Federal Trade Commission

Staff Report on

An Analysis on Competitive Structure in the Uranium Supply Industry

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Staff Report to the Federal Trade Commission

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Joseph P. Mulholland is the author of this report. It is based on an unpublished study, "Report to the Federal Trade Commission on Competition in the Nuclear Fuel Industry", co-authored by John Haring and Steven Martin (The Haring-Martin study was completed in April, 1977 and is available from the Federal Trade Commission's Public Reference Branch).

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An Analysis of
Competitive Structure
in the Uranium Supply Study

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Introduction

This report analyzes competitive conditions within the uranium production industry. This sector comprises the exploration, mining, and milling of uranium, a fissionable raw material used in the manufacture of nuclear reactor fuel.[1] Our objective is to assess the workability of competition within the uranium industry and, correspondingly, to evaluate the appropriateness of structural antitrust remedies that may be applied to it.

Primary emphasis is placed on the evaluation of uranium industry structure; i.e., economic and institutional elements that influence the distribution of productive capacity among existing sellers and potential entrants. Our study is thus a deductive exercise in which the uranium industry's potential for competitive behavior is inferred from the nature of its structural environment.

Analysis relies heavily on confidential information obtained from the Department of Energy and from the principal uranium producers. The chief data year is 1974, the latest year for which individual company figures on reserves, production, and exploratory effort were available. This information is supplemented by more aggregated company data for the years 1975 and

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1 Apart from its use as a fuel, uranium has only limited commercial applications. It is also used to manufacture weaponry. The Government acquired a uranium stockpile for weapons manufacture during the 1950's and early 1960's.

1976. Also, public information on 1977 mill capacity and planned mill additions as of January 1978 are utilized.

Plan of Research

The main text of this report is divided into four chapters:

Chapter I provides an outline of the nuclear energy sector and the uranium industry's role in it.

Chapter II analyzes the uranium industry's competitive structure. The first part details the principal technological and institutional characteristics of the market. These elements provide a framework for the subsequent analysis of seller concentration, condition of entry, and a review of actual entry into the market during the 1970's. A final section estimates the industry's potential for workable competition based on its structural characteristics.

Chapter III views the uranium industry from the perspective of a broad energy market where uranium is presumed to compete with other energy fuels. Emphasis is placed on evaluating the role of petroleum firms' entry into uranium and the consequences of such activity on competitive conditions in an expanded energy market.

Chapter IV applies the previous findings to the principal policy issues concerning the uranium industry.

The text is followed by an extensive set of appendices designed to provide supplementary information on the uranium industry and to give the reader an overview of the remaining stages of the nuclear fuel cycle.

Appendix A contains a set of statistical tables that supplement information presented in the text.

Appendix B analyzes the competitive implications of joint venture activity within the uranium industry.

Appendix C provides a summary of mergers and acquisitions in the uranium industry since 1955 and discusses integration across the various stages of the nuclear fuel industry.

Appendix D describes the data collection procedures utilized in this study.

<u>A Note on the Identity of Government Regulatory Agencies</u>

The identity of Government agencies involved in the nuclear energy sector has changed a number of times during the period this report was in preparation. In 1975 the Atomic Energy Commission (AEC) was divided into the Energy Research and Development Administration (ERDA), to develop and promote all forms of energy; and the Nuclear Regulatory Commission (NCR), to oversee aspects of nuclear power dealing with safety. In 1977, ERDA was subsumed under the newly created Department of Energy (DOE). In the interest of chronological consistency, this report will refer to each of these agencies in its relevant historical context.

Summary of Findings[1]

1. Analysis indicates that the uranium industry is currently structured in a workably competitive manner. In particular, the uranium market exhibits neither high concentration nor impeded entry, two necessary conditions for monopolistic performance. In regard to concentration, there exists a sufficiently large and diverse group of producers with supply capacity necessary to satisfy the needs of electric utilities (the chief purchasers of uranium). Investigation of the principal sources of entry barriers--economies of scale, capital requirements, and potential resource monopolization--indicates that they do not constitute significant impediments to entry into uranium supply. This latter finding is supported by the record of extensive entry that has recently taken place in response to the marked rise in uranium price over the 1973-74 period.

2. Petroleum firm entry into uranium, while high, does not, at present, represent a significant threat to competition. This conclusion follows irrespective of whether competition is viewed from the perspective of the uranium market or a wider energy market where a number of energy fuels are presumed to compete with each other. Overall energy diversification efforts by petroleum firms have been of such a relatively diverse nature that concentration in relevant energy submarkets has remained low. In the absence of identifiable anti-competitive effects

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1 More detailed summaries are presented in chapters II and III.

from energy diversification efforts, petroleum firm entry into uranium seems best viewed in a pro-competitive light since this activity has led to considerable enlargement of the industry's productive capacity.

3. The above findings suggest that the most appropriate antitrust posture at present is one of surveillance rather than attempts at modification of the industry's structure. Those competitive difficulties that do arise in the uranium sector will most likely stem from lower than expected demand levels (leading to seller exit) rather than to correctable structural defects.

Chapter I

The Nuclear Energy Sector: An Overview

Nuclear energy is utilized to generate electricity through the nuclear fission of uranium. Fission is a nuclear reaction in which the nucleus of the fuel atom is split by a neutron, thereby releasing the energy that binds the nucleus together. During fission, additional neutrons are released that continue the energy-liberating process in a "chain reaction." If nuclear fuel is concentrated in sufficient quantity, known as the "critical mass," the fission process can be sustained at controlled levels of power.

Uranium-235 is the only naturally occurring, readily fissionable material, and it is currently the primary nuclear fuel commercially utilized in the United States. This isotope is relatively rare, constituting less than 1 percent of natural uranium. Virtually all of the remainder is uranium-238. During the fuel production process, natural uranium is "enriched" to increase the concentration of uranium-235 atoms. The final fuel product still contains considerable amounts of uranium-238 and some thorium-232. These are both "fertile" materials that may be converted into fissionable isotopes (plutonium-239 and uranium-233, respectively) upon capture of an additional neutron. Each time a fuel atom is split an average of 2.43 neutrons are released. Since only one additional neutron is required to sustain a chain reaction, extra neutrons are available to convert fertile atoms present in the fuel into fissionable atoms.

In present vintage reactors, many of these extra neutrons are absorbed in other reactor materials (fission products, control rod material, and structural parts of the reactor). These reactors are known as "converters," meaning that they operate with a net loss of fissionable material. About six atoms of new fissionable material are formed for every ten atoms of original fissionable material consumed. This is referred to as a "conversion ratio" of 0.6. As the uranium-235 fuel is periodically depleted below the critical concentration in a converter reactor, the reactor plant is reloaded with new fuel. The unused portion of the old fuel may then be "recycled."

Two potential improvements in the utilization of nuclear power are the breeder reactor and fusion. In the breeder reactor, neutron losses are minimized to the extent that it becomes possible to operate with a net gain in fissionable material. The generation of energy through fusion would do away completely with the need for uranium since it entails the combination of two atoms of hydrogen, one of the earth's most abundant elements. Neither of these processes is commercially viable at present, a situation that is expected to continue throughout the remainder of this century.

A. The Nuclear Fuel Cycle

To be capable of fission, uranium must undergo a series of changes from raw ore to the finished fuel element that is loaded into the core of a nuclear reactor. Once mined, raw ore is milled to separate the uranium (in a form commonly referred to as "yellowcake") from waste material. To increase its U-235 content, the yellowcake is converted into uranium hexafluoride gas (UF_6) and shipped to an enrichment plant where the concentration of U-235 atoms is increased by a gaseous diffusion process.

The enriched gas is converted into solid pellets of uranium dioxide (UO_2) and inserted into the zirconium tubing that comprises the individual fuel elements. These tubes are then bundled and loaded into the reactor plant. After a period of reactor operation, the expended fuel elements are removed from the reactor and processed to remove both unused uranium and any plutonium that has been created from U-238 atoms during the fission process. These recycled fuels may be utilized in the manufacture of new fuel elements,[1] and the nonusable waste disposed of in underground burial sites.[2] The nuclear fuel cycle thus encompasses all of the activities related to reactor fuel manufacturing, reprocessing, transportation, and waste disposal. An estimate of the relative costs entailed in each stage of the cycle is presented in table I-1.

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[1] No recycling plants are currently in operation in the United States. Spent fuel is being stored in large cooling baths at reactor sites and other locations pending Nuclear Regulatory Commission (NRC) decisions with respect to the licensing of proposed facilities.

[2] As with recycling, radioactive waste burial awaits the licensing of appropriate sites by the NRC.

Table I-1

Estimated Cost Components of the Nuclear Fuel Cycle*

Cost component	Cost (mills per kWh in mid-1976 dollars)	Percent of total fuel cost
U_3O_8	2.5	46.3
Conversion to U_6	0.1	1.9
Enrichment	2.0	37.0
Fabrication	0.4	7.4
Spent fuel storage and disposal	0.4	7.4
Total fuel cost	5.4	100.0

* This estimate is for a nuclear power plant expected to begin operation in 1985. It is based on a price of $30/lb for U_3O_8. Other assumptions: tails assay of 0.20 percent; no reprocessing of spent fuel; cost of $3.33/kg for conversion; $80/kg/SWU for enrichment; and $90/kg for fabrication. All costs are in terms of mid-1976 dollars.

Source: Nuclear Energy Policy Study Group, Nuclear Power Issues and Choices, The Mitre Corporation for the Ford Foundation (Cambridge, Mass.: Ballinger, 1977), table 3-3, p. 126.

B. Industrial Organization

The nuclear energy sector encompasses two principal subsectors: the nuclear fuel cycle and reactor manufacture. Five distinct industries comprise the fuel cycle: uranium production, refining, enrichment, fabrication, and reprocessing of spent fuel. At present, the enrichment stage is a Government monopoly and no reprocessing activity is currently being undertaken. Table I-2 lists the principal producers in the remaining segments of the fuel cycle along with those engaged in reactor manufacture.

The chief focus of this report is the uranium production industry. It is composed of three segments, exploration, mining, and milling. The final product is a uranium concentrate (U_3O_8) which is shipped to refining plants. The industry is relatively young. Its history as a separate sector begins in 1946. As sole purchaser of mill output during the 1956-66 period, the U.S. Government played a significant role in determining the industry's structure and performance. After that time, the uranium industry gradually made the transition to a private market with relatively little Government intervention. During most of the 1966-72 period, the industry was in a dormant state as low prices and an uncertain future discouraged the expansion of productive capacity. This situation began to change in 1972 when rising oil prices significantly increased the

TABLE I-2

Principal Companies Operating in
the Nuclear Energy Sector

Company	Uranium production	Refining	Fuel fabrication	Reactor manufacture
1. Allied Chemical Corp.		X		
2. Allis Chalmers Corp.				X
3. Anaconda Co.	X			
4. Babcock & Wilcox Co.			X	X
5. Beker Industries Corp.		X		
6. Combustion-Engineering, Inc.			X	X
7. Continental Oil Co.	X			
8. Exxon Corp.	X		X	
9. Federal-American Partners	X			
10. General Atomic Co.				X
11. General Electric Co.			X	X
12. Getty Oil Co. (including Skelly Oil Co.)	X			
13. Gulf Oil Corp.	X			
14. Kerr-McGee Corp.	X	X		
15. Mobil Oil Cop.	X			
16. Phelps Dodge Corp. (Western Nuclear Inc.)	X			
17. Pioneer Corp.	X			
18. Union Carbide Corp.	X			
19. Union Pacific Corp.	X			
20. United Nuclear Corp.	X			
21. Utah International, Inc.	X			
22. Westinghouse Electric Corp. (Wyoming Minerals Corp.)			X	X

Note: principal uranium producers are the 15 largest reserve holders as of 1974. For the remaining nuclear industries, all producing firms as of 1977 are included.

Source: Federal Trade Commission, Bureau of Economics.

economic attractiveness of nuclear generated electricity which in turn led to an upsurge in uranium demand. The general expectation is that the demand for uranium will remain high through the end of this century.[1]

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[1] See U. S. Department of Energy, Energy Information Administration, Annual Report to Congress, vol. II, 1977, DOE/EIA-0036/2, pp. 191-203.

Chapter II

The Economics of Uranium Supply

This chapter analyzes the economic structure of the uranium supply sector. Our aim is to evaluate the industry's potential for workably competitive performance. We begin with a description of the uranium production process, focusing on the primary factors that influence seller structure. Seller concentration levels are then tabulated. Next, the chief sources of entry barriers are described and their importance evaluated. We then examine the actual record of entry by analyzing the response of producers and new entrants to the upsurge in uranium prices that took place during the 1973-76 period. The final section summarizes the evidence on structure and the conclusions that can be drawn from it.

A. Characteristics of the Industry

1. The Production Process[1]

The uranium production process involves three principal activities:

a. exploration, encompassing the search for uranium deposits and the determination of their commercial value;

b. mining of the uranium ore; and

c. milling of the raw ore into uranium concentrate.

In the sections which follow, each of these activities is described in greater detail.

a. Exploration. The first step in a successful mining venture is the discovery of a mineral deposit worth mining. Uranium makes up only about two parts per million of the earth's crust, and while traces of it are found almost everywhere, economically recoverable deposits in the United States have been discovered mainly in veins and in flat, irregular, tabular, sandstone bodies. Discovered deposits generally range in thickness from a few feet to about 100 feet, and in depth from surface outcroppings to about 4,000 feet below ground. The physical property commonly associated with uranium, its radioactivity, provides an important aid in exploration. Geiger and scintillation counters can detect the rays and particles emitted by uranium at considerable distances, thereby enabling aerial as well as ground reconnaissance.

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1 Much of the information discussed in this section is based on J. F. Hogerton, Atomic Fuel (New York: Reinhold, 1963) and Electric Power Research Institute (EPRI), Uranium Price Formation (Palo Alto, 1977) (hereinafter cited as Uranium Price Formation).

Uranium exploration is a protracted and risky undertaking. Based on past prices and considering all firms collectively, there is evidence that suggests four to six years as representative of the average time period necessary to discover a commercial ore body.[1] During this period, the nature of exploratory activity varies. At first, a general reconnaissance of many different potential prospects is undertaken. Using existing geological information and data gathered from air and ground surveys, prospective areas of mineralization are delineated. The most promising of these areas is then investigated more thoroughly. Land acquisition usually precedes this intensive survey. If the discovery is on land in the public domain, a claim is staked, and a record of the claim and its location is filed at the county courthouse. If the discovery is on privately owned land, the property is leased if possible. Detailed geologic studies are then undertaken. These include surface mapping, sample taking and the preparation of subsurface maps by projecting data that have been obtained from examination of the surface and exploratory penetrations of the ground.

The value of a deposit is estimated by taking samples at enough points to reflect the size and grade of the deposit. Exploratory penetrations are made by drilling small holes or by excavating underground workings large enough for men and

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[1] A. E. Jones, Manager, Grand Junction Office, AEC, Remarks to the Ninth Annual Minerals Symposium, Moab, Utah, May 1964, reprinted in Private Ownership of Special Nuclear Materials, 1964, p. 180.

equipment to enter. The latter method is more expensive, but often yields higher quality information. Drilling is usually done with core, rotary, pneumatic percussion, and churn drills. Core drilling is the most expensive but often is the most informative type of drilling. The drilling strategy used in exploration depends upon the type of deposit. For deposits located near the surface of the ground, sample drilling can be closely spaced at low cost. For deep, subterranean deposits, fewer, more selectively chosen holes are drilled.

After evaluating data from gamma-ray logs, drill hole and channel sample assays, and descriptions of the logged or sampled areas, a decision is reached regarding which of the deposits (if any) are worth developing. The exploration cycle is thus characterized by increasingly intensive examination of an increasingly diminishing number of prospects until a decision is reached regarding development.

Having settled upon an area to be developed, additional drilling is undertaken to determine the best method for removing the ore. The topography, elevation, climate, availability of water, and the general geologic environment must be considered in determining the kind and extent of effort to be expended. The extractive technique adopted will differ depending upon the characteristics of the property. If the ore is to be removed using open-pit methods, a large volume of over-burden must then be removed. In the case of subterranean deposits, shafts and adits must be dug. Additional facilities (roads, buildings, etc.) must also be constructed.

The time frame during which these activities occur exhibits considerable variation. One survey showed periods of two to seven years between the beginning of development work and the first commercial production. Based on historical experience and thus reflecting past price expectations, the AEC estimated between four and six years as the average development period for a uranium mining operation.[1]

b. Mining. Uranium ore is mined in much the same way as other minerals, although there are variations to fit the unusual characteristics of uranium deposits in sandstone, the kind of deposit from which most domestic production has been drawn. Coal mining technology is not directly applicable, for example, because uranium ore bodies, although similar to coal deposits in their flat-lying attitude are harder, smaller, and more irregular. In addition, because the uranium at any one site is often quickly depleted, mining operations must be highly mobile, designed to permit an inexpensive and rapid conclusion of digging.

The principal mining methods are open-pit and underground with open-pit accounting for a slight majority (55 percent) of total mine output.[2] Open-pit mines are generally limited to

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1 A. E. Jones, Private Ownership of Special Nuclear Materials, op. cit., p. 181.

2 Uranium Price Formation, op. cit., pp. 6-12.

a depth of 300 feet while underground mines have gone to depths of greater than 5,000 feet. Solution mining, principally in the forms of in-situ and heap leaching, is a third form of uranium extraction. It is a relatively minor operation (accounting for approximately 2 percent of total uranium output) that is generally applied to low grade ore deposits that may not be economically mined using conventional methods.

c. Milling. From the mine, raw ore is shipped by ore carrier or rail to a mill where the uranium content is extracted in the form of a concentrate called "yellowcake." Uranium milling is basically a leaching process in which crushed raw ore is subjected to the action of percolating sulfuric acid in a series of perforated vessels to dissolve out gangue minerals. Because raw uranium ore is bulky and has a high density (65 percent heavier than lead), it is expensive to transport.[1] Furthermore, only about .02 percent of the raw ore is recovered as yellowcake. For these reasons, processing mills are generally located no more than 20 to 25 miles from mine sites.[2]

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1 See U. S. Bureau of Mines, "Uranium," Mineral Facts and Problems, 1970, p. 222.

2 For an extended discussion of uranium milling processes, see U.S. Department of the Interior, "Availability of Uranium at Various Prices from Resources in the United States," Bureau of Mines Information Circular (1971), pp. 76-81.

2. Cost Conditions[1]

The nature of cost conditions differs significantly between the exploration and mining-milling stages. Scale economies as well as the required initial capital investment are substantially more important in mining-milling than in exploration. We briefly review cost characteristics for each sector below.

