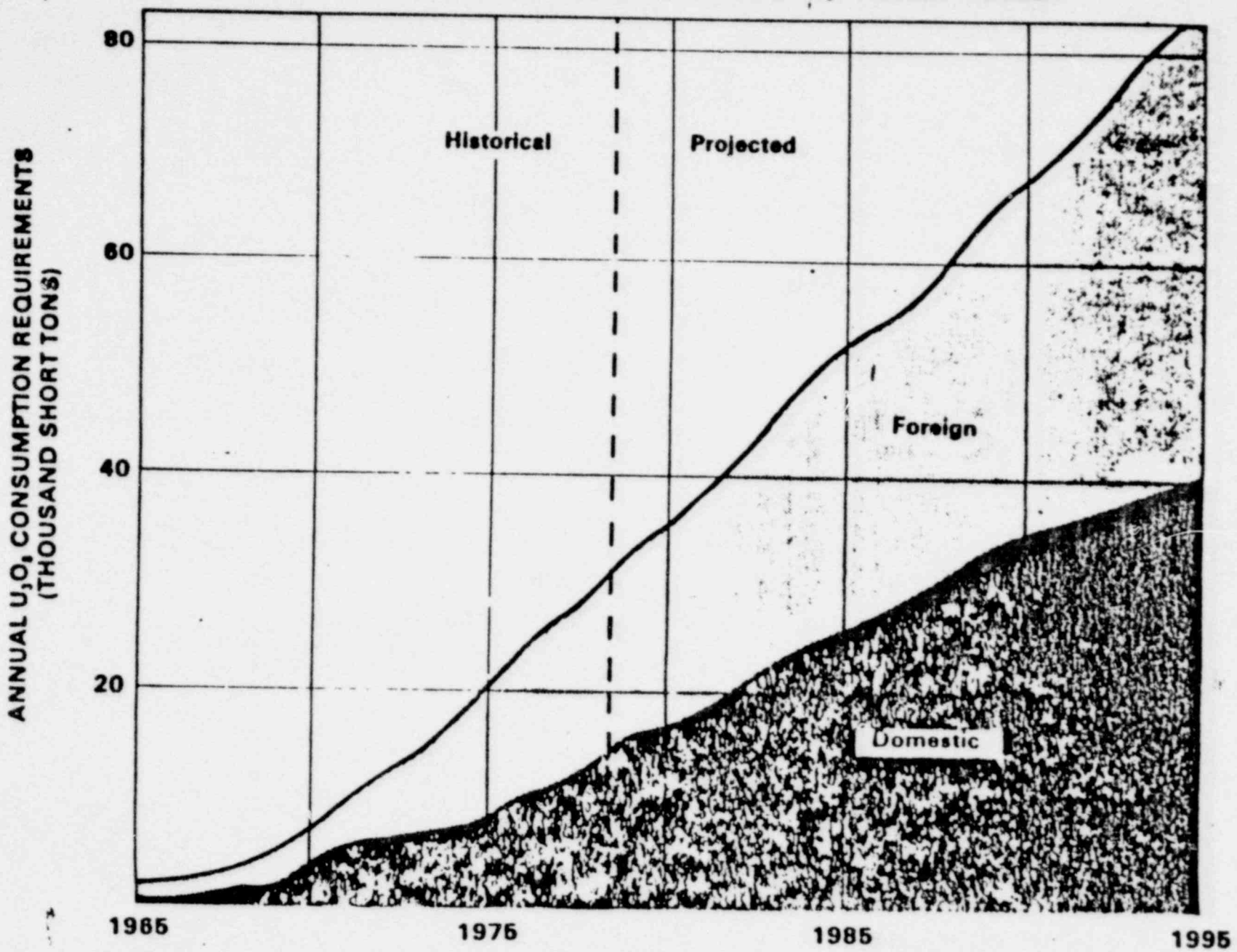
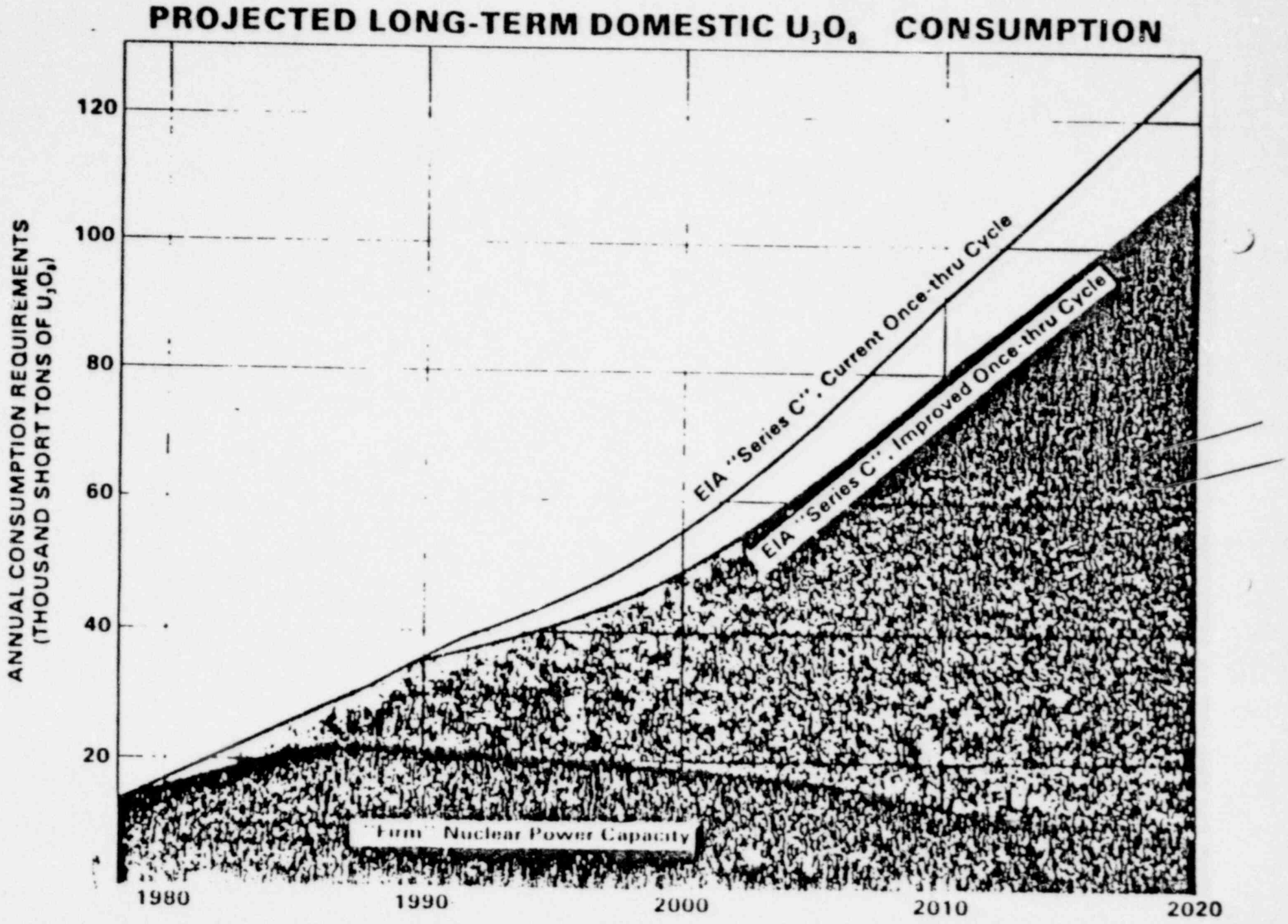


Figure 6


PROJECTED LONG-TERM DOMESTIC U_3O_8 CONSUMPTION
ANNUAL CONSUMPTION REQUIREMENTS
(THOUSAND SHORT TONS OF U_3O_8)
120
100
80
60
40
20
1980
1990
2000
2010
2020
EIA "Series C", Current Once-thru Cycle
EIA "Series C", Improved Once-thru Cycle
Firm Nuclear Power Capacity

Uncertainties and Sensitivities

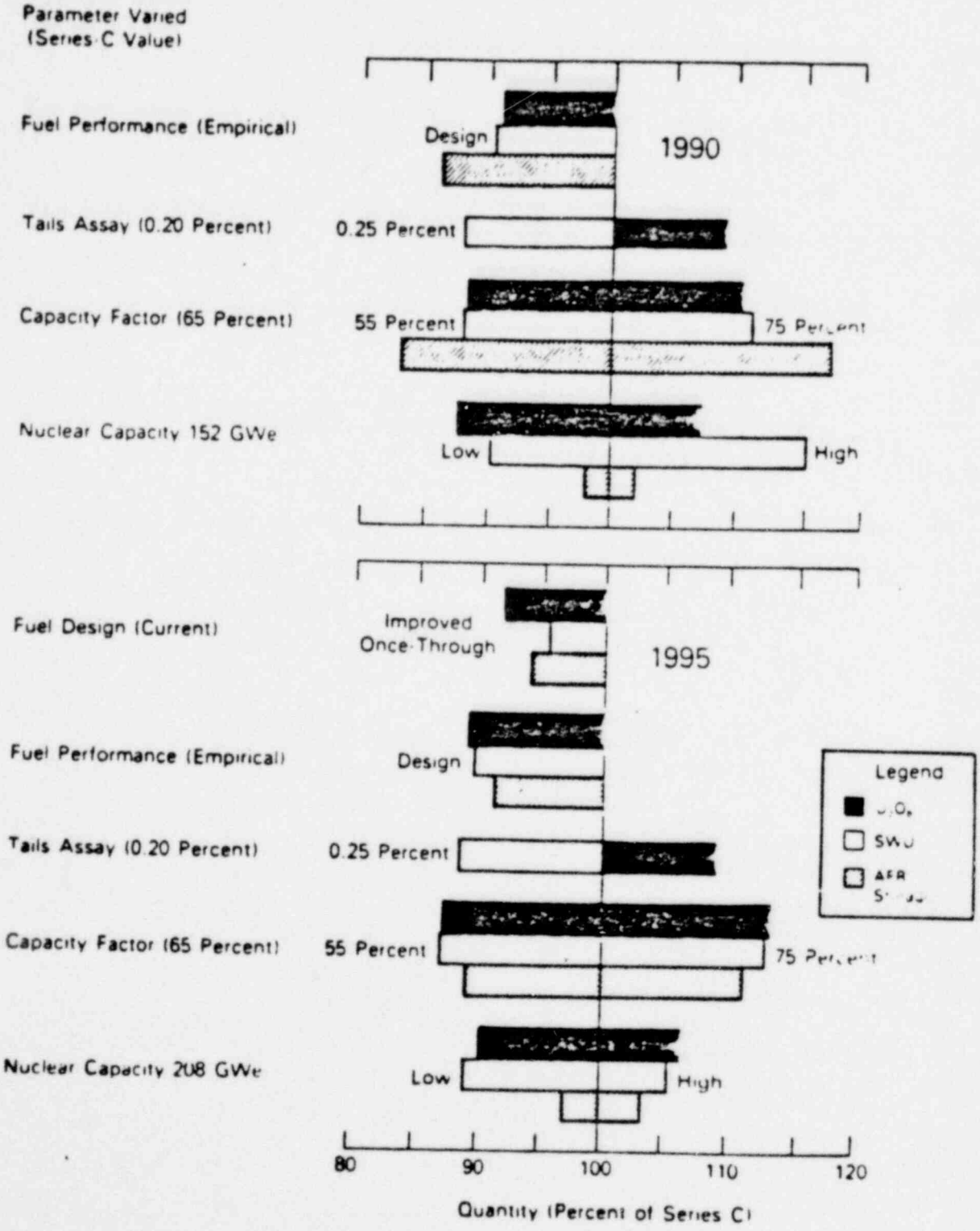
As mentioned earlier, there are several sources of uncertainty in deriving uranium requirements. Figure 7 addresses these uncertain factors and the sensitivities of the uranium requirements to individual variations in these factors for the 1990 and 1995 domestic reference case. (Also shown are the sensitivities of the corresponding enrichment and spent-fuel storage requirements.) The fuel requirements sensitivities in Figure 7 are shown as percentages of the reference case. This presentation mode enables the simple estimation of the impact of combined uncertainties through multiplication of the individual impacts.