Scale economies appear to be minor in the exploration stage. This situation largely reflects the relative unimportance of fixed investment in exploratory activity. Neither research and development expenditures nor capital equipment, the two most common sources of scale related efficiencies, is a significant component of the typical exploratory budget. Rather, drilling costs constitute the most important expense component, accounting for over 40 percent of total exploration expenditures.[2] As a consequence, the minimum investment outlay necessary for efficient exploration effort is considered to be relatively low. Recent estimates of a "reasonable" minimum exploration budget range from \$3 to \$8 million.[3]

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1 This section utilizes cost information presented in Uranium Price Formation, *op. cit.*, chapters 5 through 7.

2 *Ibid.*, table 5-6, pp. 5-25.

3 *Ibid.*, pp. 5-41.

On the other hand, cost factors potentially constitute an important determinant of seller structure in the mining and milling stages. Cost estimates developed by ERDA suggest that there may be significant economies of scale at the plant level in uranium mining and milling.[1] ERDA defines a plant as a processing mill plus a set of mines supplying the mill with ore. Table II.1 presents ERDA's estimates of the capital and operating costs (per pound of U_3O_8 recovered) associated with various planned rates of output for open-pit and underground mining and milling operations. These estimates indicate that the average cost of producing yellowcake declines at a decreasing rate with the size of the venture, regardless of the type of mining operation. Three factors account for declining average cost: the costs associated with mine development; equipment costs in underground mining operations; and, most importantly, the costs of constructing and operating a mill.

Scherer has described the basis of scale economies in a "process" operation like uranium milling in the following terms:

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1 We focus exclusively on individual plant economies in this discussion. Multiple-plant, or firm, economies are not a significant factor in the uranium sector. As of 12/31/77, only three milling companies maintained more than one plant: Union Carbide and General Electric had two plants each; United Nuclear owned one plant outright and possessed a joint venture interest in another. The combined market share of these multi-plant companies was 28.6 percent of total mill capacity. [Mill capacity ownership is presented in appendix table 1, American Petroleum Institute, The Structure of the U. S. Uranium Industry and the Role of Petroleum Firms (Washington, 1978), table 6, p. 24.]

Table II-1

Cost Estimates for Various
Sizes and Types of Uranium Concentrate
Production Facilities
($/Lb. U_3O_8 Recovered)

Open Pit a/	500 tons/day	1,000 tons/day	2,000 tons/day	3,000 tons/day	5,000 tons/day
Costs:					
Capital					
Acquisition	0.158	0.158	0.158	0.158	0.158
Exploratory Drilling	0.526	0.526	0.526	0.526	0.526
Development Drilling	0.263	0.263	0.263	0.263	0.263
Mine Primary Development	1.605	1.421	1.368	1.355	1.329
Mine Plant and Equipment	0.053	0.053	0.053	0.053	0.053
Mill Construction	0.632	0.513	0.421	0.368	0.316
Total Capital	3.237	2.934	2.789	2.723	2.645
Operating					
Mining	0.632	0.632	0.632	0.632	0.632
Hauling	0.171	0.171	0.171	0.171	0.171
Milling	1.592	1.224	1.013	0.908	0.868
Royalty	0.355	0.355	0.355	0.355	0.355
Total Operating	2.750	2.382	2.171	2.066	2.026
TOTAL	5.987	5.316	4.960	4.789	4.671

(Continued)

Table II-1 (Continued)

Cost Estimates for Various
Sizes and Types of Uranium Concentrate
Production Facilities
($/Lb. U_3O_8 Recovered)

Underground b/	500 tons/day	1,000 tons/day	2,000 tons/day	3,000 tons/day	5,000 tons/day
Cost:					
Capital					
Acquisition	0.158	0.158	0.158	0.158	0.158
Exploratory Drilling	0.526	0.526	0.526	0.526	0.526
Development Drilling	0.263	0.263	0.263	0.263	0.263
Mine Primary Development	0.874	0.684	0.579	0.547	0.495
Mine Plant & Equipment	0.189	0.147	0.116	0.105	0.095
Mill Construction	0.505	0.411	0.337	0.295	0.253
Total Capital	2.515	2.189	1.979	1.894	1.790
Operating:					
Mining	2.947	2.526	2.316	2.211	2.126
Hauling	0.168	0.168	0.168	0.168	0.168
Milling	1.305	1.011	0.842	0.758	0.727
Royalty	0.368	0.368	0.368	0.368	0.368
Total Operation	4.788	4.073	3.694	3.505	3.389
Total Cost	7.303	6.262	5.673	5.399	5.179

a/ Estimates based on operations at 0.20 percent U_3O_8 in ore, a depth-to-thickness ratio of 24, and a productive life span of 10 years.

b/ Estimates based on operations at 0.25 percent U_3O_8 in ore, a depth-to-thickness ratio of 76, and a productive life span of 10 years.

Source: J. Klemenic, Chief, Production and Cost Evaluation Branch, Ore Reserves and Production Division, Grand Junction Office, U. S. Atomic Energy Commission, "Examples of Overall Economies in a Future Cycle of Uranium Concentrate Production for Assumed Open Pit and Underground Mining Operations," October 20, 1972, tables I and II.

> The output of a processing unit tends within certain physical limits to be roughly proportional to the volume of the unit, other things being equal, while the amount of materials and fabrication effort (and hence investment cost) required to construct the unit is more apt to be proportional to the surface area of the unit's reaction chambers, storage tanks, connecting pipes, etc. Since the area of a sphere or cylinder of constant proportions varies as the two-thirds power of volume, the cost of constructing process industry plants can be expected to rise as the two-thirds power of their output capacity, at least up to the point where they become so large that extra structural reinforcement and special fabrication techniques are required. There is considerable empirical support for the existence of this two-thirds rule, which is used by engineers in estimating the cost of new process equipment.[1]

Table II-2 presents estimates of the increase in total mill construction costs associated with various output increases based on the two-thirds rule, along with the actual total mill construction cost increases derived from the estimates in table II-1. The mill construction cost estimates in table II-1 conform fairly closely to the two-thirds rule.

The costs of operating a mill also decline with increases in size according to the estimates in table II-1. These economies derive from spreading fixed amounts of labor over larger volumes of output. Consider the following representative illustration: The flow of material between the leaching vessels is controlled by a laborer operating a valve. Larger vessels and connecting

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1 F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1970), p. 73.

Table II-2

Uranium Mill Construction Cost Estimates
(Two-thirds rule)

Output increase*	Predicted cost increase (Two-thirds rule)	Actual cost increase Open-pit	Actual cost increase Underground
X 2	1.587	1.623	1.628
X 4	2.520	2.665	2.337
X 6	3.302	3.494	4.004
X 10	4.642	5.000	5.010

* Base estimates are for a 500 tons-per-day mill.

Source: Table II-1.

pipes may permit larger volumes of material to be processed, but still only one laborer is required to operate the flow-controlling valve. Labor cost per unit may therefore decline with increases in mill size.

Although the estimates cited above suggest significant scale economies in uranium milling, the size of deposit has limited their full exploitation. As of 1977, the average mill size was roughly 2,000 tons per day (TPD), substantially lower than the optimal size implied by plant technology alone. The average projected size of planned new mills is also approximately 2,000 tons TPD, indicating that deposit size will remain a significant constraint on mill size in the near future.[1]

Another factor that influences the scale of a milling complex is the grade of ore to be processed. Studies indicate that ore quality (measured in terms of the percent of U_3O_8 concentrate that can be extracted from a unit of uranium ore) is negatively associated with the per unit cost of concentrate output.[2] As a result, higher than average ore grades can justify construction

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1 The capacity of current (1977) and planned mills is listed in appendix tables A-1 and A-2, respectively. The size distributions of current and planned mills are similar. The range of current plant sizes is 400 to 7,000 TPD while it is 550 to 3,000 TPD for the set of planned mills. Twenty-seven percent of the current mills exhibit a capacity greater than 2,000 TPD whereas 30 percent of the planned mills are in this size class range.

2 Uranium Price Formation, op. cit., pp. 7-11.

of relatively small mills.[1] Alternatively, the recent increase in concentrate prices has encouraged producers to utilize increasingly lower ore grades which in turn induces them to build relatively large milling facilities.

Due primarily to the nature of the technology involved, capital investment necessary for participation in the mining-milling stage is significantly higher than for exploration.. The required investment expenditure for opening a 1,000 TPD mine (including costs incurred for land acquisition, drilling and associated mining plant and equipment) was estimated in 1972 at $34 million for an open-pit mine and $31 million for an underground mine.[2] A 1974 cost estimate for mill construction ranged from $18.6 million for 1,500 TPD capacity to $38.3 million for 5,000 TPD capacity.[3] Combining these estimates and adjusting them in terms of 1977 dollars,[4] the minimum cost of full scale entry into uranium concentrate production ranges from $68.9 to $98.2 million.

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1 One example is the Cotter mill in Canon City, Colorado. This mill has a relatively low ore capacity of 450 TPD yet the quality of ore it processes is far above average. (Personal correspondence with DOE official John Klemenic, September 24, 1978.)

2 Uranium Price Formation, op. cit., pp. 6-37.

3 Ibid., pp. 7-13.

4 The price deflator for fixed, non-residential investment was used to adjust for inflation, Economic Report of the President (Washington, 1978), table B-3, p. 260.

3. Exchange Conditions[1]

Since the only non-military use for uranium is fuel for nuclear power reactors, utilities constitute the sole group of final private buyers. Sales of uranium concentrate by millers to utilities are conducted either directly or through brokers and reactor manufacturers.[2] At present, utilities purchase practically all of their supplies directly. The earlier importance of reactor manufacturers as uranium purchasers declined sharply as the utilities became experienced in the uranium market. Due to the 10- to 11-year leadtime between the decision to build a reactor and its initial operation, utilities have considerable flexibility in the timing of their uranium orders.

The bulk of contracts are long-term agreements for the delivery of concentrate at some future date. Approximately 75 percent of uranium sales are of such a long-term nature while the remainder are spot market transactions in which the uranium concentrate is delivered within a year of the contract agreement. Although a nuclear power reactor requires uranium for at least 30 years, contract terms typically are written for considerably

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1 This section is based on the discussion in Uranium Price Formation, op. cit., chapters 4 and 8; U.S. Dept. of Energy, Survey of United States Uranium Marketing Activity, May 1978, DOE/RA-0006; George White, Jr., "Procurement Mechanisms," Address at the ANS Sponsored Executive Conference on Uranium Fuel Supply, Monterey, Calif., January 24, 1977.

2 Also, a relatively small amount of concentrate is sold to foreign buyers.

shorter periods. At present, the bulk of non-spot contracts are from 5 to 10 years in duration.[1]

Uranium is sold under a variety of pricing provisions. In contrast to earlier periods when fixed price contracts were the norm, most agreements now contain provisions for subsequent price modifications keyed to changes in specified cost or price indices. Coincident with this development has been an increase in pre-production advances by purchasers to millers as an aid in the financing of mine-mill complexes. Utilities have also begun to enter more directly into the production stage through development of exploration and production operations. At the beginning of 1978, 30 utilities were identified as being directly involved in uranium raw material activities.[2]

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1 Interview with DOE marketing specialist Jeff Coombs, July 25, 1978.

2 DOE, Survey of U.S. Uranium Marketing Activity, op. cit., p. 15.

4. Resource Measures

DOE annually reports estimates of domestic "reserves" and "potential resources" at various cost cutoffs. These estimates are derived from information provided voluntarily by all known uranium exploration and mining companies. DOE believes that its total reserve universe figures include approximately 99 percent of all existing reserves. "Reserves" are defined as:

> the quantity of uranium in known deposits which it is calculated can be economically produced within the stated cost. The quantity, grade and physical characteristics have been established with reasonable certainty by detailed sampling, usually by surface drilling initially, and later supplemented by underground drilling and sampling.[1]

"Potential resources" are:

> estimates of the quantity of uranium in addition to reserves that may exist in unexplored extensions of known deposits or in undiscovered deposits within or near known uranium areas. The estimates are based on extrapolations from explored to unexplored or incompletely studied areas applying favorability factors based on geologic evaluations.[2]

DOE's resources estimates indicate the quantity of uranium which could be produced at or below a given cost per pound of U_3O_8. For purposes of estimation, these "forward costs encompass operating and capital expenditures yet to be incurred at the time an estimate is made. Excluded are profit, cost of money, and sunk costs. In effect, forward costs primarily

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1 U.S. Atomic Energy Commission, "Nuclear Fuel Resources and Requirements," WASH-1234, April 1973, p. 12.

2 *Ibid.*, p. 15.

reflect "the shortrun variable costs of reproducing from a developed facility."[1] Thus, market prices higher than a given forward cost level would be required to produce the reserves at that cost level.

Table II-3 shows reserves estimates for 1974, the latest year for which reserves concentration ratios are available, and for 1977. The cumulative totals of reserves are listed for each relevant forward cost category. These cost groups ranged from $8 to $30 in 1974 and from $15 to $50 in 1977. Rising costs served to eliminate the $8 reserves category for 1977 while the addition of the $50 group reflects substantial rises in the price of uranium. Most of the higher cost reserves are adjacent to or within areas of lower cost reserves. In 1974, for example, less than 10 percent of the $30 reserves were contained on deposits having only $30 reserves.[2]

DOE's "potential resources" category represents an estimate of the amount of undiscovered uranium ore in areas about which enough geological information exists to indicate the nature and extent of the environmental conditions favorable for the occurrence of uranium. The amount, specific location, and nature of potential resources are inherently much less known than those

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1 Paul Joskow, "Commercial Impossibility, the Uranium Market and the Westinghouse Case," Journal of Legal Studies (Jan. 1977), p. 124.

2 R. J. Meehan, "Uranium Reserves and Exploration Activity," U.S. Energy Research and Development Administration, Uranium Industry Seminar, October 7-8, 1975, GJO-108 (75), p. 123.

Table II-3

Uranium Reserves Estimates: 1974 and 1977

Forward cost category (cost per ton in dollars)	Reserves (tons U_3O_8) 1974	Reserves (tons U_3O_8) 1977
$ 8	200,000	*
15	420,000	370,000
30	600,000	690,000
50	*	890,000

* No reserves calculated.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1978, GJO-100 (78), p. 9.

of reserves. Table II-4 lists potential resources estimates for 1977, distributed according to "probable," "possible," and "speculative" categories. Probable resources are those containe within favorable trends largely delineated by drilling data within productive uranium districts. Possible resources are out side of identified mineral trends but are in geologic provinces and formations that have been productive. Speculative resources are those estimated to occur in formations or geologic provinces which have not been productive but which, based on the evaluatic of available geologic data, are considered to be favorable for the occurrence of uranium deposits.

Table II-4

Potential Uranium Resources Estimates as of
January 1, 1978
(tons U_3O_8)

Cost category per pound U_3O_8 (dollars)	Probable	Possible	Speculative
$15	540,000	490,000	165,000
30	1,015,000	1,135,000	415,000
50	1,395,000	1,515,000	565,000

Note: Each cost category includes all lower cost potential resources.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1978, GJO-100 (78), p. 27.

5. Vertical Integration

It is useful to distinguish among the following three types of vertical integration in connection with the uranium sector: integration within the production sector (i.e., vertical links between the exploration, mining, and milling stages); forward integration between the production sector and the downstream stages of the fuel cycle, including reactor manufacture; and production activities by electric utilities. We examine each of these elements in turn.

a. Vertical Integration Within the Production Sector. Integration between the mining and milling stages is high. As of 1970 (the latest year for which data are available), approximately 96 percent of uranium ore was captively mined by milling companies. This level represents a sharp rise from earlier periods: Captive production by milling companies was equivalent to 35 percent of ore receipts in 1955, 64 percent in 1960, and 73 percent in 1965.[1] The causes of this pattern are governmental, geological, and economic.

A number of Government policies, operative during the 1950's and early 1960's, which were designed to help small explorers and producers also led to artificially low integration levels. In addition to overall price guarantees for the ore, particularly important were a transportation allowance for the haulage of raw

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1 J. P. Mulholland and D. W. Webbink, Concentration Levels and Trends in the Energy Sector of the U.S. Economy, Staff Report to the Federal Trade Commission (March 1974), pp. 164, 219.

ore to the mill and a regulation that each mill save a portion of its capacity for independent miners. The termination of these programs led to the exit of a number of smaller independent miners and a subsequent rise in vertical integration.

A significant rise in the size of uranium deposits discovered during the late 1950's stimulated greater emphasis on the development of integrated mine-mill complexes. Previously, millers were forced to acquire ore from a number of different small mines, many owned by independents, in order to operate at efficient scale. As the size of deposit increased, there was less need for such purchases.[1]

Complementing the first two factors is the ability of vertical integration to avoid costs of market transactions entailed in the interactions between the mining and milling stages. Scherer lists the potential efficiencies associated with integrated operations vis-a-vis reliance on the market:

> Integration may permit significant real economies in transferring goods from one stage to another--i.e., minimizing of sales representation and contracting functions, better coordination of production with requirements, streamlining of distribution channels, lower spoilage, etc. It can also be a means of ensuring the availability of supplies in boom periods, or when suppliers are struck by labor union disputes. And given that transfer prices under bilateral oligopoly must be established through bargaining, vertical

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1 <u>Uranium Price Formation</u>, <u>op</u>. <u>cit</u>., pp. 8-35.

integration may be a way of avoiding the stalemates (with consequent supply interruptions) otherwise likely to arise.[1]

Notwithstanding the above, there are recent signs that independent mining operations are increasing in importance.[2] If so, this development reflects the influence of an important economic law: The division of labor is limited by the extent of the market. As the size of the uranium sector grows, the scope for specialized operation, such as independent mines and mills, may also increase. Such a development is not inevitable; rather, it occurs only if the efficiency gains from independent operations outweigh the market associated transactions costs noted by Scherer.

b. Forward Integration. Table II-5 outlines the vertical links that currently exist between uranium producers and downstream stages of the nuclear fuel cycle (including reactor manufacture) The most prevalent contacts are made in the fuel fabrication sector where six uranium producers maintain productive capacity. Two producers are engaged in reactor manufacture and one participates in the uranium refining stage. In addition, a number of producers have expressed interest in expanding into these downstream sectors and also into uranium enrichment if the Government decides to allow private operations.[3]

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1 Scherer, op. cit., p. 247.