Both domestic and foreign fuel utilization efficiencies have two uncertainty factors that would tend to decrease the fuel requirements. The first improvement factor would result if the industry were to achieve its current design parameter values for fuel burnup and plant thermal efficiencies on an industry-average basis. Another (independent) improvement factor reflects the introduction of a hypothetical improved once-through LWR fuel cycle "design" beginning around 1990 and fully implemented by, perhaps, the year 2000.

The enrichment plant tails assay uncertainty reflects the following considerations. The value of 0.20 percent is probably a reasonable lower bound, especially since the bulk of DOE's enrichment capacity will still be gaseous diffusion technology well beyond 1990. For an upper bound, the value of 0.25 percent is consistent with DOE's announced intentions.

Figure 7

SENSITIVITIES OF ENRICHMENT (SWU), URANIUM (U_3O_8), AND AWAY-FROM-REACTOR (AFR) SPENT FUEL STORAGE REQUIREMENTS: SERIES C, 1990-1995



Possibly the most difficult uncertainty area is that of uranium and plutonium recycle. Domestically, reprocessing and recycling are an area of policy consideration. Obviously current domestic policy precludes reprocessing for an indefinite period. Foreign LWR reprocessing is more open to consideration since there are operating and planned facilities. The present analysis considers no ranging for domestic reprocessing and recycle, but it does consider a lower bound reflecting no reprocessing and a higher bound reflecting planned foreign reprocessing capability by the year 2000. The absence of recycle in the foreign case increases uranium requirements by about 25 percent for both 1990 and 1995.

The variation range for the average nuclear plant capacity factor reflects a 10-percentage point swing of the "plateau" about the reference value of 65 percent.

Finally, the nuclear capacity growth sensitivities reflect a displacement to the low and high nuclear capacities of the EIA 1978 Annual Report.

3. URANIUM MARKET STUDIES

Part of the mandated activities at EIA involve study of the markets for fuels under various conditions. For uranium, the major analysis tool for such study (including that reported in the EIA Annual Report for 1978) utilizes the methodology developed by Dr. Don R. deHalas and embodied in his "EUREKA" uranium market model.

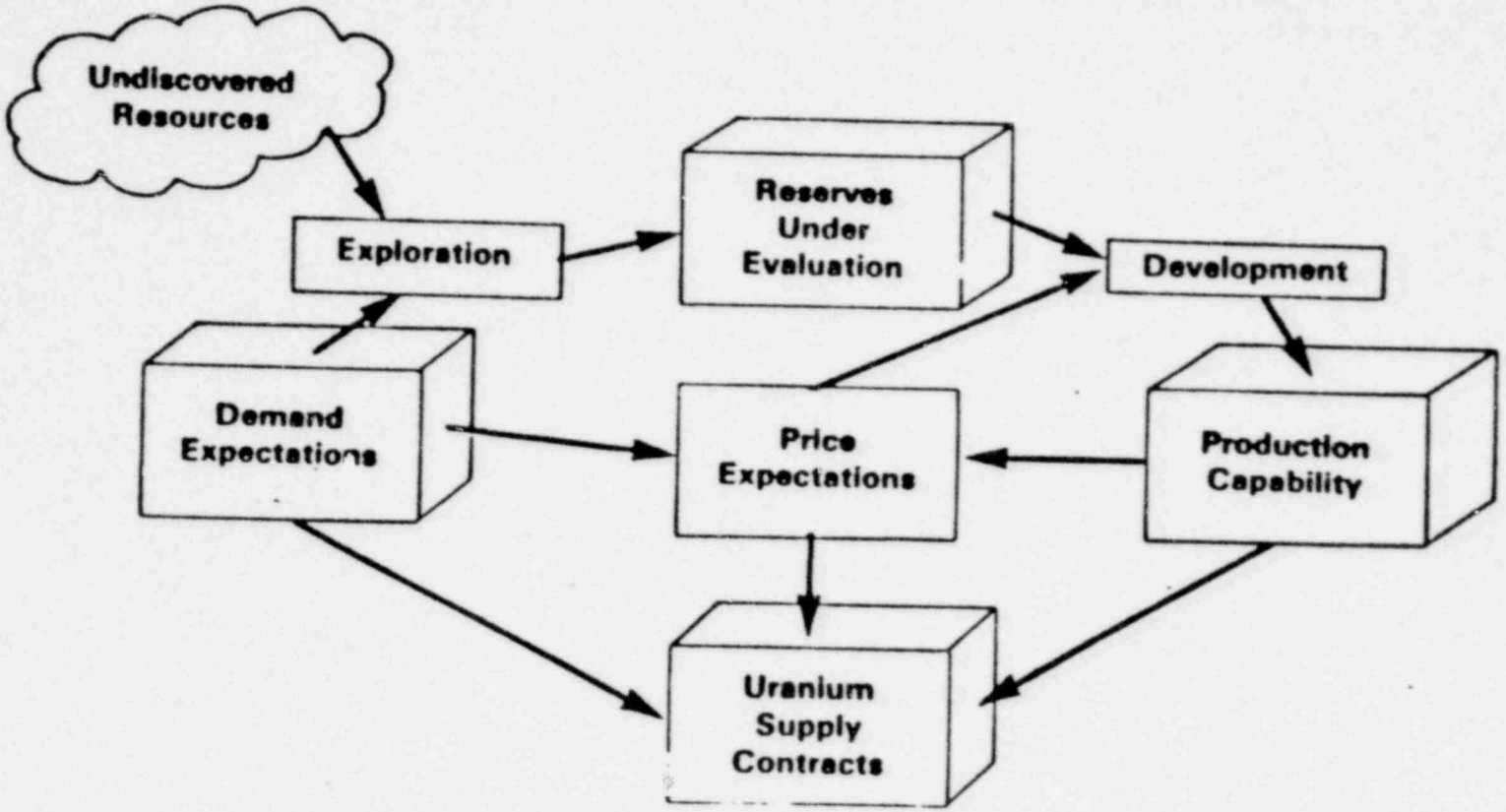
Methodology

The methodology is basically a simulation of uranium producer investment decision behavior, coupled with purchasing decisions on the part of uranium consumers. This methodology, in its present state, is confined to the domestic market (with allowances for imports and exports), although a major development effort is underway to produce a world-market level capability. As Figure 8 indicates, the methodology encompasses market activities (in the consummation of uranium supply contracts) and investment activities in both exploration and production capacity, with special emphasis on the decisi processes involved in successive years.

In the methodology's present application, the future demand for uranium is an exogenous input not related to price. Supply contracts made for uranium in a given year are based on the buyers' forward-looking expectations for uranium requirements. These expectations can be dynamic in that they can evolve in a predetermined manner with the simulation of time. A record is maintained of supply arrangements as

Figure 8

Uranium Market Analysis Methodology



they are forecasted, beginning with contracts in place at the start of the analysis period. Of course, commitments can be made only to the extent that sufficient production capacity can be brought on stream, although allowances are made for drawing down consumer inventories or importing to specified levels, if domestic production capacity is not adequate to meet demand in a given year.

The base price for new contracts signed in a year of the simulation, or for the settlement of previously-signed "market price" contracts, is initialized at a given level and then adjusted each year to reflect the ratio of uncommitted production capacity to demand without supply contracts, over a specified forward time span.

Concurrently with the market transactions in a given year, uranium producers are making investment decisions that respond to their expectations of future price and demand and to their current revenues. For example, exploration activities are carried out in a given year at a level determined by the expected demand in a future time window, and the amount of exploration expenditures is somewhat constrained by the availability of profits from industry revenues. In a shorter time frame, reserves that have been identified by exploration activities are evaluated on the basis of expected production costs and profit requirements against the then-current trend of market price.

Those properties favorably evaluated are partially developed during the year being currently simulated. Furthermore, properties requiring development are re-evaluated each year on the basis of any new trends in the market price and on the basis of current forward costs. Development activities may be halted during periods in which the market price trend is not favorable.