2 Uranium Price Formation, op. cit., pp. 8-36.

3 See appendix C, table C-3.

Table II-5

Integrated Uranium Reserves Holders

Uranium reserves holders*	Downstream segment of the nuclear sector		
	Refining	Fabrication	Reactor manufacturer
Exxon Oil Corp.		X	
General Electric (Utah Inter.)		X	X
Getty Oil		X	
Gulf Oil		X	
Kerr-McGee	X		
United Nuclear		X	
Westinghouse Elec. (Wyoming Minerals Corp.)		X	X

* Uranium reserves holders defined as those included in either of the following groups: (a) the list of 1974 reserves holders supplied by ERDA to the FTC; (b) current or planned mill owners as of January 1978.

Source: Federal Trade Commission, Bureau of Economics.

At present the vertical links maintained by producers have no effect on the organization of the uranium production industry. There are no technological interrelationships between sectors that would give integrated producers a cost advantage over non-integrated producers. Moreover, current marketing practices serve to isolate the production phase from downstream sectors since utilities purchase the bulk of their uranium supplies from the mill, contracting independently for the remaining stages of the nuclear fuel cycle. Reactor manufacturers, once important marketers of nuclear fuel, now play a minor role.

It is possible that future institutional arrangements may result in an environment where vertical integration may influence structure in the production sector. For example, "privatization" of the enrichment sector would allow companies to process their raw ore through the entire fuel cycle. If utilities found it economically advantageous to purchase the final nuclear fuel product from such integrated producers (instead of separately contracting at each stage of the fuel cycle), then full integration over the fuel cycle might become a necessary condition for participation in the production sector. At present, the chance of such a development is remote since privatization of the enrichment sector appears unlikely.

c. Uranium Production Activities by Electric Utilities.

Electric utilities are becoming an important element in uranium production. Currently there are 30 utilities engaged in one or more aspects of the uranium supply stage (i.e., exploration, reserves ownership, involvement in mine development, and production).[1] As of January 1, 1978, approximately 30 percent of uranium commitments scheduled for 1985 delivery are to be produced by utilities.[2]

Since utilities are not among the major reserves holders, their participation in the production sector serves a pro-competitive purpose by further diffusing seller structure. Also, the demonstrated ability of utilities to enter production gives them significant bargaining leverage in their dealings with independent producers. The chief negative aspect of utility integration concerns the added burden it places on regulators who attempt to price electricity services at a competitive level. This problem is discussed in chapter IV.

6. International Aspects

The domestic uranium market has been relatively unaffected by international factors. Throughout most of the commercial period (i.e., after 1966), imports were proscribed by law while domestic producers had a relatively small market for their output among foreign buyers. International influences have become more important since 1974, but it is unclear how important they will be in the future.

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1 DOE, Survey of United States Uranium Marketing Activity, op. cit., p. 15.

2 Ibid., pp. 12, 13. Captive production is not listed directly. Rather, it is subsumed in the "Other" category of fuel procurement for which no price is specified (table V, p. 13). DOE estimates that 80 percent of the arrangements listed in this category are captive production (p. 12).

The AEC implemented a ban on uranium imports in 1964. Under this ruling, foreign uranium destined for domestic use could not be processed at U.S. enrichment facilities. The Commission's aim was to protect the domestic uranium industry during the transition to a commercial market. The depressed state of the uranium market led to continuation of the ban until 1974 when the AEC announced a phased withdrawal beginning in 1977 and lasting through 1983 (after which an unlimited amount of foreign uranium could be processed for U.S. consumption).[1]

In reaction to the Government's intention to relax the import ban, utilities immediately began to purchase foreign uranium for future enrichment in U.S. facilities. As of January 1, 1978, domestic buyers had made purchase commitments for 36,400 tons of foreign U_3O_8 for delivery from 1975 through 1990. Imports in 1977 amounted to 2,800 tons, which is approximately 17 percent of total purchases made by domestic buyers in that year.[2] The principal foreign sources of uranium are Canada and the Union of South Africa.

Exports of uranium concentrate were relatively insignificant through 1973. Since that time foreign market sales have increased largely due to the expansion of foreign demand and, recently, the declining exchange value of the dollar. Uranium

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1 Uranium Price Formation, op. cit., pp. 3-35 and 3-36.

2 U.S. Department of Energy, Survey of United States Uranium Marketing Activity, op. cit., p. 16.

exports in 1977 amounted to approximately 13 percent of total concentrate production in that year.[1]

Since transportation costs of uranium concentrate make up a small portion of its total value, the impending removal of import constraints may signify the emergence of a world market where U.S. producers would compete with suppliers of other non-Communist countries. The likelihood of such a development is clouded, however, by indications that foreign supplies may be restricted. It is now well established that the uranium producers from Australia, Canada, France, South Africa, and England formed a cartel in 1972 to raise the price of uranium by establishing production shares and rigging bids. Although sales to the U.S. were, ostensibly, not a target of the cartel, the potential for affecting U.S. sales did exist.[2] The cartel may now be disbanded or dormant but it may reappear in the future. At present, Canada sets a minimum price for uranium exported from that country.

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1 U.S. Department of Energy, Survey of United States Uranium Marketing Activity, op. cit., p. 17.

2 The Justice Department successfully prosecuted Gulf Oil Corp. for taking part in the cartel but did not have sufficient evidence to charge that the conspiracy extended beyond 1974. (The Washington Post, May 10, 1978, p. A2.) Also, several private antitrust suits include allegations that the cartel had or conspired to have direct or indirect effects on uranium sales to U.S. buyers. (Those cases also involve allegations of a conspiracy within the domestic uranium industry.) See In re Uranium Industry Antitrust Litigation (Homestake Mining Corp. v. Enerdyne Corp.), 466 F. Supp. 958 (Judicial Panel on Multidistrict Litigation, Feb. 27, 1979); In re Uranium Industry Antitrust Litigation, 458 F. Supp. 1223 (J.P.M.L. 1978).

To conclude, the removal of restrictions on imports of uranium concentrate may increase the supply alternatives open to domestic buyers. The likelihood of this development is uncertain, however, due to recent attempts by foreign governments to restrict the supply of uranium available in the U.S. market.

B. Concentration Levels

As illustrated in figure II-1, concentration levels in uranium are diverse and have undergone a number of different trends during the 1955-77 period. The most continuous series available is for production where concentration initially declined and then, starting in 1960, began a steady increase until 1972, after which a slight reduction has taken place. Indices based on mill capacity and proved reserves are only available in more recent periods. While mill capacity concentration has remained relatively constant during the post-1972 period, reserves concentration increased significantly between 1973 and 1974 and then fell slightly during the next two years.

We now take a more detailed look at concentration levels in 1974, the latest year for which individual company data are available. Market share ratios based on actual and potential output (proved reserves, mill capacity, and mill production) and exploratory effort (acreage held for exploration and exploratory drilling footage) are tabulated and aggregated for selected groups of companies. Since confidentiality restrictions prevent identification of each company's market share, we list the 4-, 8-, and 15-firm concentration ratios.[1]

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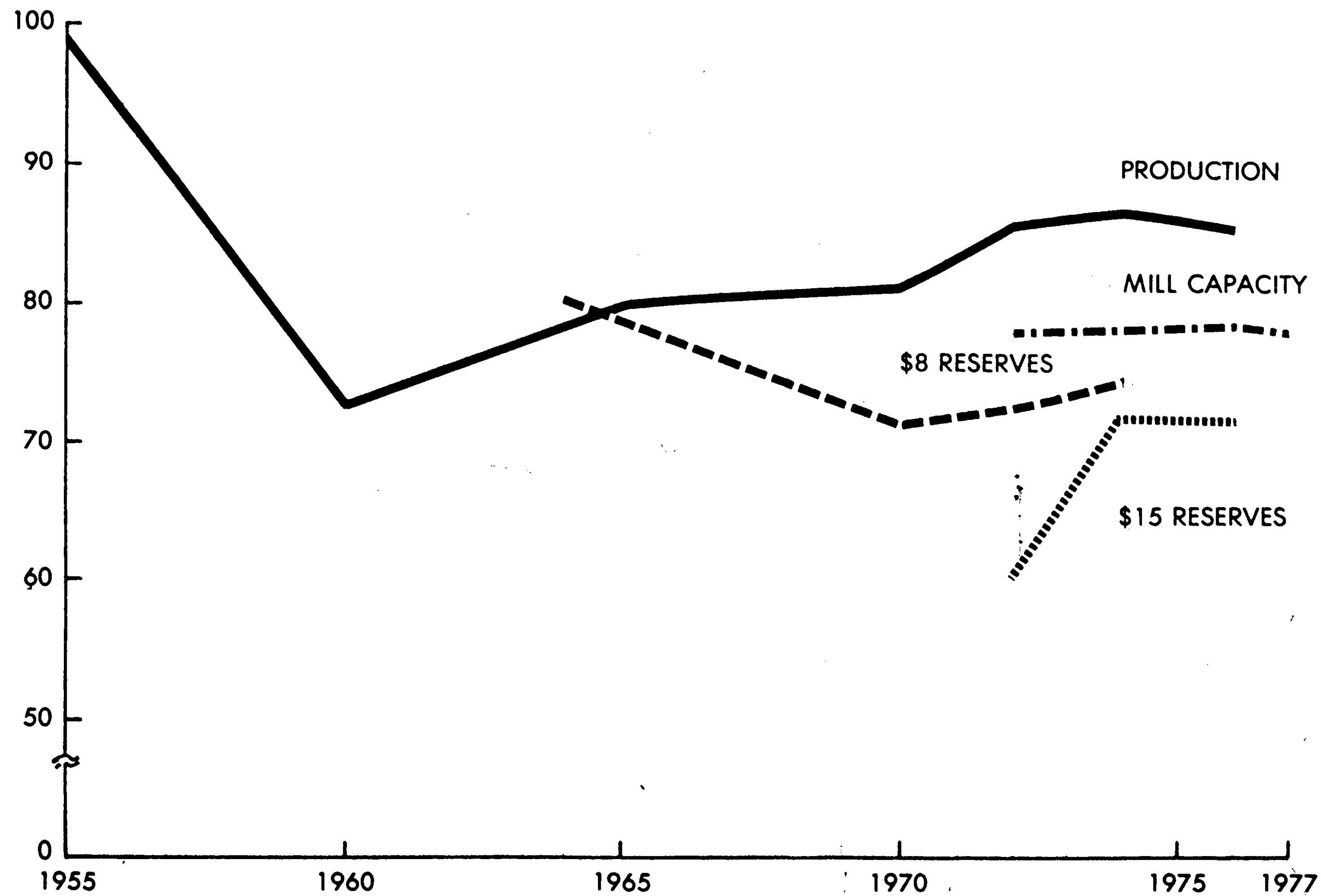
[1] The one exception is mill capacity where individual company figures are publicly available.

FIGURE II-1
8 FIRM CONCENTRATION LEVELS IN URANIUM: 1955-1977

8 FIRM CONCENTRATION



Source: Federal Trade Commission, Bureau of Economics. See Appendix Table A-4.

Table II-5a presents concentration levels based on the stock of proved reserves, measured at each principal forward cost category. Concentration levels are similar among each of the respective forward cost categories, ranging from 67 to 74 percent at the 8-firm level. Table II-6 lists the identity of companies within each size group for the $30 forward cost category.

The reserves tabulated in table II-5a include those already committed to sellers as well as those not yet committed. Since significant amounts of reserves are typically dedicated to buyers, there is the possibility that seller structure for uncommitted reserves differs significantly from that based on total reserves. Tabulations supplied by DOE suggest that this is not the case, however. For $30 reserves, the relative importance of uncommitted reserves differs little among size classes. Uncommitted reserves as a percentage of the total ranged from 73 percent for the top 4 firms to 77 percent for all companies (table II-7).

Table II-8 presents information on concentration at the milling stage. Concentration levels are tabulated for both mill production of uranium concentrate (U_3O_8), and mill capacity as measured by a company's potential to process uranium ore. Not surprisingly, concentration levels are similar for the two measures. Those variations that exist are due to different levels of capacity utilization among plants and to variations in the grade of ores utilized. The overall level of concentration is higher than that found for proved reserves. At the 8-firm

Table II-5a

Uranium Reserves
Concentration Ratios
(percent)

Concentration category	Forward cost reserves group		
	$8/lb	$15/lb	$30/lb
4-firm	56.0	47.7	45.2
8-firm	74.4	71.2	67.8
15-firm	85.5	83.1	81.2

Source: Federal Trade Commission, Bureau of Economics.

Table II-6

Identity of the Leading Holders
of $30 Uranium Reserves: 1974

Reserve size class by rank	Companies (listed alphabetically within each size group)
1 - 4	Exxon Corp. Gulf Oil Corp. Kerr-McGee Corp. United Nuclear Corp.
5 - 8	Anaconda Co. Getty Oil Co. (including Skelly Oil Co.) Phelps Dodge Corp. (Western Nuclear Inc.) Utah International, Inc.
9 - 15	Continental Oil Co. Federal-American Partners Mobil Oil Co. Pioneer Corp. Union Carbide Corp. Union Pacific Corp. Westinghouse Electric Corp. (Wyoming Minerals Corp.)

Source: Federal Trade Commission, Bureau of Economics.

Table II-7

Percentage of $30 Uranium Reserves
Uncommitted to Purchasers: 1974

Size class (Firms ranked by holdings of $30 reserves)	Percentage of $30 reserves uncommitted
Top 4	73
Top 8	75
Top 15	77
Top 25	77
All companies	76

Source: Federal Trade Commission, Bureau of Economics.

Table II-8

Concentration Levels
at the Milling Stage: 1974

Concentration category	Concentration (percent)	
	Mill production	Mill capacity
4-firm	61.3	55.7
8-firm	86.2	77.8
15-firm	99.0	95.1

Source: Federal Trade Commission, Bureau of Economics.

level, mill production concentration is 86.2 percent whereas that based on mill capacity is 77.8 percent.

Finally, table II-9 lists concentration levels for two indices of exploratory effort: acreage held for exploration and exploratory drilling footage. Concentration levels for these two measures are similar to each other and are significantly lower than the output measures listed above. Eight-firm concentration is 50 percent for acreage and 52 percent for drilling footage.

Table II-10 summarizes the range of concentration ratios for the principal areas of uranium supply activity. Concentration levels for proved reserves and at the milling stage are relatively high: the 8-firm concentrations range from 71.2 percent for proved reserves to 86.2 percent for mill production. These figures are higher than the manufacturing sector average and are above corresponding indices for other energy fuel markets.[1] The limited nature of the concentration ratio along with the disparate nature of the uranium market makes such comparisons misleading, however. This is so because reliance on the concentration ratio obscures significant variations in ownership rankings among firms in different stages of the uranium supply sector. A less concentrated picture of the uranium sector emerges when these differences are taken into account.

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[1] The weighted average 8-firm concentration ratio in manufacturing for 1966 was 39.0. Eight-firm concentration levels for energy production in 1974 are: natural gas, 42.6; crude oil, 49.6; coal, 34.8. See Joseph P. Mulholland, Economic Structure and Behavior in the Natural Gas Production Industry (Washington: 1979), table III-19, p. 66.

Table II-9

Uranium Concentration Levels
Based on Exploratory Activity: 1974

Concentration category	Concentration ratios (percent)	
	Acreage held for exploration	Explorator drilling foot
4-firm	36.3	41.5
8-firm	50.1	52.5
15-firm	59.4	63.7

Source: Federal Trade Commission, Bureau of Economics.

Table II-10

Summary of Concentration Levels
in the Uranium Supply Sector: 1974
(percent)

	4-firm	8-firm	15-fi
Proved reserves ($15)	47.7	71.2	83.
Mill production	61.3	86.2	99.
Mill capacity	55.7	77.8	95.
Exploration acreage	36.3	50.1	59.
Exploration drilling	41.5	52.5	63.

Source: Federal Trade Commission, Bureau of Economics.

To gauge the extent of ownership divergence within the major producer groups, we compare the identities and market shares of the top 8 producers in each phase of uranium activity analyzed above. Table II-11 identifies the top 8 producers in each activity; table II-12 tabulates their respective market shares for each of the categories listed (e.g., for the top 8 producers, table II-12 lists their aggregate market shares of reserves, exploratory effort, mill capacity, and mill production). Analyses of these two tables indicate a significant variety in ownership among the chief areas of uranium activity. In regard to the first comparison, there are 12 firms among the top 8 in at least one of the output categories (i.e., among the top 8 ranked by proved reserves, mill production, or mill capacity.) As displayed in table II-12, this pattern leads to significant variations in the respective market shares of the top reserves holders and millers. For example, although the top 8 mill producers control 86 percent of mill production, their share of proved reserves is only 48 percent. A similar pattern is found when the dominant proved reserves holders are compared to the leaders in exploratory effort. There are 14 companies included within at least one top 8 producer group as measured by proved reserves, acreage held for exploration, and exploratory drilling footage. Thus, although the top 8 reserves holders control 71 percent of total reserves, their share of exploration acreage is

Table II-11

Leading Eight Companies for Selected Categories of Uranium Activity: 1974

Company	Reserves ($15)	Mill production	Mill capacity	Acreage held for exploration	Exploratory drilling footage
	Top 8 membership (denoted by x)				
Anaconda Co.	x	x	x		
Exxon Corp.	x	x	x	x	x
Gulf Oil Co.	x			x	x
Getty Oil Co.	x		x		
Kerr-McGee Corp.	x	x	x	x	x
Phelps Dodge Corp. (Western Nuclear Inc.)	x				x
Utah International Inc.	x	x	x		
United Nuclear Corp.	x	x	x		
Cotter Corp.		x			
Rio Algom Ltd.		x			
Union Carbide Corp.		x	x		
Atlas Corp.			x		
American Nuclear Corp.				x	x
Continental Oil Co.				x	x
Mobil Oil Corp.				x	x
Pioneer Corp.				x	
Union Pacific				x	x

NOTE: Company placement within groups reflects alphabetical order, not relative ranking.

Source: Federal Trade Commission, Bureau of Economics.

Table II-12

Market Shares for Selected
Groups of Top Eight Companies: 1974

Top eight group - largest eight companies as measured by:	Top eight group's percentage share of:				
	($15) Proved reserves	Mill production	Mill capacity	Acreage held for exploration	Exploration drilling
Proved Reserves ($15)	71.2	69.7	70.3	33.9	29.9
Mill Production	48.2	86.2	71.9	29.3	26.4
Mill Capacity	51.0	78.7	77.8	29.1	27.4
Acreage held for Exploration	49.0	36.5	34.8	50.1	51.7
Exploration drilling	53.4	35.6	36.5	50.1	52.5

NOTE: Table is not a matrix. Figures should be read across the page. Thus, the top 8 reserves holders control 71.2 percent of reserves, 69.7 percent of mill production, etc. Similarily, the top 8 mill producers control 48.2 percent of proved reserves, 86.2 percent of mill production, etc.