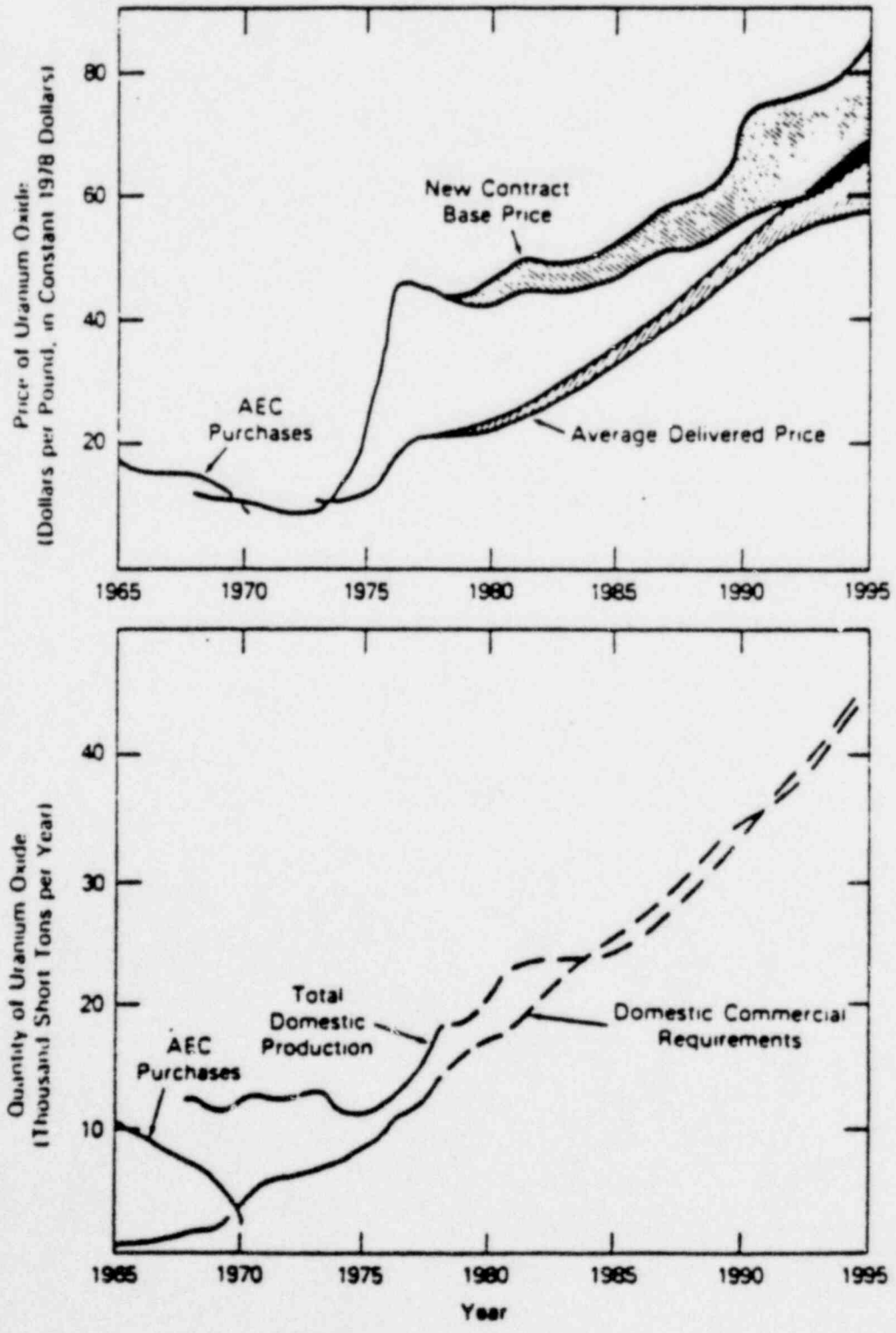
As developed properties come into production, this additional supply contributes to the supply/demand ratio and, thus, the pressure on the market price to respond appropriately.

Reference Case and Sensitivities

The domestic requirements discussed above as the EIA "reference case" were specified as the uranium demand, after adjustment for the constraining effects of feed delivery schedules, as specified in enrichment contracts. (Such modifications were made by assuming that current enrichment contracts would be adjusted gradually to cumulatively match forecasted requirements by the year 1990.) This adjusted quantity schedule and the price trajectories, resulting from the market analysis, are shown in Figure 9. The band of prices shown in the figure reflect the sensitivity to a wide range of variation in the assumptions for behavioral parameters in the analysis framework. Such behavioral parameters include such factors as the producers' required rate of return on equity, the risk premium for uranium investment, the degree of buyer inventory mobility, and the relative market shares for fixed-price/market-price contracts and captive production.