Source: Federal Trade Commission, Bureau of Economics.

34 percent and their market share of exploratory drilling is approximately 30 percent. Overall, 17 companies are included in at least one top 8 output or exploration category.

The above ownership variations reflect past and ongoing structural changes within the industry. Differences in market shares among the dominant reserves holders and millers are a consequence of earlier variations in exploratory effort that allowed smaller millers and new entrants to increase significantly their proved reserves position vis-a-vis more established producers. Such a development originally manifests itself in differences between reserves and mill ownership since many of the successful new entrants have yet to develop mill capacity commensurate with their reserves holdings.

Similarly, ownership differences between reserves and exploratory effort may presage subsequent shifts in the identity of the top reserves holders. Such a development is not inevitable, it should be noted, since the correspondence between exploratory effort and subsequent reserves formation is inexact. Of particular relevance, differences in the quality of land holdings (a factor we cannot observe) can alter the prospects for discovery of commercial deposits. Nevertheless, the past relationship between the exploratory effort measures and subsequent reserves discoveries,[1] plus the significant financial resources of the top explorers not included among the major reserve holders (for example, Union Pacific, Continental Oil, and Mobil), lead to an expectation that some movement in subsequent reserve market shares will take place.

To conclude, uranium concentration in 1974 displays a mixed pattern. While concentration ratios for the individual output sectors are high, differences in the identities of the dominant companies among the principal phases of the uranium sector suggest a more expanded range of prospective suppliers than the separate concentration indices would indicate. This is especially true considering the long leadtimes involved in nuclear plant construction which allow purchasers a number of years to search for prospective sellers before actual supplies are needed. As a result, the relevant focus of competition in uranium pertains to the distribution of current exploratory capacity, rather than a single, narrowly defined, index of ex post capacity such as production. Concentration from this perspective appears to be low since there is a large nucleus of companies that maintain a leading position in one or more of the major areas of uranium supply. The validity of this assessment is further considered

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1 Uranium Price Formation, op. cit., notes that: "[I]n the past, when exploration activities have increased, they have been successful in the sense that rapid increases in reserves followed rapid increases in exploration activity" (p. 5-1). The report goes on to note that the apparent productivity of exploration effort has been declining (pp. 5-51 to 53).

in the next section where we analyze the uranium industry's condition of entry; i.e., the ability of smaller producers and new entrants to expand supply in response to favorable demand signals.

C. Condition of Entry

We now examine entry conditions within the uranium industry. Our aim is to ascertain the existence and importance of institutional and technological factors that can hinder the supply expansion potential of small producers and potential entrants.[1] Such factors, termed "barriers to entry," may increase the likelihood of monopoly performance (in an industry with a sufficiently small number of dominant producers) by removing the threat of competition created by potential entrants. Alternatively, a condition of "easy" entry makes adoption of monopoly pricing unlikely since the dominant producers are confronted by the threat of a competitive supply expansion by new entrants in response to attempts at raising price above longrun marginal cost.

The following factors, considered to be the most likely sources of entry barriers into the uranium supply sector, will be evaluated: long gestation period, control of superior resources by existing firms, economies of scale, and capital requirements for new entry.

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1 For economy of style, most references in this section will be to "new entrants" only. This term should be interpreted as including smaller existing uranium companies who may desire to enlarge considerably their scale of operation.

1. <u>Long Gestation Period</u>

The estimates cited earlier in this chapter indicate a lead time for uranium exploration and mine development of somewhere between 8 and 12 years. If firms could sell uranium only after production capacity has been established, the existence of a relatively lengthy gestation period might be construed as an entry barrier. In particular, if a small group of firms were able to raise prices above marginal costs of production and new entrants could bring competitive pressure to bear only after a 10-year period of exploration and development, there is at least the potential for short-term monopoly abuse. The long-term nature of exchange in the uranium market tends to mitigate this possibility, however.

Uranium is traded in two markets, a short-term "spot" market and a long-term or "futures" market. Contracting in the long-term market currently accounts for approximately 75 percent of total sales (measured annually by weight) and this percentage has been increasing as the commercial market for uranium has grown. Reliance on long-term contracts tends to be pro-competitive since the result is a flexible system of exchange from the standpoint of both buyer and seller. While a producer must have reserves producible for immediate delivery in order to compete in the spot market, it need not possess extant production capacity in order to secure a long-term contract for future delivery. What is required in the latter case is exploration and development activity sufficient to persuade a buyer of the potential seller's subsequent ability to meet the contract commitment. This situation is preferable from the buyer's point of view since it gives him access to a larger number of potential suppliers than would be the case under an exclusively spot market situation.

2. Superior Resources

One way in which entry into the uranium industry could be prevented is if all potential uranium-bearing lands were held by a small group of existing producers. This situation appears unlikely, however, since vast areas of potential uranium land in the United States remain unexplored and unclaimed. Virtually all of the uranium discovered thus far in the United States is in sedimentary rocks. Most of the deposits are found in a 450,000 square mile region in the West (See figure II-2). According to T. B. Cochran, "the majority of the exploration effort today is still concentrated in the vicinity of the producing districts, with less than 15 percent of that effort directed toward new prospects in non-producing areas."[1]

In addition, vast areas outside of the western region considered by the National Petroleum Council as potentially favorable for the discovery of uranium remain unexplored. One industry figure estimates that "50 percent of the United States is prospective territory and only a small part of this area has been explored to any appreciable extent."[2] This 50 percent figure includes much of the southeastern United States and Alaska.

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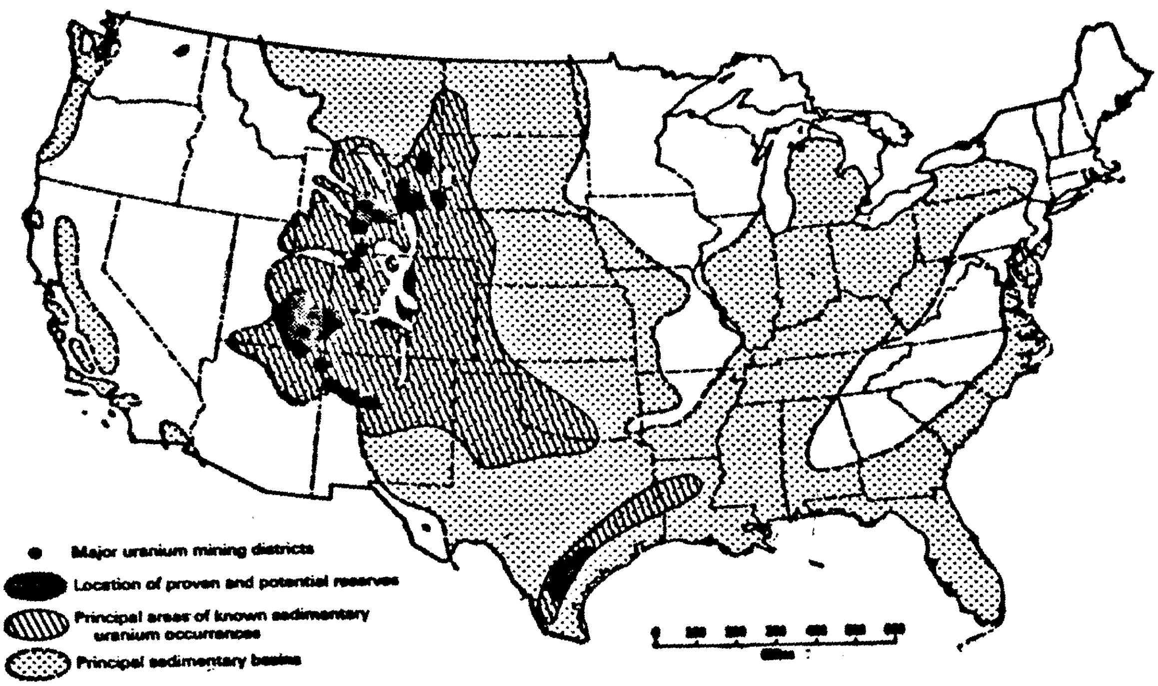
[1] T. B. Cochran, The Liquid Metal Fast Breeder Reactor, An Environmental and Economic Critique (Resources for the Future, 1974), p. 84.

[2] George Hardin, Jr., "Outlook for Nuclear Fuels," Quarterly of the Colorado School of Mines, vol. 68, no. 2 (April 1973), pp. 172, 173.

Figure II-2

Principal Sedimentary Basins in the United States

FIGURE 14. Principal Sedimentary Basins of the United States



Source: T. B. Cochran, The Liquid Metal Fact Breeder Reactor, An Environmental and Economic Critique (Rsources for the Future, 1974), p. 85.

Knowledge of uranium resources is also incomplete in other respects. Uranium deposits that are rich enough to exploit exis at over 4,000 feet, yet the average depth of drilling for uraniu in 1973 was less than 500 feet. To date the search for uranium has also been limited in terms of knowledge of depositional phenomena and environments. An Electric Power Research Institut study notes that

> Most of the uranium found in the United States so far has been in sandstones and the bulk of exploration has been directed at this type of deposit. In Canada and South Africa, on the other hand, Pre-Cambrian quartz pebble conglomerates have been dominant, whereas black shales have been productive in Sweden and Alaskatic segmatites are entering production in South-West Africa. Knowledge is still increasing as to the manner in which uranium deposits are formed and new knowledge will inevitably lead to new discoveries. Uranium also occurs in many mineral forms. Forms presently unimportant in some areas may play a large role in other areas.[1]

To summarize, the scope of unexplored uranium land is so extensive that prospects of resource monopolization appear remote. Such a conclusion is necessarily tentative, however, since no one can tell whether in fact significant quantities of uranium will be found in such non-established areas until extensive exploration actually takes place.

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1 "Uranium Resources to Meet Long Term Uranium Requirements," Electric Power Research Institute, Special Report (November 1974), pp. 23, 24.

3. Economies of Scale

When economies of scale make the efficient-sized firm large relative to the size of the market, it is possible for existing firms to set a price above the long-run marginal cost of production without attracting new entry.[1] This situation arises if a new firm is forced to enter at a scale that possibly will result in a perceptible decline in price and, thus, in profitability expectations. In deciding whether or not to enter, the new firm will estimate what price will prevail after its entry. If this price is below the competitive level, the firm will not enter even though the price prevailing before entry is in excess of the competitive level. Scale economies in this instance act as a barrier to entry by creating a significant divergence between pre- and post-entry price levels. Such a difference is greatest in an industry where initial output of a new entrant is large relative to the market as a whole and where growth in market demand is relatively low. The latter condition is important since a significant rise in market demand can offset the increase in supply created by new entry, leaving price unaffected.

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1 For a more thorough analysis of scale economies as a barrier to entry, see Scherer, op. cit., pp. 72-103. In addition to the factors noted below, the gap between pre- and post-entry price as perceived by the potential entrant depends on the expected supply response of the established sellers, the shape of the cost curve, and the price elasticity of demand.

In the case of uranium, a number of factors point to a relatively insignificant role for the scale economy barrier. Of particular relevance, DOE projections indicate that supply and demand conditions will allow for the entry of a large number of mine-mill production centers in the near future. By 1990 there are expected to be 49 production centers in operation, a gain of 29 over the mid-1977 total.[1] Prominent among these new facilities are those utilizing non-conventional milling methods that can operate on a relatively small scale.[2] Overall, the average size of the projected new plants relative to total output should be significantly lower than the relative size of current facilities since the average market share of new plants expected to be in operation by 1990 is 2 percent vis-a-vis a

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1 This estimate is derived from the DOE supply projection for production centers classified as classes 1, 2, and 3. The total concentrate output for these plants, 46,000 tons, roughly coincides with the projected uranium requirements (at .25 percent tails assay) of 47,000 tons uranium concentrate production for 1990. Both demand and supply analyses are derived from reports contained in DOE, Uranium Industry Seminar, October 26-27, 1977, GJO-108(77). The demand projection is from R. Brown and R. Williamson, "Domestic Uranium Requirements," p. 63. The supply analysis is from J. Klemenic and D. Blanchfield, "Production Capability and Supply," pp. 195-226. In regard to the latter, the number of plants is presented in figure 8 (p. 206) while production is listed in figure 12 (p. 210).

2 Six of the new mills are expected to be of non-conventional design, raising to 12 the number of such facilities anticipated in 1990. The number of non-conventional mills are provided by DOE staff specialist John Klemenic in personal correspondence. The distinction between conventional and non-conventional milling methods is described in J. Q. Jones, "Uranium Processing Developments," in DOE, Uranium Industry Seminar, op. cit., p. 193.

corresponding market share figure of approximately 4 percent for current plants.

The uranium industry's reliance on long-term contracts also tends to mitigate the impact of potential scale-related entry effects. This is so because entrants have the option of selling all or part of their planned output before plant construction actually takes place. The latter approach has been used with increasing frequency, especially by smaller producers desirous of outside financing. In such cases, the relevant stage of entry becomes the exploration phase where competition takes the form of rivalry for long-term contracts. Here the potential entrant is not concerned with the price depressing effects of his entry but, rather, has to deal with the less troublesome concern over the extent to which his entry into exploration will have on the price he must pay for potential uranium bearing lands. Since the minimum efficient scale for uranium exploration is quite low (see section II-b, above), the latter concern should not be of significant import.[1]

To conclude, expected demand and supply conditions, along with reliance of the industry on long-term contracts, point to an insignificant role for scale economies as an entry deterrent in

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1 This line of analysis is used in the Department of Justice report on the coal industry where the dedication of output before mine construction is common. U.S. Department of Justice, Competition in the Coal Industry (Washington: U. S. Government Printing Office, 1978), p. 74.

the uranium sector. It should be stressed, however, that this evaluation depends to a large degree on the attainment of the uranium demand levels projected by DOE. A sizable shortfall from these levels could create a more concentrated seller structure and an attendant scale-induced barrier problem. Such a development can be ascribed as well to deficient demand as to scale economies since the two are different sides of the same coin.

4. Capital Requirements

Investment expenditures required for establishment of an efficient scale of operation in an industry can form a barrier to entry if most of potential entrants are incapable of accumulating the requisite funds. In the case of uranium, capital requirements vary significantly with the extent of entry considered. Initial costs at the exploration stage are low, with most estimates being below $10 million. Initial expenditures necessary to produce uranium concentrate, however, are significantly higher. Minimum startup costs at this level, including expenditures for exploration, mining, and milling, have been estimated to range from 70 to $100 million (see section A.2).

While no convenient formula exists for determining the extent to which capital expenditure levels constitute a barrier to entry, the following factors suggest that initial capital requirements in uranium are not a formidable entry deterrent:

(a) In relative terms, the expenditure necessary for full scale entry (i.e., through the mill production stage) does not appear high. The $70 to $100 million range for full scale entry into uranium is equal to or below that required in eight of the twelve industries studied by F. M. Scherer et al., for example. (These industries are: Beer, Cigarettes, Petroleum Refining, Glass Bottles, Cement, Steel, Refrigeration, and Storage Batteries).[1] On the other hand, full entry into the uranium industry tends to be more expensive than establishment of coal production capability, which is estimated to range from $21 million to $84 million.[2] These latter values, it should be noted, have been characterized as presenting no entry obstacles.[3]

(b) Institutional arrangements within the uranium sector considerably reduce the capital expenditure (and associated uncertainty) burden borne by potential entrants. The nature of the contracting process is such that an entrant does not enter immediately at all stages but, rather, begins only at the exploration level, where capital expenditures are modest. It is

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1 F. M. Scherer, A. Beckenstein, E. Kaufer, R. Murphy, The Economics of Multi-Plant Operation (Cambridge: Harvard U. Press, 1975). The minimum capital requirement for each industry was calculated by the authors of the present report in the following manner: The minimum capital expenditure necessary to equate a minimum optimal scale (MOS) plant in 1965 was obtained from appendix table 3.7 (p. 426). This value was then multiplied by the smallest number of MOS plants deemed necessary for efficient operation by a firm (table 7.6, p. 336). The resulting capital expenditure figure was then adjusted for inflation by multiplying it by a factor of 1.96, the ratio of the 1977 implicit price deflator for total non-residential fixed investment to the corresponding figure for 1965 (Economic Report of the President, op. cit., table B-3, p. 260). Estimated capital expenditures for the 8 industries ranked above uranium ranged from $78 million for storage batteries to $2.4 billion for steel.

2 E. Pantos and R. Smith, Report to the Federal Trade Commission on the Structure of the Nation's Coal Industry, 1964-74 (Washington: U.S. Government Printing Office, 1978), p. 145.

3 Ibid., p. 125; Department of Justice, Competition in the Coal Industry, op. cit., pp. 74, 75; Electric Power Research Institute, Coal Price Formation, EPRI EA-497, pp. 3-11.

only after a commercial uranium deposit is found that decisions concerning the funding of a mine-mill complex must be confronted. At this juncture, the task of raising the necessary funds is considerably eased since documentation of the uranium deposit acts as confirmation to the capital market of the proposed project's viability. Firms also have the alternative of selling options on their yet unexploited reserves to purchasers in return for financing of the mine-mill complex. The latter form of fundraising has been utilized in a number of recent long-term contracts.

To summarize, the capital required for participation in the uranium production cycle does not, per se, appear to raise a formidable entry barrier. The necessary funds are of such a magnitude as to permit participation by a large variety of companies through internal financing or via capital markets. In addition, purchaser financing of a mine-mill complex is available to new entrants with the requisite uranium deposit.

5. Conclusion

The above analysis suggests that technological and institutional factors within the uranium sector do not pose a significant deterrent to supply expansion by potential entrants. The key elements in determining future supply appear to be expectations of future demand subject to technological and geological constraints that are faced more or less equally by existing and potential suppliers alike. Hence, the ability of one or a set of large producers to monopolistically restrict supply appears remote. This conclusion is necessarily tentative since it is based largely on deductive analysis, influenced by projections of future demand and supply patterns. As a useful complement to this approach, we now study the actual record of entry that has taken place in response to the post-1973 rise in uranium concentrate prices.

D. Record of Entry: 1974-77

We now review the actual record of entry into the uranium supply sector. Attention focuses primarily on the differential supply response of existing producers and new entrants to the substantial price rise in uranium concentrate that took place from late 1973 through 1976.[1] The magnitude and effect of this supply expansion is gauged by analyzing post-1974 developments in exploration activity and output concentration levels.

1. Exploration Activity

The uranium price rise that began in the latter part of 1973 stimulated a significant increase in the level of exploration activity. Between 1974 and 1977 exploration drilling footage increased 90 percent while the value of overall exploration expenditures rose at twice that rate. Also, the total acreage acquired for exploration during 1975-77 was over 90 percent higher than the corresponding level for the 1972-74 period (table II-13). By 1977 exploratory drilling footage had exceeded that for any earlier year (table II-13a).

The uranium price rise has also induced a significant number of new entrants into the exploration stage of the industry. A comparison of DOE surveys indicates that the number of firms exploring for uranium doubled over the 1974-77 period: DOE

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[1] The spot price of uranium concentrate rose from $9 per pound in 1973 to $21 per pound in 1974 and then increased to $44 per pound in 1976 (all in 1978 dollars). As of January 1978, the spot price was $43. U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, vol. 11, 1977, DOE/EIA-0036/2, p. 194.

Table II-13

Changes in Exploration Activity: 1974-77

1. Land acquired for uranium exploration (millions of acres)

1972-74	7.40
1975-77	14.23

2. Exploration Drilling:

	millions of: feet	millions of: dollars
1974	17.72	34.9
1977	27.96	99.4
Percent change	90.00	184.8

Source: Department of Energy, Uranium Exploration Expenditures . . . ., selected years: 1972 through 1978.

Table II-13a

Uranium Exploration Effort, Selected Indices: 1966-77

Year	Surface exploration drilling (mil. ft.)	Land acquired for uranium exploration (mil. acres)
1966	1.8	1.6
1967	5.4	4.1
1968	16.2	6.5
1969	20.5	3.6
1970	18.0	2.0
1971	11.4	1.6
1972	11.8	1.3
1973	10.8	2.8
1974	16.0	3.3
1975	16.5	3.5
1976	19.5	4.8
1977	28.0	6.0

Source: U.S. Department of Energy, Uranium Exploration Expenditures, selected years: 1971 through 1977.

surveyed 83 companies for its 1974 report vis-a-vis 168 in 1978.[1] Although the list of new entrants includes many small minerals concerns, it also contains firms of substantial size as well. For example, 8 of the new entrants are listed among the Fortune 500 Industrials, including U.S. Steel, Bethlehem Steel, International Paper, and a number of large petroleum concerns.[2] In addition, utilities have begun entering the production stage in increasingly greater numbers. Whereas less than 5 utilities were participants in the production sector in 1974, 30 were so identified in 1977.[3] As of January 1, 1978, approximately 30 percent of the uranium scheduled for delivery in 1985 was controlled by utilities, vis-a-vis less than 5 percent for 1978 delivery.[4]

Not surprisingly, the combination of new entry and increased exploration activity has led to a significant diffusion of exploratory effort. Between 1974 and 1976, 8-firm concentration levels based on drilling footage decreased 19 percent and the

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1 U.S. Department of Energy, Uranium Exploration Expenditures in 1977, and Plans for 1978-79 (Grand Junction Office, 1978); U.S. Energy Research and Development Administration, Uranium Exploration Expenditures in 1974, and Plans for 1975-76, GJO-103 (75).

2 The possible anti-competitive effects of petroleum firm entry are discussed in chapter III.

3 The 1974 figure is an estimate supplied by DOE officials. The 1977 figure is reported in U.S. Department of Energy, Survey of United States Marketing Activity, May 1978, DOE/RA-0006, p. 15.

4 Ibid., pp. 12, 13.

corresponding acreage-held-for-exploration measure declined 14 percent (table II-14).

2. Output Concentration Levels

Entry into the exploration stage is important chiefly to the extent that it results in increased ownership diffusion in the production phase. In this regard, the most important output measure is proved reserves, the successful end product of an exploration program. No direct link between recent entry and reserve ownership is possible, however, since insufficient time has elapsed between the onset of increased exploration activity in 1974 and the latest available year for reserve concentration data, which is 1976. Observation of the pattern of reserve concentration levels for the 1972-76 period indicates a rise in concentration through 1974, followed by a slight decline (see figure II-1, above). This later pattern may indicate the fruition of earlier (pre-1974) entry activity discussed in section B.

Effects of recent exploration activity are best ascertained through analysis of projected mill ownership patterns since a company's mill construction decision reflects its existing and anticipated reserves position. At the beginning of 1978, the volume of actual and planned capacity initiated since 1974 totaled 19,210 tons--55 percent of the 1974 mill capacity. This expansion should materially alter future ownership patterns since a significant amount is accounted for by new entrants and previously smaller millers. Thirty-nine percent of new capacity,

Table II-14

Acreage and Drilling
Footage Concentration: 1972-76
(percent)

	8-firm concentration level				
Exploration category	1972	1973	1974	1975	1976
Acreage held for exploration	54	54	50	NA	43
Drilling footage	64	68	68	58	55

Percentage change in 8-firm concentration ratio:

Period:	Acreage	Drilling
1972-76	-20.8	-14.1
1974-76	-14.0	-19.1

Source: Federal Trade Commission, Bureau of Economics.

for example, is accounted for by five companies that had no mills in 1974. Also, Phelps Dodge, a relatively small mill owner in 1974, is embarking on a mill expansion program that should significantly increase its future market share. Table II-15 lists actual and planned mill expansion totals for each company.

Effects of the recent mill expansion on ownership structure are tabulated in table II-16 where 1974 concentration levels are compared to a "future" concentration index based on current plus planned capacity.[1] At the 8-firm level, mill capacity concentration declines 11 percent, from an index of 78 to 69. Also noteworthy is the market share erosion of the dominant companies in 1974 considered as a group. The top 8 reserves holders' (as of 1974) share of mill capacity drops 11 percent while that of the 8 largest mill owners in 1974 declines 20 percent.[2]

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1 The planned mill capacity is expected to be completed within four years. Fred Facer, "Uranium Production Trends," in Department of Energy, Uranium Industry Seminar, 1977, GJO-108(77), p. 173.

2 The expectational nature of the future capacity base dictates caution in interpretation of concentration changes. Future mill capacity is biased downward to the extent that: (1) not all of the proposed expansion takes place and/or (2) newer mills utilize a lower grade ore (and thus have a lower concentrate yield per unit of ore processed) than existing mills. Although there is some probability that both of these developments may take place, the magnitude of their effect is expected to be relatively slight according to a DOE official. (Interview with DOE production specialist Fred Facer, July 26, 1978.) On the other hand, future capacity levels are biased upward to the extent that some mills will come on stream that have not yet been officially announced. The most prominent example of this latter possibility is Gulf: The company is in the process of developing extensive mining operations but has not yet officially announced construction of an associated mill.

Table II-15

Actual and Planned Changes in Mill Capacity: 1978

1974 Mill capacity rank	Company	Change in mill capacity: planned plus 1977 capacity minus 1974 capacity (tons daily)
1	Kerr-McGee Corp.	+ 2,500
2	United Nuclear Corp.	0
3	Atlantic Richfield (Anaconda Co.)	+ 3,000
4	Exxon Corp.	0
5	General Electric Corp. (Utah Intl., Inc.)	+ 1,050
6	Union Carbide Corp.	+ 200
7	Getty Oil Co.	+ 250
8	Atlas Corp.	− 400
9	Phelps Dodge Corp. (Western Nuclear Corp.)	+ 2,500
10	Continental Oil Co.[1]	+ 702
11	Homestake Mining Co.	+ 650
12	Standard Oil Co. (Ohio)[2]	+ 80
13	Reserve Oil & Minerals Co.[2]	+ 80
14	Pioneer Nuclear, Inc.[1]	+ 348
15	Federal Resources Corp.	0
16	Rio Algom Ltd.	+ 200
17	Commonwealth Edison Co. (Cotter Corp.)	+ 550
18	Newmont Mining Co. (Dawn Mining Co.)	0
19	American Nuclear Corp.	0
*	Southern California Edison[3]	+ 500
*	Union Pacific Corp.[3]	+ 500
*	Union Oil of Calif.	+ 3,000
*	Standard Oil Co. of Calif.	+ 2,500
*	Tennessee Valley Authority[4]	+ 1,000
	Total	19,210

* No mill Ownership in 1974

1 JV between Continental Oil and Pioneer.
2 JV between Standard Oil (Ohio) and Reserve Oil.
3 JV between Southern California Edison and Union Pacific.
4 JV between United Nuclear and Tennessee Valley Authority.

Source: "The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms," Discussion Paper #013, April 20, 1978, p. 24 and p. 30. ERDA "Uranium Industry Seminar," October 1975, p. 204.

Table II-16

Mill Capacity Concentration Trends for
Selected Groups of Uranium Producers

Group	Eight-firm concentration ratio (percent) 1974 Capacity	Future capacity*	Percentage change
8 Largest mill owners	77.8	69.4	-10.8
8 Largest mill owners in 1974	77.8	62.3	-19.9
8 Largest $30 reserve holders in 1974	70.3	62.5	-11.1

* Future capacity is defined as existing capacity as of 12/31/77 plus planned additions in 1978 and subsequent years.

Sources: Federal Trade Commission, Bureau of Economics; Ursula Guerrieri, The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms (Washington: American Petroleum Institute, 1978), table 9, p. 30.

To summarize, the level and diversity of the recent upsurge in exploration activity appears to be significant. Although its full effect cannot yet be delineated, it appears that this rise in exploratory effort is creating a greater diffusion in seller structure than that observed in 1974. Appreciable mill expansion efforts have been undertaken by relatively small existing millers as well as by new entrants. Such a development tends to confirm the a priori analysis in section 3 where it was concluded that entry barriers in the uranium supply sector are not high. The events reviewed in this section suggest that smaller producers and new entrants can in fact successfully expand output in response to favorable demand conditions.

E. Summary and Conclusions

The salient characteristics of the uranium supply sector reviewed in this chapter can be summarized as follows:

(1) The production cycle consists of four stages: exploration, development, mining, and milling. The discovery of a commercial ore deposit through exploration and development leads to construction of a mine, followed by erection of a mill for transformation of the ore into uranium concentrate. The mining and milling stages are closely linked since high transportation costs dictate that the mill be located close to the mine site. At present a high degree of integration exists between mining and milling: The bulk of ore milled by a company is also mined by it.

(2) Approximately 75 percent of uranium concentrate is sold under long-term contracts. Most sales are made by mill owners to utilities. The distinction between seller and purchaser sectors is becoming increasingly less clearcut as utilities become more involved in the production stage. Such backward integration has taken place through exploration financing agreements with independent producers and, more directly, through the establishment of production subsidiaries by utilities. Forty-seven percent of all uranium concentrate committed for delivery in 1985 is characterized by some form of purchaser control at the production stage.

(3) Scale economies are relatively minor at the exploration stage where technology permits efficient search activity by

a large number of companies. Although scale related efficiencie are potentially more significant at the mining and milling stages, their effect has been limited by the typical deposit siz which dictates a smaller scale of plant than the theoretical maximum.

(4) Capital costs necessary for entry into the exploration stage are not substantial. Capital expenditures are significantly higher at the mining and milling stages where combined initial investment is currently estimated at upward of $70 million. Such investment expenditures do not constitute an important impediment to entry, however, since a company's demonstration of a commercial ore deposit (the possession of which leads it to require a mine-mill complex in the first place) allows it to obtain adequate financing from either the capital market or purchasers of the final concentrate output.

(5) As conventionally defined, seller concentration based on output measures is relatively high. Based on various output and capacity indices, the 8-firm concentration ranged from 71 to 86 percent in 1974. These levels are significantly higher than corresponding levels in other energy sectors and greater than th average 8-firm index for the manufacturing sector. Yet the concentration of current productive capacity (i.e., the relative domination over future uranium supply generation by a specified number of firms) appears much lower than output concentration levels would indicate. For example, 17 firms in 1974 were

included in at least one top 8 uranium activity (reserves, production, acreage holdings, drilling footage). Since that time, a number of other producers have shown, through mill construction plans, significant supply generation ability. Five such companies had no mill facilities at all in 1974. The downward trend in exploratory effort concentration levels (i.e., those based on exploratory drilling and acreage held for exploration) may presage a further diffusion of productive capacity in the future.

The above characteristics lead us to conclude that the uranium supply sector is organized in a workably competitive manner. The principal area of competition takes place at the exploration stage where producers vie for the right to supply uranium to utilities under long-term contracts. There exists within this market a large and diverse set of potential suppliers, including the utilities themselves. In addition, the lack of significant entry barriers into uranium production suggests that the distribution of productive capacity is capable of further diffusion in response to the anticipated growth in uranium demand. We thus observe that the two necessary conditions for a non-competitive structure, control of productive capacity by a few producers and the existence of significant barriers to entry, are absent from the uranium supply market.

Chapter III

Interfuel Competition, Petroleum Firms, and the Competitive Potential of the Uranium Supply Market

Chapter II evaluated the uranium industry in the context of a separate market. We now consider the competitive potential of the industry from the perspective of a wider energy market where uranium is presumed to compete with other fuels. From this viewpoint the key issue to be analyzed concerns the effect of petroleum firm entry on the industry's competitive potential. Since these firms produce fuels that may compete with uranium, a possibility exists that their emphasis on uranium supply expansion will be less than that of an independent firm with no such conflicting interests to consider.

The first section reviews the role of petroleum firms in the uranium sector. The second section summarizes the nature and extent of interfuel competition. In the third section we analyze the competitive implications of petroleum firm entry into uranium.

A. Petroleum Firm Interest in the Uranium Industry[1]

The uranium sector is dominated by firms whose primary source of revenue lies in other sectors of the economy. Measured by 1977 mill capacity, petroleum firms are the most important industry group, accounting for over 42 percent of productive capacity. Independent uranium firms, in contrast, account for less than 20 percent of mill capacity. Among other industries represented are Electrical Equipment, Electric Utilities, and miscellaneous mineral and mining industries (table III-1).

Petroleum company interests extend to all facets of the uranium sector. As a group they account for approximately 55 percent of 1974 reserves and smaller, but significant, portions of drilling effort, acreage, and production (table III-2). This reflects a significant increase from 1965 when the petroleum group's share of reserves totaled 31 percent.[2] Signs point to a continued rise in petroleum sector interest since firms primarily classified as petroleum companies account for over 60 percent of the mill expansion planned as of the beginning of 1978.[3] Table III-3 lists those petroleum firms with mill capacity as of the end of 1977.

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[1] The petroleum group totals in this section include Anaconda's interests under those of Atlantic Richfield. Anaconda was officially acquired by Atlantic Richfield on January 12, 1977, pursuant to an agreement reached on July 26, 1976. Atlantic Richfield had earlier purchased 27 percent of Anaconda common stock on March 31, 1976.

[2] Thomas Duchesneau, Competition on the U.S. Energy Industry (Cambridge, Mass: Ballinger, 1975), p. 19.

[3] See table II-15, above.

Table III-1

Primary Industry of Companies Controlling
Uranium Mill Capacity: 1977

Industry group	Percentage of 1977 mill capacity
Petroleum	42.6
Uranium	19.0
Minerals Exploration and Mining	15.6
Electrical Equipment	9.8
Chemicals	7.1
Electric Utilities	2.7
Other	3.1
Total	100.0*

* Detail does not add to 100.0 due to rounding.

Source: Ursula Guerrieri, "The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms," American Petroleum Institute Discussion Paper (Washington: 1978), table 9, p. 30.

Table III-2

Summary of Petroleum Company Participation in Uranium: 1974

Category	Percentage of total accounted for by petroleum companies
Reserves ($30):	
Total	54.8
Drilling Footage:	
Exploratory	49.4
Total	62.9
Acreage	41.1
Mill Production	46.2

Companies included in the Petroleum Group: Atlantic Richfield Co., Continental Oil Co., Exxon Corp., Getty Oil Co./Skelly Oil Co., Gulf Oil Co., INEXCO Oil Co., Kerr-McGee Corp., Mobil Oil Co., Phillips Petroleum Co., Standard Oil Co. of Calif., Standard Oil Co. of Ohio, Union Oil Co. of Calif.

Source: Federal Trade Commission, Bureau of Economics.

Table III-3

Uranium Mill Capacity of Petroleum Firms
as of December 31, 1977

Rank	Producer	Mill capacity (tons U_3O_8 daily)	Market share (percent)
1	Kerr-McGee Corp.	7,000	19.9
2	Atlantic Richfield Co.	3,000	8.5
3	Exxon Corp.	3,000	8.5
4	Continental Oil Co.[1]	1,170	3.3
5	Standard Oil Co. (Ohio)	830	2.4
	Total Petroleum Firms	15,000	42.6
	Total all firms	35,160	100.0

[1] Joint venture where Continental's financial share is 66.7 percent and Pioneer's is 33.3 percent.

Sources: Federal Trade Commission, Bureau of Economics; Ursula Guerrieri, "The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms," American Petroleum Institute Discussion Paper #013, April 20, 1978, p. 30.

B. Uranium and Interfuel Competition

The demand for uranium is derived from the demand for nuclear fuel which in turn is derived from the demand for nuclear reactors by utilities. In addition to nuclear fuel, utilities also purchase oil, natural gas, and coal for their generating facilities. The degree of competition among these fuels in the utility market is far from uniform, however. In the short run, where utilities purchase fuel to supply existing facilities, relatively little competition takes place since most plants are not equipped to switch profitably from one fuel to another.[1] Uranium is particularly immune from such shortrun competition since the relatively low operating costs of nuclear reactors dictate that they be fully utilized within a wide range of nuclear fuel costs.[2]

The most significant potential for interfuel competition takes place in a longrun context via competition between rival generating systems. Fuels compete with each other to the extent that their costs represent a component in the overall cost of the generating facilities. In this market, the principal competitors are nuclear and coal plants. Petroleum fuel products, in contrast, are a relatively insignificant element due to a series

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1 U.S. Department of Justice, Competition in the Coal Industry (Washington: U.S. Government Printing Office, 1978), pp. 37-38.

2 U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, vol. II, 1977, DOE/EIA-0036/2, p. 205.

of economic and regulatory developments that have severely eroded their viability in the electric utility market. The OPEC stimulated rise in oil prices has practically eliminated that fuel from consideration in the choice of new power plants.[1] In addition, Government policy has attempted to discourage the use of both oil and natural gas as boiler fuels for new power plants.[2] As a result, projections indicate a significant drop in the share of the utility market supplied by oil and gas. Comparison between 1976 and DOE's "mid" (middle) case for 1990 indicates a drop of 50 percent in oil's share and a 64 percent decline in that of natural gas (table III-4).[3]

The principal area of interfuel competition in the electric utility market takes place between nuclear and coal power generating plants. These two systems are close substitutes from the view of utilities desirous of expanding their electrical

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1 For example U.S. Department of Justice calculations indicate that the price of oil would have to fall from 35 to 75 percent for it to prove competitive with coal in the relevant electric utility regional markets. U.S. Department of Justice, op. cit., p. 34. See also, Department of Energy, Annual Report to Congress . . ., op. cit., p. 214.