Figure 9

DOMESTIC NATURAL URANIUM MARKET SUPPLY, DEMAND, AND PRICE: ACTUAL AND SERIES C, 1965-1995

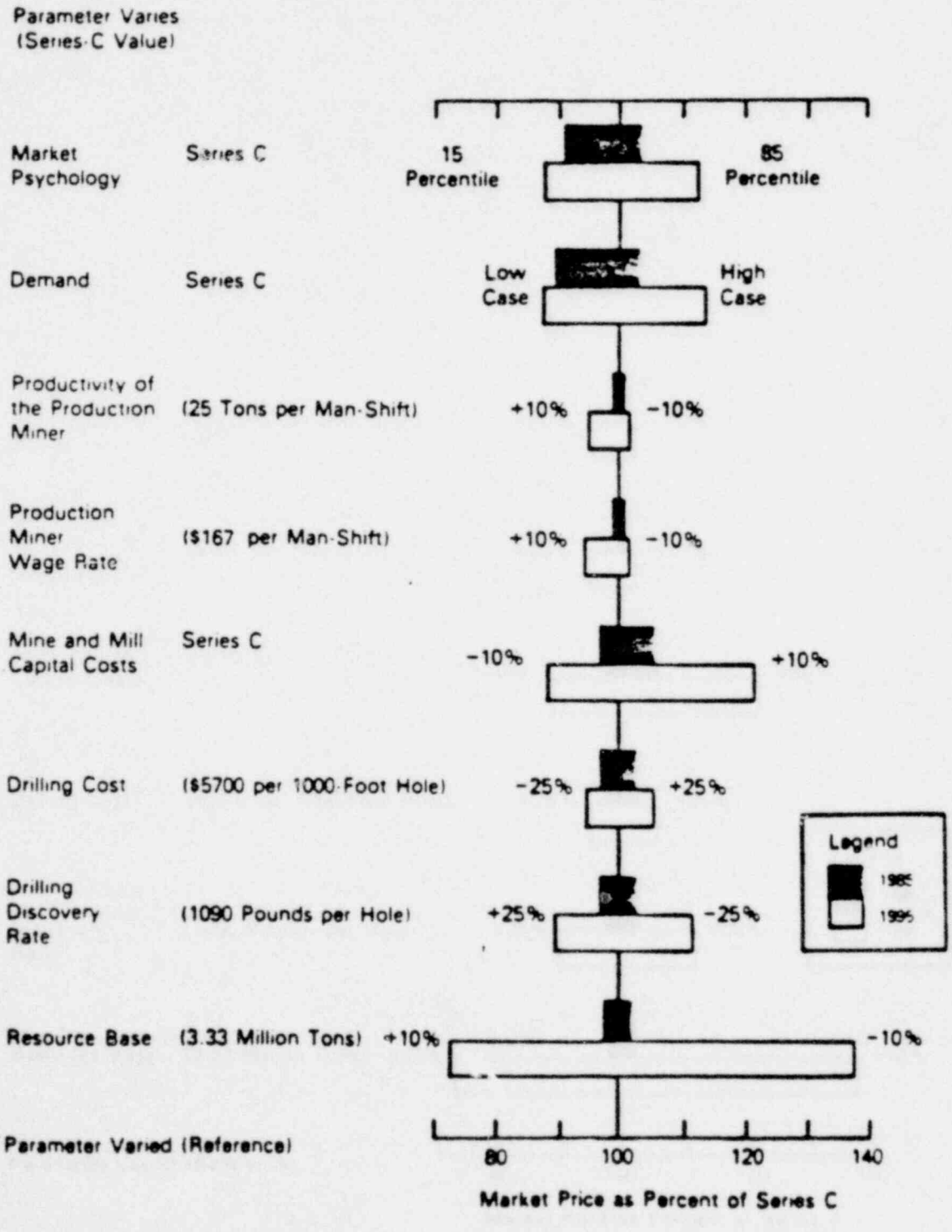


As shown in the top half of Figure 9, both the base price for new contracts and the average for deliveries increase substantially in real terms over the midterm period for the reference assumptions.

The reference values of some key parameters and the sensitivity of the new-contract (i.e., "market") price for 1985 and 1995 are shown in Figure 10. The 1985 market price is depicted to be most sensitive to the "market psychology" (behavioral) parameters and to the demand level, whereas for the year 1995 the mine and mill construction cost and the drilling discovery rate become as important as the first two parameters. More importantly, by 1995 the market price is projected to be extremely sensitive to the assumed size of the domestic resource base, as the price begins to respond to resource depletion effects.

Figure 10

URANIUM MARKET PRICE SENSITIVITIES: SERIES C REFERENCE 1985-1995



5. THE CURRENT DOMESTIC OUTLOOK

The events of 1979, to date, have not been particularly supportive of the Nation's nuclear power program. Certainly the accident at TMI will probably have repercussions for quite some time, for example. In the short term, TMI has apparently brought about a differential consideration (i.e., risk premium) for nuclear versus non-nuclear electric utilities in the eyes of the Nation's financial markets, although it is too early to determine if this is a long-term effect.

While the TMI accident was the most publicized nuclear event of the year, there are also other events, outside the context of TMI, that mark the year 1979 as a significant one for nuclear power. As one example, the decision in New York, in which the State government refused to grant permission to construct the Jamesport plant, is conclusive evidence that that State's anti-nuclear position has crystalized. In addition, such industry stalwarts as TVA, Duke Power Company, and Commonwealth Edison Company have announced major delays in their nuclear construction programs.

These and other events of 1979 have prompted EIA to make a major reevaluation of the nuclear forecasts published in its latest Annual Report and on which the foregoing analysis is based. Consideration has been limited to new data introduced in 1979, using essentially the same analytical techniques as before. The effect of new information has been the creation of a "bow wave" of delayed or deferred projects--a

bow wave that has pushed many trailing projects beyond the midterm period. In addition, the old "Series C" midcase assumes six, net, new orders over the next four years; these orders do not now appear likely.