2 U.S. Department of Energy, Annual Report to Congress . . ., op. cit., p. 205.

3 Another possible uranium-petroleum link is through the transformation of coal into synthetic forms of crude oil and natural gas. These processes would allow coal to compete with oil in non-utility markets such as transportation. This development would indirectly link uranium to petroleum through the former's competition with coal. The near term outlook for synthetic is not optimistic, however. DOE's estimates place 1990 output of such products at well under 1 percent of total projected energy supply. (Ibid., p. 229.)

Table III-4

Market Shares for the Primary Fuel Inputs to Electric Utility Sector: 1976 and 1990

Primary fuel input	Percentage of total generation 1976	1990	1990 mid demand and supply case	Percentage change - 1976 to mid forecast for 1990
Coal	46	49-53	51	+ 10.9
Fuel oil	16	7-9	8	- 50.0
Natural Gas	14	1-6	5	- 64.3
Nuclear	9	26-27	26	188.9
Hydro	14	10-11	10	- 28.6

Source: U. S. Department of Energy, Energy Information Administration, Annual Report to Congress, vol. II, 1977, DOE/ELA -0063/2, table 10.12, p. 216.

generation capacity.[1] It is as necessary inputs for such systems that coal and uranium compete with each other. Uranium's influence in this competition is somewhat muted, however, because it represents a relatively small portion of total nuclear power costs. According to a recent study, the cost of uranium concentrate accounts for only 10 percent of total costs at the busbar for a nuclear generation plant.[2] As a result, changes in the price of uranium concentrate generate a proportionately lower change in the cost of a nuclear power plant. For example, a 50 percent increase in the price of uranium would, cet. par., increase the cost of a nuclear power plant by approximately 5 percent.

To conclude, uranium's competition for utility sales comes chiefly from coal, primarily in the market for new generating systems. Little competition is expected to take place between uranium and petroleum products due to a series of economic and regulatory developments that have severely constrained the ability of the latter to compete effectively in the market for utility purchases.

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[1] Electric Power Research Institute (EPRI), Coal and Nuclear Generating Costs (Palo Alto, Calif., 1977). This study finds that coal and nuclear power generation are "economically attractive" in all regions of the country (p. 6).

[2] Nuclear Energy Policy Study Group, Nuclear Power Issues and Choices, The Mitre Corporation for the Ford Foundation (Cambridge, Mass.: Ballinger, 1977), table 3-3, p. 126. This estimate is for a midwestern plant expected to begin operation in 1985. It is based on a price of $30/lb for U_3O_8. Other assumptions: tails assay of 0.20 percent; no reprocessing of spent fuel; costs of $3.33/kg for conversion, $80/kg/SWU for enrichment, and $90/kg for fabrication. All costs are in terms of mid-1976.

C. Evaluation

To restate the issue: Does the growing influence of petroleum firms in the uranium supply sector create a serious anti-competitive situation? An affirmative answer to this question is based on either (or both) of two potential monopolistic scenarios. Under the first, the withholding theory, petroleum firms restrict uranium supply in order to support the price of petroleum and thus maintain the value of their petroleum investments. The second entails a straightforward monopoly maneuver where entry into uranium is part of an overall plan to control a relevant portion of the energy market. Under this latter scenario, the objective is not to "protect" one fuel vis-a-vis another but, rather, to obtain a dominant position in both so as to pursue a monopolistic supply strategy aimed at the combined fuel market. The nature of interfuel competition suggests that the most likely target in this context would be a combined coal-uranium market. We now evaluate the plausibility of these two scenarios from the standpoint of the uranium market.

1. Uranium Entry as a Means of Protecting Petroleum Investments

The withholding theory imputes to petroleum entrants into uranium both the incentive and the ability to set the supply of uranium at a level below that desired by an independent uranium producer. The aim of this strategy is not to make supernormal profits in uranium but to protect returns to investments in the petroleum sector. This story is unconvincing since current supply and demand conditions within the relevant energy sectors suggest that a withholding action by petroleum companies is unlikely. The following factors are particularly relevant:

a. A key element in the withholding theory is the presumed sensitivity of petroleum demand to changes in uranium supply. It is this link that creates the incentive for petroleum firms to restrict uranium supply. In fact, analysis suggests that movements in uranium supply will have little influence on the market for petroleum products. As noted in section B, the principal area of competition involving uranium takes place in the market for new generating systems. Due to a series of economic and governmental developments, petroleum products are not expected to play a significant role in this market. The uranium-petroleum linkage is further reduced by the relative insensitivity of the cost of nuclear power to changes in uranium price. The estimates presented earlier suggest that to create a 5 percent increase in nuclear power cost, uranium price would have to rise by 50 percent.

b. The withholding scenario necessarily imputes to the petroleum firms the ability to raise the price of uranium by restricting its supply. Analysis indicates that the structure of the uranium supply market is not conducive to such action. The industry's relatively low entry barriers act as a constraint on attempts at monopolistic supply control in the long run since there exists a large nucleus of smaller producers and potential entrants, often financed by utilities, that appear capable of expanding supply to the competitive level. Similarly unlikely is a noncollusive withholding maneuver where an individual petroleum firm attempts to raise price by sitting on uranium reserves so as to force development of less efficient deposits. This notion implies a deterministic schedule of steeply rising resource extraction costs from which a producer can calculate his effect on price. In fact, supply studies indicate a highly uncertain supply response where a large variety of possible price scenerios are possible.[1]

c. Although the period of observation and the available data are inadequate to serve as a conclusive test, the petroleum firms' behavior in the uranium sector cannot be utilized to support allegations that they have attempted to restrict supply. A likely withholding pattern would be one where petroleum firms amass sizable stocks of acreage and, possibly, reserves but engage in relatively little mill capacity expansion. As indicated by the figures summarized in table III-5, such a development has not taken place. While the reserves position of the petroleum firms is significant, they have pursued a substantial mill capacity expansion program, accounting for over 60 percent of mill tonnage additions executed or planned as of

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[1] For example, see the discussion in Electric Power Research Institute, Uranium Price Formation (Palo Alto, California, 1977), pp. 10-1 to 10-37. The study concludes by noting that "it is unwise to underestimate the supply response of U_3O_8 to rising prices" (p. 10-37).

Table III-5

Selected Market Share Indices of Petroleum
Company Activity in the Uranium Sector: 1974-77

Uranium category	Market share (percent)	
	All petroleum companies	Major petroleum companies[1]
1. Proved reserves ($30)		
1974	54.8	31.6
1976	56.0	N.A.
2. Acreage held for exploration		
1974	41.0	26.8
1976	43.0	N.A.
3. Mill capacity		
1974	47.0	10.7
1977	42.6	21.9
future[2]	52.5	22.7
4. Mill capacity expansion		
1974-78[3]	62.2	28.6

N.A. - not available

1 Atlantic Richfield, Exxon, Gulf, Mobil, Standard Oil of California, Standard Oil of Indiana, Shell, and Texaco.

2 Future capacity is December 31, 1977, mill capacity plus additions announced as of January 1, 1978.

3 Change in mill capacity calculated as the difference between 1974 capacity and the future "future" capacity index, defined as 1977 capacity plus announced expansions.

Source: Federal Trade Commission, Bureau of Economics

January 1, 1978. Firms within the major producer group have accounted for approximately 28 percent of mill expansion.[1]

Also of note, most petroleum firm entry has taken place _de novo_ rather than via the acquisition of existing companies.[2] Thus, the initial entry movements of petroleum companies have not represented a corporate transfer of productive capacity but, rather, additions to it.

To conclude, the withholding theory of petroleum firm entry into uranium does not appear likely. Under present conditions petroleum companies possess neither the incentive nor the ability to pursue such a strategy. Furthermore, the available evidence indicates that they have not attempted to do so.

2. Domination of the Coal-Uranium Market

Since coal is uranium's principal effective competitor, joint ownership of coal and uranium interests becomes the more important antitrust issue. From this viewpoint, the diversification efforts of petroleum firms are relevant primarily because of the apparently greater tendency of such firms to enter both coal and uranium markets. (For example, 7 of the 10 companies surveyed by the FTC that maintained both coal and uranium reserves

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[1] As commonly defined, these are: Atlantic Richfield, Exxon, Gulf, Mobil, and Standard Oil of California. The remaining members of the major group for which no milling activity was recorded are Shell Oil, Standard of Indiana, and Texaco.

[2] The principal exception is the 1977 acquisition of Anaconda by Atlantic Richfield.

were classified as petroleum companies.)[1] Objections to such energy diversification efforts stem from the fear that they will lead to higher prices in one or both of the coal and uranium markets. From this viewpoint, the concern is that energy conglomerates will minimize the effect of interfuel competition by pursuing a joint fuel supply strategy. At the extreme, this position is based on the premise that coal and uranium trade in the same market so that simultaneous entry into both fuel sectors represents a horizontal expansion movement leading eventually to monopolistic domination by a few petroleum firms.

The degree to which the concern over multi-fuel ownership is valid depends on the susceptibility of the coal and uranium sectors considered individually to monopolization. The undesirability of cross ownership is greatest when each sector is capable of being organized in a monopolistic fashion since such a pattern negates the deconcentrating effects of a widening market. Alternatively, multi-fuel ownership cannot create a monopolistic environment where each sector is competitively structured. The following simplified example illustrates the nature of these considerations.

Consider an industry with two regionally distinct production centers, A and B. Due to minimal transportation costs, the goods

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[1] This finding probably overstates the relative importance of petroleum firm multi-fuel ownership, however, since the FTC coal survey placed a special emphasis on obtaining returns from coal owning petroleum companies. See, E. Pantos, R. Smith, Structure of the Nation's Coal Industry, 1964-74, FTC Staff Report (Wash.: U.S. Govt. Printing Office, 1978), p. 9.

from each center trade in the same market. An antitrust policy issue that arises is whether companies should be allowed to own production facilities in both geographic areas. Polar situations of high and low anti-competitive potential stemming from multi-area ownership are the following:

a. High anti-competitive potential. Each area can be classified as a "natural monopoly" where technology dictates a single seller. In this case, dual ownership implies that the same seller will prevail in both areas, leading to a single firm monopoly for the industry as a whole. A ban on such ownership is clearly preferable here since it doubles the number of sellers, from one to two.

b. Low anti-competitive potential. Structural conditions in A and B are such that a large number of sellers can be accommodated in each. Specifically, consider a case where 30 sellers can be accommodated in each area, each with the same share of productive capacity. In this situation, chances of anti-competitive effects from dual area ownership become remote. Since concentration in each area is low, the concentration in the combined national market must be low also. In the "worst" case, where the 30 firms in one area have identical positions in the other, concentration in the aggregate market remains at the same level as each area considered individually. Since the latter were deemed competitive, a similar organization for the aggregate market must be judged likewise.

The coal-uranium case obviously does not precisely fit either of the above examples. The situation does appear much closer to the second case than to the first. However, structural conditions within the two sectors, as well as the actual pattern of multi-fuel ownership, suggest that the anti-competitive potential of petroleum firm entry into coal and uranium is quite low.

In regard to structure, neither coal nor uranium appear susceptible to monopolization--through either internal expansion or new entry by petroleum firms. Both sectors exhibit relatively moderate entry barriers and are expected to experience high growth rates in demand over the near term future.[1] The trend in production concentration levels has followed a similar pattern in both sectors: significant increases during the 1960's when demand was slack, followed by slight declines in the 1970's as supply expanded in response to more optimistic market conditions. This latter development reflects in part the record of entry,

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1 The nature of seller structure in the uranium market is described in chapter II of this report. The following studies have found the coal industry to be structured in a workable competitive manner: U.S. Department of Justice, Competition in the Coal Industry, op. cit.; Electric Power Research Institute, Coal Price Formation (Palo Alto, Calif.: 1977) EPRI/EA - 497, esp. pp. 3-11; General Accounting Office (GAO), The State of Competition in the Coal Industry (December 30, 1977) EMD -78-22; E. Pantos, R. Smith, The Structure of the Nation's Coal Industry, op. cit. A number of the above reports point out the possibility of future problems in the western coal market if Federal leasing does not resume. For a view holding that the coal sector is susceptible to monopolization, especially by petroleum firms, see H. Sanger and W. Mason, The Structure of the Energy Markets: A Report of TVA's Antitrust Investigation of the Coal and Uranium Industries (Tennessee Valley Authority: February 1979).

which has been significant. Based on projected supply and demand conditions, scale economies in both sectors appear to allow for the coexistence of a large and diverse population of firms.

In addition to the competitive structure of the coal and uranium sectors, the effect of dual fuel ownership on aggregate concentration levels for a composite energy market has so far been minimal. This can be inferred from table III-6 which tabulates 1974 coal and uranium reserves for groups of companies ranked by their $30 uranium reserves holdings.[1] In addition to the nationwide coal market, coal reserves indices for the western region[2] are also presented since it is in this area that coal and uranium compete most closely in the market for new power generating systems.[3] The resulting pattern shows little ownership overlap between the two fuel sectors. The top 8 uranium reserves holders control less than 8 percent of either national or western coal reserves. Overall, firms with uranium reserves holdings account for less than 15 percent of national coal reserves and approximately 20 percent of western coal reserves. Only one company ranked within the top 8 uranium

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1 Coal reserves market shares are tabulated from responses to the FTC Coal Reserves Survey. The base utilized in deriving company market share is the Geological Survey estimate of total coal reserves less those on unleased Federal lands.

2 The western region includes the following States: North Dakota, South Dakota, Montana, Wyoming, Idaho, Colorado, Utah, Arizona, New Mexico, Alaska, Washington, Oregon, and California.

3 <u>EPRI</u>, <u>Coal and Nuclear Generating Costs</u>, <u>op</u>. <u>cit</u>., p. 6.

Table III-6

Coal and Uranium Reserves Market Shares
for Uranium Reserves Holders: 1974

	Percentage share of 1974 reserves accounted for by uranium firms in designated size group		
Size group arranged by $30 uranium reserves rank	$30 Uranium reserves	Nationwide coal reserves*	Western coal reserves*
Top 8	67.9	7.0	7.9
Remainder	32.1	7.2	12.2
Total	100.0	14.2	20.1

* Calculated by dividing company reserves by a base consisting of total coal reserves less those on unleased Federal lands.

Source: Federal Trade Commission, Bureau of Economics.

reserves holders has a similar position in the national and western coal sectors.

The above analysis casts considerable doubt on fears that energy conglomerates will dominate a combined coal-uranium market. Viewed separately, neither sector appears susceptible to domination by a small group of firms, whatever their interests in other energy markets. In addition, the diversity of multi-fuel investments indicates no tendency for the relevant fuel markets to be controlled by a similar set of firms.

D. Conclusions

The analysis of this chapter indicates that petroleum firm entry into uranium does not pose a competitive threat. Two theories of monopoly effects from such entry were examined. The first viewed the petroleum firms' interest in uranium as a means of protecting the value of their oil and gas properties. The second viewed the petroleum firms' participation in uranium as part of a strategy designed to dominate a combined coal-uranium market. Both of these theories were found to be unconvincing. Four principal factors led to this conclusion:

First, the moderate nature of entry barriers into uranium make it difficult for any group of companies to set supply levels monopolistically. Structural conditions are such that a large and diverse set of companies have sufficient supply capability to frustrate attempts at monopoly pricing.

Second, the diverse nature of interfuel diversification contradicts the view of a monolithic movement leading to domination of relevant energy markets by a few petroleum based energy conglomerates. The top 8 uranium reserves holders, for example, control only 20 percent of petroleum production and less than 8 percent of coal reserves. Only one company is ranked within the top 8 group of petroleum, coal, and uranium reserves holders.

Third, the monopoly theories seriously overstate the current and expected degree of interaction between the petroleum, coal, and uranium markets. Very little interfuel competition takes place between petroleum and uranium. Uranium and coal do compete via the rivalry between nuclear and coal powered generating systems, yet this competition is indirect since each fuel comprises a relatively small portion of total generating system costs.

Fourth, petroleum firms have added significantly to productive capacity in the uranium sector. Contrary to the expectations of the monopoly models, they have not simply amassed reserves and acreage but are in the process of significantly expanding the industry's mill capacity. They also have tended to avoid entry by merger in favor of developing supply capability through internal expansion.

These findings recommend against proposals to limit the participation of petroleum firms in the uranium sector. Considering the general importance of unrestricted entry as a pro-competitive element, attempts to limit such activity should be undertaken only where a strong case can be made that the net effect will be positive. In our view, the position in favor of restrictions on petroleum firm entry into uranium fails to meet this test at the present time.

Chapter IV

Policy Recommendations

A. Antitrust within the Uranium Production Industry

No need for structural antitrust action in the uranium production sector is apparent at this time. Evidence developed in this report favors the view that the industry is organized in a workably competitive manner. Of prime importance, institutional and technological factors provide an environment of relatively easy entry. Also, ownership patterns suggest the development of a relatively unconcentrated seller structure that should become more diffuse as the uranium market grows.

This finding does not necessarily imply that monopolistic activity within the industry cannot occur. A combination of the uranium market's emphasis on long-term contracts and the sometimes erratic nature of demand may create situations where short-term, noncompetitive displacements exist. What the analysis does suggest is that such occurrences are best approached through surveillance of the industry's behavior, rather than by attempts at modification of its structure.

B. Petroleum Firm Entry into Uranium Production

No economic justification for the limitation of petroleum firm entry into uranium is apparent at this time. The workably competitive nature of the uranium market, along with the diversity of multi-fuel petroleum company holdings and the limited nature of interfuel competition (especially between uranium and petroleum), suggest no significant anti-competitive effects from petroleum firm participation. In the absence of such effects, petroleum firm entry should be viewed as a pro-competitive development since this activity has generally taken place de novo and has contributed significantly to the expansion of uranium milling capacity.

C. Backward Integration of Electric Utilities into Uranium Production

Electric utilities have displayed an increasing preference for direct participation in the uranium production stage. This development raises a difficult policy issue since positive as well as negative elements are involved.

On the positive side, utility entry into uranium production can strengthen competition by providing a well-financed, alternative source of productive capacity. Even the potential for such action can give utilities important leverage in their dealings with producers. Also, control of uranium supply by utilities may result in efficiency gains due to their ability to avoid certain transactions costs involved in long-term contracts with producers.[1]

On the other hand, utility ownership of production facilities may create regulatory difficulties. As natural monopolies, the price charged by a utility for its electricity is regulated on a cost of service basis in an attempt to approximate competitive

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[1] A discussion of the efficiency gains from integration is contained in O. E. Williamson, "The Economies of Anti-trust: Transaction Costs Considerations," University of Pennsylvania Law Review (May 1974), pp. 1439-1496.

levels. Such a procedure is frustrated if a backwardly integrated utility can shift monopoly profits to its production subsidiary by charging an inflated price to itself for the uranium fuel input. Attempts by regulators to control the input transfer price charged by integrated utilities may exacerbate the situation by creating additional distortions.[1]

Information sufficient to support an opinion on the likely net effect of the above tendencies is not available. The potential distortions from utility integration are significant enough, however, to warrant further investigation into the matter. Such a probe might be usefully linked with a study of utility integration into coal production, such as that recently announced by the Department of Justice.[2]

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[1] For example, attempts at rate of return regulation can induce firms to seek an inefficiently large base of physical capital. See W. Baumol and A. Klevorick, "Input Choices and Rate of Return Regulation: An Overview of the Discussion," Bell Journal of Economics and Management Science (Autumn, 1970), p. 162.

[2] U. S. Department of Justice, Competition in the Coal Industry, (Washington: U. S. Government Printing Office, 1978) p. 118.

APPENDIX A

Supplementary Tables

Table A-1

Uranium Mills Operating as of December 31, 1977

Mill	Parent company	Mill location	Tons ore/day
1. Kerr-McGee	Kerr-McGee Corp.	Grants, New Mexico	7,000
2. UNC Homestake Partners	United Nuclear Corp.--70% Homestake Mining Co.--30%	Grants, New Mexico	3,500
3. Church Rock Mill	United Nuclear Corp.	Church Rock, New Mexico	3,000
4. Anaconda	Atlantic Richfield Co.	Grants, New Mexico	3,000
5. Exxon	Exxon Corp.	Highland, Wyoming	3,000
6. Lucky Mc Shirley Basin	General Electric Co.	Shirley Basion, Wyoming	1,800
7. Conquista	Continental Oil Co.--66.7% Pioneer Corp.--33.3%	Falls City, Texas	1,750
8. Western Nuclear	Phelps Dodge Corp.	Jeffrey City, Wyoming	1,700
9. L-Bar	Standard Oil Co. (Ohio)--50% Reserve Oil and Minerals Co.--50%	Ceboletta, New Mexico	1,660
10. Lucky Mc Gas Hills	General Electric Co.	Gas Hills, Wyoming	1,650
11. Union Carbide Uravan	Union Carbide Corp.	Uravan, Colorado	1,300
12. Union Carbide Gas Hills	Union Carbide Corp.	Natrona County, Wyoming	1,200
13. Atlas	Atlas Corp.	Moab, Utah	1,100
14. Bear Creek Mill	Southern California Edison Co. --50% Union Pacific Corp.--50%	Bear Creek, Wyoming	1,000
15. Federal-American	Federal Resources Corp.--60% American Nuclear Corp.--40%	Gas Hills, Wyoming	950
16. Rio Algom	Rio Algom Ltd. (Canadian Corp. controlled by Rio-Tinto-Zinc Corp. Ltd.)	LaSal, Utah	700
17. Cotter	Commonwealth Edison Co.	Canon City, Colorado	450
18. Dawn/Midnite	Dawn Mining Co. is 51% owned by Newmont Mining Corp. and 49% owned by Midnite Mines	Ford, Washington	400
		TOTAL	35,160

Source: Ursula A. Guerrieri, "The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms," American Petroleum Institute discussion paper #013 (April 20, 1978). Table 6, p. 24.

Table A-2

Uranium Mills Under Construction or Announced as of December 31, 1977

Mill		Parent company	Mill location	Nominal tons capacity ore/day
1.	Anaconda Mill	Atlantic Richfield Co.	Grants, New Mexico (expansion)	3,000
2.	--	Union Oil Co. of Calif.	Red Desert, Wyoming	3,000
3.	--	Chevron, USA	Panna Maria, Texas	2,500
4.	--	United Nuclear Corp.--50% Tennessee Valley Authority--50%	Morton Ranch, Wyoming	2,000
5.	--	Phelps Dodge Corp.	Wellpinit, Washington	2,000
6.	Petrotomics Mill	Getty Oil Corp.	Shirley Basin, (renovation) Wyoming	1,750
7.	--	Kerr-McGee Corp.	Power River Basin, Wyoming	2,500
8.	Conquista Mill	Continental Oil Co.--66.7% Pioneer Corp.--33.3%	Falls City, Texas (expansion)	1,050
9.	Pitch Mill	Homestake Mining Co.	Marshall Pass, Colorado	600
10.	Cotter Mill	Commonwealth Edison Co.	Canon City, Colorado (expansion)	550
			TOTAL	18,950

Source: Ursula A. Guerrieri, "The Structure of the U.S. Uranium Industry and the Role of Petroleum Firms," American Petroleum Institute discussion paper #013 (April 20, 1978). Table 8, p. 29.

Table A-3

Largest U.S. Petroleum Producers: 1976

Rank	Producer	U.S. Petroleum Production (BBls./Day)	Market Share (percent)
1	Exxon Corp.	1,757,608[1]	9.5
2	Royal Dutch Shell Group	1,551,185[2]	8.4
3	Texaco, Inc.	1,323,983[3]	7.1
4	Std. Oil Co. Ind.	1,040,890[4]	5.6
5	Mobil Oil Corp.	790,499[5]	4.3
6	Gulf Oil Corp.	685,600	3.7
7	Atlantic Richfield Co.	624,117	3.4
8	Std. Oil Co. Calif.	596,987	3.2
9	Getty Oil Co.	481,261[6]	2.6
10	Union Oil Co. Calif.	464,847	2.5
11	Phillips Petroleum Co.	427,087	2.3
12	Sun Oil Co.	421,181	2.3
13	Cities Service Co.	356,749	1.9
14	Continental Oil Co.	346,942	1.9
15	Tenneco, Inc.	296,608	1.6
16	Marathon Oil Co.	256,575[4]	1.4
17	Amerada-Hess	169,229[4]	0.9
18	Kerr-McGee	81,165[7]	0.4
19	Std. Oil Co. Ohio	39,601[4]	0.2
20	Apco Oil Co.	33,824	0.2
	Total Domestic Production	18,577,080	

Note: Natural Gas liquids converted to BBls/Day of crude oil using the equivalency factor: 1BBl. oil = 1.454 BBls. N.G.L. Natural Gas converted to BBls./Day of crude oil using equivalency factor 1 BBl. oil = 5.626 cu. ft. Gas.

1 Gross production.
2 Figure include: No. Amer. Oil Prod. for Royal Dutch and Western Hemisphere Gas Prod. for Royal Dutch.
3 Texaco's oil + N.G.L. figures are gross and includes interest in non-subsidiary Cos.
4 Natural Gas figure is for North America.
5 Natural Gas figure is for Western Hemisphere.
6 Used 1975 figure for No. Amer.--1976 Not available.
7 Used 1975 figure--1976 Not available.

Sources: National Petroleum News Fact Book Issue, Mid-May, 1977, pp. 22, 23; Moody's Industrial Manuals, 1976, 1977; Moody's--Public Utility Manual, 1977; John Herold, Inc., Oil Industry Comparative Appraisals, various issues. Total Domestic Production--AGA, API, CPA. Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1976, Vol. 31, May 1977, pp. 10, 11, 91.

Table A-4

Concentration Levels in Uranium: 1955-77

Year	8-Firm Concentration Level (percent) Production	Mill capacity	Reserves $8	Reserves $15
1955	99.1			
1960	72.4			
1964			80	
1965	79.3			
1970	80.8		71	
1972	85.2	77.6	72	59.6
1974	86.1	77.8	74.4	71.2
1976	85.0	78.0		71.0
1977		77.4		

Source: Federal Trade Commission, Bureau of Economics.

APPENDIX B: JOINT VENTURE ANALYSIS*

Joint venture activity in the nuclear industry is extensive, with approximately 106 on-going agreements as of January 1, 1975. Of these agreements, 96 involved uranium exploration, mining, and milling (See table B-1), while the remaining 10 involved the development of new mining techniques, reactor systems, and components and materials, as well as the construction and operation of reactor systems and fuel reprocessing plants. This discussion focuses on those nuclear joint ventures involving domestic uranium exploration, mining and milling.[1]

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* This section was written by Steven C. Martin. It was completed in April 1977 and is based on information derived from FTC subpoenas issued in 1975.

[1] While there are a significant number of foreign joint ventures involving domestic corporations, such ventures are primarily conducted with foreign partners and are not considered here.

Table B-1

Uranium Industry Joint Ventures Active as of January 1975

Operator	Year entered into	Partners
American Nuclear (See also Federal Resources, Phelps Dodge)		
	1972	Tennessee Valley Authority
Atlantic Richfield Co.		
	1969	Private Individuals
	1972	Pioneer Corp.
	1972	Dalco Oil Co. (Sabine Royalty Co.)
	1972	Lonestar Producing Co.
Cities Service Co.		
	1970	Continental Oil Co.
Cleveland Cliffs Iron Co.		
	1968	Getty-Skelly Oil Co.
	1972	Getty-Skelly Oil Co. Pioneer Corp. Texas Eastern Transmission Corp. Thunderbird Petroleum
	1974	Texas Eastern Transmission Corp. Pioneer Corp.
	1975	PNC (Japanese)
Continental Oil Co. (See also Cities Service Co.)	1967	Pioneer Corp.
	1969	Pioneer Corp.
	1969	Pioneer Corp.
	1969	Inexco Oil Co.

Table B-1 (continued)

Operator	Year entered into	Partners
	1970	Pioneer Corp.
	1970	Cities Service Co. Pioneer Corp.
	1971	Kerr-McGee Corp.
	1972	Private Individuals
	1973	PUK) Total-CMN) French
	1973	Framco (French)
	1974	Urangesellschaft (German)
Dennison Mines U.S.		
	1973	Cabot Corp. Pioneer Corp.
Earth Resources Co.	1969	Marathon Oil Co.
	1969	Phillips Petroleum Co.
	1970	Marathon Oil Co. Union Pacific Corp.
Federal Resources Corp. (See also Pioneer Corp., Union Pacific Corp.)		
	1959	American Nuclear Corp.
	1970	Pioneer Corp. Texas Eastern Transmission Corp.
	1973	Pioneer Corp. Texas Eastern Transmission Corp.
FRAMCO (Frontier Mining Co.)	1974	Occidental Minerals Corp. Ranchers Exploration and Development Co.

Table B-1 (continued)

Operator	Year entered into	Partners
Getty Oil Co. (includes Skelly Oil Co.) (See also Pioneer Corp. and Cleveland Cliffs Iron Corp.)	1960	Kerr-McGee Corp.[1]
	1970	Phelps-Dodge Corp. (Western Nuclear Corp.) Trend Exploration Co.
	1970	Kerr-McGee Corp.
	1971	Pioneer Corp. Trend Exploration Co. Phelps-Dodge Corp. (Western Nuclear Corp.)
	1971	Cities Service Corp. Phelps-Dodge Corp. (Western Nuclear Corp.) Trend Exploration Co.
	1974	Public Service Co. of Oklahoma
Gulf Oil Co.	1970	Kerr-McGee Corp.
	1970	Exxon Corp.
	1970	Exxon Corp. Superior Oil Co.
	1972	H. R. Smith Group Skinner Corp. J. D. Davidson
	1973	Exxon Corp. Superior Oil Co.
	1974	U.S. Energy Co.
	1974	Cabot Corp.

[1] Getty purchased Kerr-McGee's share of "Petrotomics" in 1975. Calculations include this joint venture since it was in effect as of 1/1/75.

Table B-1 (continued)

Operator	Year entered into	Partners
Homestake Mining Co.	1968	Pioneer Corp.
	1968	United Nuclear Corp.
Kerr-McGee Corp. (See also Gulf Oil Corp., Continental Oil Co., Getty Oil Co., Marathon Oil Co.)	1968	J Group (Japanese)
	1974	Colorado Corp.
Marathon Oil Co. (See also Earth Resources Co.)	1969	Kerr-McGee Corp. Earth Resources Co. (Vitro)
Mobil Oil Co. (See also Pioneer Corp., Gulf Oil Corp.)	1969	Cordero Mining Co.
	1970	Cordero Mining Co.
	1970	Morrison
	1973	Gulf Oil Corp.
Mono Power Co. (Southern California Ed. Co.) (See also Earth Resources Co.)	1970	Union Pacific Corp.
Newmont Mining Co. (Dawn Mining Co.)	1969	Pioneer Corp.
Phelps-Dodge Corp.		

Table B-1 (continued)

Operator	Year entered into	Partners
(Western Nuclear Corp.) (See also Getty-Skelly Oil Co., Reserve Oil and Minerals Co.)		
	1969	American Nuclear Corp.
	1971	Geomet Mining and Exploration Co.
	1974	New Mexico and Arizona Land co. Reserve Oil and Minerals Co.
Phillips Petroleum Co. (See also Earth Resources Co.)	1968	Private Individuals
	1969	Private Individuals
	1969	Nuclear Dynamics, Inc.
	1973	Everest Exploration Co.
	1973	Pioneer Corp. Texas Eastern Transmission Corp.
Pioneer Corporation (Pioneer Nuclear) (See also Getty-Skelly Oil Co. Union Pacific Corp., Continental Oil Co., Newmont Mining Corp., Phillips Petroleum Co., Atlantic Richfield Co., Federal Resources Corp., Cleveland Cliffs Iron Co., Dennison Mines U.S.)		
	1969	NEDCO Cordero Mining Co.
	1971	Koch Exploration Co. (Koch Industries)
	1972	Harrington Interest
	1972	Atlantic Minerals Corp.

Table B-1 (continued)

Operator	Year entered into	Partners
Pioneer Corp. (cont'd)	1972	Mobil Oil Cor. Federal Resources Corp.
	1973	Texas Eastern Transmission Corp.
	1973	Phillips Petroleum Co. Texas Eastern Transmission Corp.
	1974	NEDCO Texas Eastern Transmission Corp.
	1974	Getty-Skelly Oil Co. Texas Eastern Transmision Corp.
	1974	NEDCO Wyoming Minerals Corp. Texas Eastern Transmission Co.
	1974	Mobil Oil Corp. Texas Eastern Transmission Corp.
Ranchers Exploration and Development Co. (See also FRAMCO)	Not known	Houston Natural Gas and Oil Co.
	1974	Marline Oil Co. Frontier Resources, Inc.
	1974	Urangesellschaft (German)
	1974	TUFCO (Texas Utilities Co.)

Table B-1 (continued)

Operator	Year entered into	Partners
Reserve Oil and Mineral Corp. (See also Phelps-Dodge Corp. Western Nuclear, Inc., Standard Oil Company of Ohio)	1966	Phelps-Dodge Corp. (Western Nuclear Inc., Now part of joint venture between Phelps-Dodge Corp., New Mexico and and Arizona Land Co. and Reserve Oil and Minerals Co.)
	1971	Lodestar Uranium Co.
	Not Known	Woodmont (Continental Materials Corporation)
Standard Oil Company of California	1971	Natural Resources Development Co.
	1973	Centennial Development Company
	1973	Westan Kaycee
Standard Oil Company of Ohio	1969	Reserve Oil and Minerals Co.
Union Oil Company of California (Minerals Exploration Co.)	1969	Silver Bell Industries
Union Pacific Corp. (Rocky Mountain Energy Co.) (See also Mono Power Co.)	1971	Great Basins Petroleum Co. Mono Power Co. (Southern California Edison Co.)
	1971	Mono Power Co. (Southern California Edison Co.) Pioneer Nuclear, Inc. Federal Resources Corp.
	1974	Urangesellschaft (German)

Table B-1 (continued)

Operator	Year entered into	Partners
United Nuclear Corp. (Teton Exploration Co.) (See also Homestake Mining Co.)	1973	Tennessee Valley Authority
	Not Known	Duval Corp.
	Not Known	NEDCO
Uranerz (German) (See also Wyoming Minerals Corp.)	1973	Inexco Oil Co.
	1974	Inexco Oil Co.
Wyoming Minerals Corp. (Westinghouse Elec. Corp.) (See also Pioneer Corp.)	1973	Uranerz (German)
	1974	Power Resources Corp.
	1975	Meeker
	1975	Burlington Northern Inc.

Source: Federal Trade Commission, Bureau of Economics.

Joint ventures may have both pro- and anti-competitive effects.[1] These effects must be carefully analyzed and balanced before any action is considered to restrict the freedom to enter into such ventures.

Joint ventures in uranium exploration and development can be pro-competitive in several ways. The first of these involves reducing the risk of uneven corporate performance which is associated with a natural resource industry. Every uranium project carries with it a certain probability that no exploitable uranium will be discovered. Since corporate managers desire to present their shareholders with a picture of steadily improving performance, they may seek to reduce the risk of uneven performance by spreading the funds they are willing to invest over a

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[1] Joint ventures also create difficulties in the measurement and analysis of reserve concentration. Specifically, where reserves are controlled in joint ventures, the significance of concentration ratios becomes clouded by the inability to ascertain what portion of jointly-held reserves is actually controlled by each of the parties to the venture. A straight apportionment of reserves by percent interest may not take into account various forces of size and economic power which in fact place control of all of the reserves in the hands of one or a limited number of partners. Various formulae have been proposed to allocate jointly-held reserves. Some have assumed that in natural resource joint ventures involving major producers, control of reserves is shared according to actual percent interests, while in ventures involving large and small producers, a majority or plurality interest controls 100 percent of the reserves. In the uranium industry approximately 90 percent of all reserves are held by individual companies, while only 9 percent are held in joint ventures (See table B-2). Due to the small role played by jointly held reserves it was decided that application of an allocation formula would have limited benefits. Thus, in calculating concentration ratios, reserves were allocated on a percent interest basis.

Table B-2

Uranium Reserves Held by Joint Ventures

	Forward cost category			
	$8	$10	$15	$30
Percent of total reserves held by producing joint ventures	8.0	8.5	8.8	9.1
Percent of total reserves held by nonproducing joint ventures	1.0	3.8	3.9	4.1
Total percent of all reserves held by joint ventures	9.0	12.3	12.6	13.2
Percent of all reserves held by individual companies	91.0	87.7	87.4	86.8

Source: Federal Trade Commission, Bureau of Economics.

number of projects. Since the amount of exploration undertaken in any given location and the size of any production complex ultimately constructed are dictated by such factors as geologic conditions and economies of scale, the size of uranium projects cannot be made arbitrarily small. Thus, the desire to achieve steady performance is likely to manifest itself in joint ventures. For small firms who have limited funds to invest, joint ventures may be the only way of achieving this goal.