These results of the reevaluation are shown in Table 6 and Figure 11. An accurate general conclusion is that the 1995 milestone has been most drastically affected, with its range being displaced downward by about 30 GWe. The range for 1990 is lower by about 15 GWe, while even the 1985 range slipped by 5 GWe.

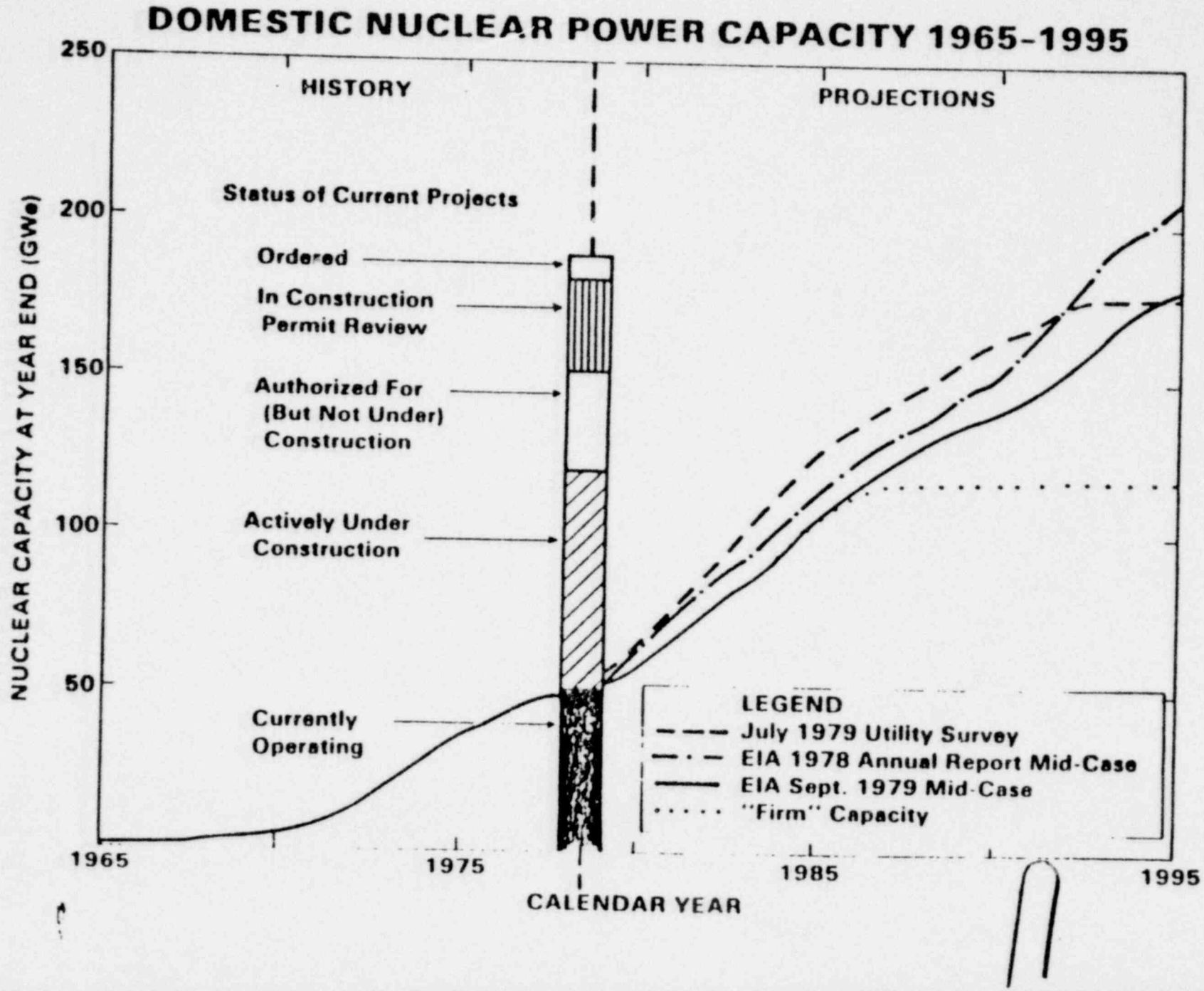
These most recent levels of projected nuclear power are subject to even further erosion, as they depend in many cases on the favorable outcome of decisions yet to be made by regulatory agencies and utility management. What portion of these projections can really be considered firm? We have analyzed all domestic nuclear projects in order to assess which are safely beyond the "point of no return" and what, in fact, the "point of no return" really means. At this time last year, a general assumption was that once work had begun on the reactor building foundation, the subject utility company was then too deeply committed to turn back, especially since some major components are often being delivered to the site at this stage. It now appears that numerous projects, especially successive units at a given site, have had construction activities halted after beginning work on the reactor building foundation and taking delivery of some major components.

Table 5

UPDATED DOMESTIC NUCLEAR POWER FORECASTS (GWe)

Year Milestone	Annual Report to Congress July 1979			Updated Forecast October 1979		
	Low	Mid	High	Low	Mid	High
1985	102	114	118	95	106	113
1990	142	152	171	129	140	155
1995	186	208	225	156	179	196

Figure 11


DOMESTIC NUCLEAR POWER CAPACITY 1965-1995
HISTORY
PROJECTIONS
Status of Current Projects
Ordered
In Construction
Permit Review
Authorized For
(But Not Under)
Construction
Actively Under
Construction
Currently
Operating
NUCLEAR CAPACITY AT YEAR END (GWe)
250
200
150
100
50
1965
1975
1985
1995
CALENDAR YEAR
LEGEND
July 1979 Utility Survey
EIA 1978 Annual Report Mid-Case
EIA Sept. 1979 Mid-Case
"Firm" Capacity

Under what conditions would the units authorized for construction (but currently stalled) be restarted? First consider those units definitely past the turnback point for which construction has been halted. Past examples might be Crystal River 3 (Florida Power Corporation) and Cook 2 (American Electric Power), and a more current example is the Braidwood plant (Commonwealth Edison Company). Projects in this category are (or were) stalled only temporarily. There was never any real question about their reactivation because they were halted typically past the 50-percent completion point.

On the other hand, the 19 GWe that have stalled after minor construction activity and the 14 GWe that have not yet begun major construction activity (but are authorized to do so) are in a different category. These projects should be very amenable to reactivation. They may well be generally awaiting favorable determination of the need for new electric generating capacity (as related to perceptions of future load growth) and/or adequate financial strength of the utilities involved. For these projects, the difficulties and uncertainties involved in the licensing process have been hurdled, for the most part. If financing the project were not the overriding concern, the decision to (re)activate the construction program need be made no greater than 8 years prior to the perceived need for new capacity. If the commitment is firm for the addition of new baseload capacity, then there would be no inducement, from an investment standpoint, to switch to a new, comparable-sized, coal-fired

project instead of continuing the stalled nuclear project. Both the construction costs and lead times, from that point forward, would be comparable for the two options. (This line of reasoning follows, of course, only if there will be no significant impacts on this category of nuclear projects resulting from the Kemeny Commission's deliberations.)

The financial-health aspect is related both to the structure and behavior of each utility's rate commission and to the financial management capability of the particular utility considered. At one hypothetical extreme, if the rate commission is primarily interested in supporting the addition of generating capacity, its rate decisions, coupled with sound utility financial management, could remove financial health as a constraint for the utility in question. On the other extreme, if the rate commission's only concern is to keep electricity rates from increasing in the short term, then its rate decisions, coupled with poor financial management on the part of the utility company, would not support a capacity expansion program. (In the real world, rate commissioners and utility managers wear hats that are shades of gray, rather than pure black or white.) Prior to the 1970's, these two viewpoints were not necessarily in contradiction since the addition of new generating capacity generally resulted in lower electricity rates. In today's world, the cost of producing electricity from new units generally requires higher unit rates, except possibly for the replacement of oil-fired baseload capacity with its very high fuel costs.

In summary, about 34 GWe of nuclear generating capacity is "waiting in the wings" for the proper load-growth and/or financial conditions.

What about the 29 GWe of nuclear capacity under construction permit review? These projects are susceptible to special problems of the licensing process, in addition to the load-growth and financial uncertainties of the stalled projects as described above. For example, the NRC has extended its self-imposed licensing pause from August 1979 to May 1980, while it devotes a major portion of its resources to evaluating the TMI accident. Further, with the release of the report from the President's Special Commission on TMI ("Kemeny Commission") on October 31, 1979, an additional factor entered the nuclear policy equation. Although the Kemeny Commission made no formal suggestion to impose a moratorium on reactor licensing, its conclusions and recommendations, taken together, can be interpreted to represent a de facto moratorium of undetermined duration, until perceived technical and personnel deficiencies within the nuclear industry can be effectively addressed.

Beyond those nuclear plants already into the licensing process, only a few projects can be identified at this time. The first signal of hope for nuclear power growing beyond the universe of identified projects will be the resumption of new orders for nuclear units. What are the prospects for new orders? It is clear that resolution of the items shown in Figure 12 is vital to the long-term prospect for nuclear

Figure 12

FACTORS FOR AN INCREASED NUCLEAR POWER PROGRAM

- A substantial increase in central base-load electricity demand is anticipated for post-1990 period.
- A major reassessment is made of utility financial practices and/or rate structures to help relieve debt/equity and cash flow burdens of constructing new generating capacity and, in particular, nuclear baseload capacity.
- The deployment of a nuclear reactor system becomes more predictable and less problematic, and in the minds utility planners, a superior choice over coal systems for both new and replacement base-load service.
- Fuel cycle uncertainties such as long-term uranium availability and waste disposition are effectively addressed and convincingly resolved.
- Environmental and social problems with mining, transporting, and burning of coal become compelling.
- A more diverse and more complete public acceptance of nuclear power is realized.

power. It appears at the present time that the first two items are overriding in the eyes of electric utility planners. That is, without a basic demand for additional electrical capacity and the financial means to construct that capacity, it matters little whether or not there is public acceptance of nuclear power or the uranium resource base to support a larger nuclear program.

[The uranium requirements and uranium market impacts of these updated nuclear power projections are currently being analyzed and will be released as an EIA Analysis Report in the future.]

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