Joint ventures may also allow firms to take advantage of any economies of scale which may exist in the industry. Small individual land holdings may be pooled into parcels susceptible to more efficient large scale drilling operations. The need for such joint venture activity is particularly prevalent in the uranium industry, where much of the public land available for exploration is splintered under the claim staking system of the General Mining Law of 1872.[1] Joint ventures also enable owners of reserves to join together to build one large mill, with its attendant economies of scale. However, less use is made of joint ventures solely for production, perhaps in part because once uranium is discovered the value of the property is more easily determined, making it more susceptible to sale or exchange.

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1 Report to the Federal Trade Commission on Federal Energy Land Policy: Efficiency, Revenue, and Competition, Bureau of Competition, Bureau of Economics, October 1975, Chapter VII.

Finally, joint ventures provide a means whereby small firms can join together or with a large capital rich firm to obtain financing for the construction of a mine and mill complex.

The basic problem raised by joint ventures is the potential for contractual relationships among participants to lead to parallel behavior with respect to control and disposition of reserves held by the venture or the individual partners.[1] This concern is of particular importance in a mining industry where the production process is of such technical complexity as to warrant extensive coordination and cooperation among the partners. Such cooperation may provide a suitable environment for explicit actions designed to restrict or otherwise control production and prices. Short of explicit conspiracy, the mere exchange of information and the development of interpersonal ties among management may indirectly lead joint venturers to be less than effective competitors in the market place. For example, knowledge of each other's costs or pricing policies may allow partners to coordinate their bidding strategies. Given a choice, management may choose not to compete as vigorously against a partner as against an unrelated corporation.

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[1] To date uranium joint ventures have been on a project-by-project basis, with the individual partners continuing to compete against each other in the sale of uranium. Thus, unlike the joint venture of the type held illegal in U.S. v. Penn-Olin Chemical Co., 378 U.S. 158 (1964), the joint ventures in the uranium industry have not substituted one enterprise (the joint venture) for two or more (the partners).

The competitive effects of joint venture activity in the uranium industry are difficult to evaluate. However, a review of the purposes and mechanics of some typical joint venture agreements and an analysis of who the typical joint venture partners are may be useful in evaluating the potential for parallel behavior and its effect on competition.

Exploration joint ventures are generally entered into for the purpose of exploring specific parcels of land within a given "area of interest." The individual parties are, in many cases, simultaneously conducting their own independent exploration in nearby areas, but agree not to purchase rights to property within the area without first offering it to the joint venture. An operator is designated to carry out the venture, but the other parties retain the right to inspect the operation and any associated financial or technical records and, should the operator fail to carry out their plans, to choose a replacement.

While some agreements are limited solely to exploration and expire after a given time period or upon completion of a specified exploration program, other agreements cover all stages of exploration, development, and production. Generally, a program is proposed for each stage of the operation. In some cases a majority interest must approve a program before any activity can be conducted. In that case, failure to obtain majority approval would presumably lead to dissolution of the venture. Other agreements provide that if a proposal does not receive majority approval, any party may elect to carry it out on its own.

If a program receives majority approval or if majority approval is not needed and some parties elect to proceed, work commences. Parties choosing not to participate need not contribute their share of expenses but are deemed to have transferred all or part of their interests in the property to the remaining parties. In the event uranium is discovered, a nonparticipating party may regain its interest only after paying back its original share of expenses plus a substantial penalty. The earlier in the project a party becomes a nonparticipant the higher the penalty and, in some cases, parties who drop out in the exploration stage cannot regain their interest in the event uranium is ultimately discovered.

Should a party desire to sell its share in the venture, agreements generally provide that it may do so at any time provided that it first offer its share to the remaining parties. A party is generally also free to take on one or more new partners to share its expenses and interest in the venture. Finally, agreements generally provide that any uranium produced from a jointly held mill is delivered in kind to the individual partners according to their share in the project.

Of the 96 exploration, mining, and milling joint ventures active as of January 1, 1975, at least 9 occurred between firms who hold little or no reserves.[1] Thirty-five involved 2 or more existing reserve holders,[2] while 52 were between existing reserve holders and companies holding little or no reserves (See Table B-3). In other words, each existing reserve holder entered into an average of 1.1 joint ventures with another reserve holder[3] and 1.7 joint ventures with newly entering companies. Table B-3 also indicates that the top 4 and top 8 firms engaged in joint ventures among themselves at a slightly lesser rate. These figures suggest that joint venture activity is occurring predominantly among reserve holders and newly entering firms. A review of the agreements indicates that these ventures typically involve a small company which owns property and is seeking capital or expertise from a more established firm. Any attempts by the larger partner to control the production or disposition of the resources appear substantially constrained by the terms of the agreement. Typical contracts provide the opportunity for smaller parties to go forward with development and production on their own or with additional parties and to receive in kind their share of the uranium produced.

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1 The subpoenas were issued to companies thought to hold uranium reserves. Thus, some joint ventures among nonreserve holders were undoubtedly missed.

2 The term "existing reserve holder" refers to those 31 firms who control between 91 percent and 96 percent of the $8-$30 reserves.

3 The total number of partners in these 35 joint ventures who were among the top 25 $8-$30 reserve holders was 74. This is an average of 2.1 partners in each venture.

Table B-3

Comparison Between Joint Activity of the Top 4, 8, and 25 $8-$30 Uranium Reserve Holders

	Top 4 (6 companies)	Top 8 (9 companies)	Top 25 (31 companies)
All Joint Ventures			
Total	17	34	87
Average per firm	2.8	3.8	2.8
Joint Ventures Among One Another			
Total	4	9	35
Average per firm	0.7	1.0	1.1
Joint Ventures With Other Reserve Holders			
Total	9	19	35
Average per firm	1.5	2.1	1.1
Joint Ventures With Nonreserve Holders			
Total	8	15	52
Average per firm	1.3	1.7	1.7

Source: Federal Trade Commission, Bureau of Economics.

The technology, personnel and expertise associated with uranium exploration and development are substantially unrelated to those involved in the production and marketing of uranium. Of the 96 existing ventures active as of January 1975, only 4 had evolved to the production stage, and these accounted for 22 percent of total 1975 domestic productive capacity (table B-4). Each of these production ventures consisted of two existing reserve holders.

Table B-4

Production Capacity Controlled by Joint Ventures as of January 1975

	Capacity tons ore/day	Percent of total
Standard Oil of Ohio Reserve Oil	1,500	4.3
Homestake Mining - United Nuclear	3,500	10.0
Continental Oil - Pioneer	1,750	5.0
Federal - American	950	2.7
Atlantic Richfield* - Dalco U.S. Steel	Pilot Project	-
Total Joint Venture capacity	7,700	22.0
Total Mill capacity	34,950	100.0

* Atlantic Richfield has since sold its interest to the remaining partners.

Source: Federal Trade Commission, Bureau of Economics.

APPENDIX C: MERGERS AND RESERVE PURCHASES IN THE URANIUM INDUSTRY, 1955 - 1974*

Since 1955, there have been approximately 40 mergers or acquisitions in the nuclear energy industry (See table C-1). In 36 of these cases, both the acquiring and acquired companies were involved in uranium exploration, development, mining, or milling. Figure C-1 plots the number of mergers and acquisitions for each of the years 1955-1974, averaged over a three-year period. The graph indicates that merger activity has decreased slightly over the years.

Table C-2 provides a breakdown of acquisitions and mergers among the top 4, 8, 15, and 25 holders of $30 uranium reserves as of January 1, 1975. According to table C-2, the top 4 reserve holders in 1974 were involved in one-third of the 36 acquisitions in the uranium industry since 1955, while the top 8 accounted for more than half of these acquisitions.

Table C-3 lists the companies which entered the uranium industry through the acquisition of on-going uranium firms. It is significant to note that no petroleum company entered the uranium business through merger or acquisition.

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* This section was written by Steven Martin and Anthony Majewski. It was completed in April 1977 and reflects material collected until that time. Its chief source of information was material obtained through the FTC uranium investigation.

Table C-1

Mergers and Acquisitions in the Nuclear Energy Industry: 1955-74

Acquiring Company		Acquired Company	Year
Atlantic Richfield Co.	-	NUMEC	1967
		Sinclair Oil Corp.	1969
Atlas Corp.	-	Almar Minerals	1955
		Lisbon Uranium	1959
		Mountain Mesa	1959
		Rio de Oro Mines	1959
		Radium King Mines	1959
		Hidden Splendor Mines	1962
		Uranium Reduction	1962
		Utex Exploration Co.	1962
		Texas Zinc Mines	1963
Babcock & Wilcox Co.	-	NUMEC	1971
Commonwealth Edison Co.	-	Cotter Corp.	1974
Federal Resources Corp.	-	Federal Uranium Co. merged with Radorock Resources to become Federal Resources Corp.	1960
		Cal-U-Mex Uranium	1965
Getty Oil Co.	-	Skelly Oil Co.	1967
		Nuclear Fuel Services	1969
Kerr-McGee Corp.	-	Pacific Uranium Mines Co.	1960
		Gunnison Mining Co.	1961
		Lakeview Mines	1961
		Ambrosia Lake Mining Corp.	1962
		Kermac Nuclear Fuels	1964
Newmont Mining Co.	-	Dawn Mining Co.	1955
		Foote Minerals	1974
Phelps Dodge Corp.	-	Western Nuclear, Inc.	1969
		(Coke River Development Co.,	1955
		Great Northern Oil & Uranium, and	1956
		Wyoming Mining & Mineral Co. were purchased by Western Nuclear Inc. prior to the purchase of Western Nuclear by Phelps Dodge)	1962
		Allied Nuclear	1970

Table C-1 (continued)

Acquiring Company	Acquired Company	Year
Union Carbide Corp.	Trace Elements	1956
	Globe Mining Co.	1958
	Beaver Mesa Uranium, Inc.	1966
United Nuclear Corp.	Pinion Uranium Corp.	1956
	Black Jack Corp.	1959
	United Western Mining Co.	1961
	Bigbee & Stephenson Group, Inc.	1963
	Quinta Corp.	1963
	Teton Exploration Co.	1968
	Uranium Recovery	1971
Utah International, Inc.	Lucky Mac Uranium Co.	1958

Source: Federal Trade Commission, Bureau of Economics.

FIGURE C-1

AVERAGE NUMBER OF MERGERS AND ACQUISITIONS 1955-1974
(THREE-YEAR AVERAGES)

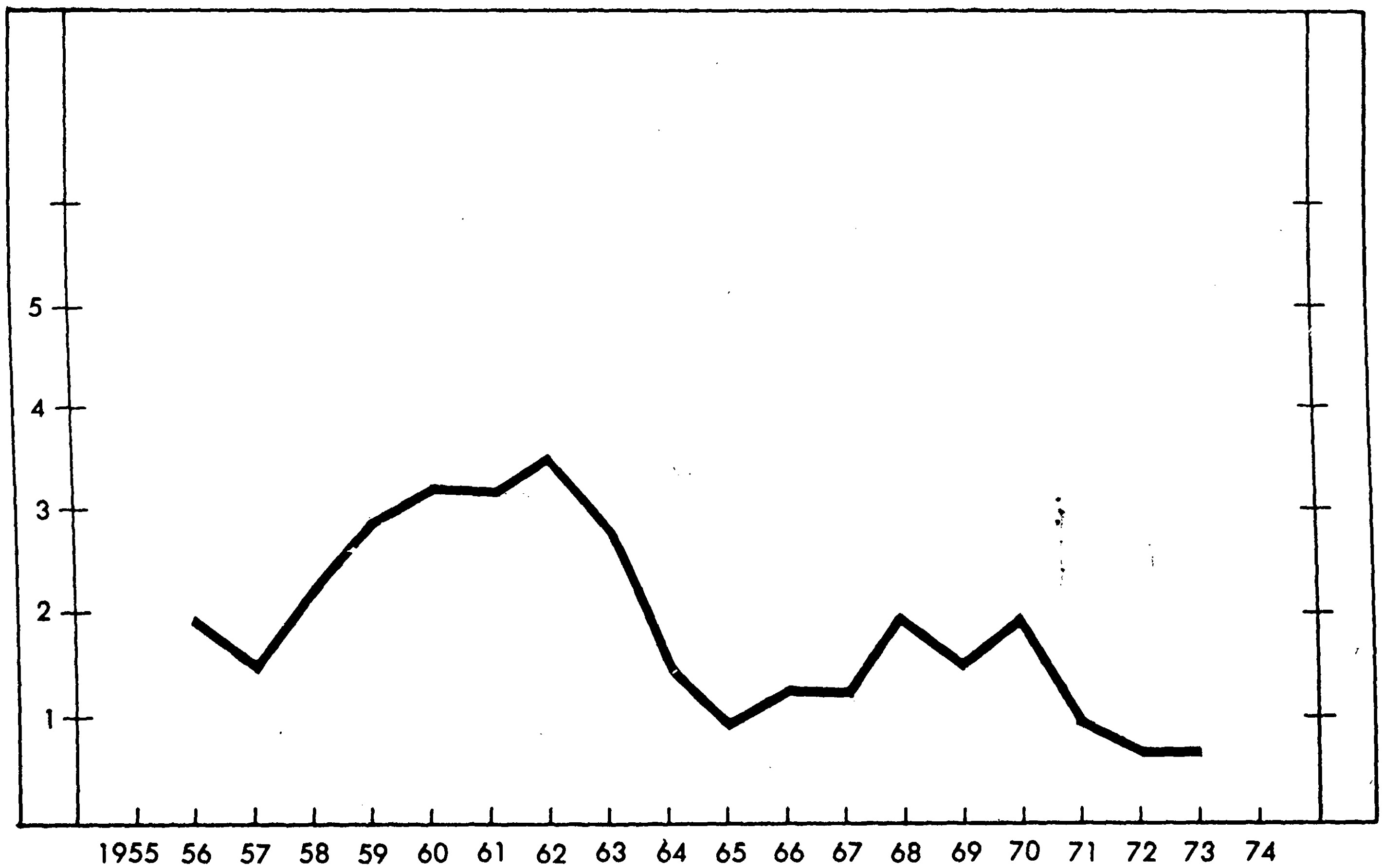

Table C-2

Uranium Company Acquisitions and Mergers by Top Reserve Holders in the $30 Forward Cost Category as of January 1, 1975

	Top 25 reserve holders	Top 15 reserve holders	Top 8 reserve holders	Top 4 reserve holders
Number of acquisitions and mergers	36	23	20	12

Source: Federal Trade Commission, Bureau of Economics.

Table C-3

Companies Which Entered the Uranium Business Through the Acquisition of Ongoing Firms

Acquiring firm	Acquired firm	Year
Utah International Inc.	Lucky Mac Uranium Co.	1958
Phelps Dodge Corp.	Western Nuclear Inc.	1969
Commonwealth Edison Co.	Cotter Corp.	1974

Source: Federal Trade Commission, Bureau of Economics.

About 49,800,000 pounds of uranium reserves changed hands through corporate mergers and acquisitions over the years (See Table C-4). In addition, some companies purchased properties containing known uranium reserves. At least 90,837,500 pounds of reserves were acquired in this manner, all by companies currently among the top 4 reserve holders (See table C-4). Most of these purchases occurred when one joint venture partner bought out another partner's shares of jointly held reserves.

Since the initiation of this study, two significant acquisitions in the nuclear energy industry have occurred. General Electric acquired Utah International, a major reserve holder, and Atlantic Richfield has acquired the Anaconda Company, also a major holder of reserves. The GE-Utah acquisition was not challenged by the Department of Justice after an agreement was executed whereby GE's holdings of Utah's stock would be placed in a trust to be voted by independent trustees until the year 2000. GE also agreed not to buy uranium from Utah. The Arco-Anaconda merger has been challenged by the FTC.

Table C-4

Partial* Tabulation of Companies Obtaining Reserves Through Mergers or Acquisitions and Purchases of Uranium Properties

Companies acquiring reserves	Type of acquisition	
	Corporate	Property
Commonwealth Edison Co.	x	
Gulf Oil Co.		x
Union Carbide Corp.	x	
United Nuclear Corp.	x	x
Total uranium reserves acquired	49,851,000 lbs	90,837,500 lbs.

* This table includes only those mergers, acquisitions, and purchases where subpoenaed data indicated specific quantities of uranium changed hands.

Source: Federal Trade Commission, Bureau of Economics.

APPENDIX D: DATA PRODUCTION PROCEDURES

At the outset of the study, it was necessary to determine the identity of the firms which make up the uranium industry. ERDA supplied the staff with a list of the 31 top reserve holders. The major domestic oil producers and large western land holding railroads were added to this list, bringing the total to 50 firms. Subpoenas were issued to each of these companies (See table D-1).

Midway through the study, a check was made to ensure that no firms had been overlooked. A list was compiled using prior studies, ERDA information and publications, subpoenaed documents, Moody's and Standard & Poor's Industrial Manuals, and Atomic Industrial Forum[1] membership lists of all companies which the staff had reason to believe might have been or presently were involved in the uranium industry. Using such sources as Dunn & Bradstreet and the Engineering and Mining Journal directories, addresses were sought for those companies still in existence and inquiries sent to each, asking the extent of their involvement in the industry. Eighteen companies responded (see table D-2). While some reported that they held up to a total of several million pounds of uranium and were actively exploring for uranium, none appeared to constitute a major member of the industry.

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* This section was written by Steven F. Martin. Except for the concluding section, all governmental references are to ERDA (Energy Research and Development Administration), the agency in charge of uranium information at the time this section was written April 1977, ERDA was subsequently subsumed under the newly created Department of Energy.

[1] The Atomic Industrial Forum is the trade association for the nuclear industry.

Table D-1

COMPANIES SUBPOENAED

Allied Chemical Corp.
American Nuclear Corp.
Anaconda Co.
Atlantic Richfield Co.
Atlas Corp.
Babcock & Wilcox Co.
Burlington Northern, Inc.
Chicago, Rock Island & Pacific R.R.
Cities Service Co.
Cleveland Cliffs Iron Co.
Combustion Engineering, Inc.
Commonwealth Edison Co.
Consumers Power Co.
Continental Oil Co.
Exxon Corp.
Federal Resources Corp.
General Atomic Co.
General Electric Co.
Getty Oil Co.
Gulf Oil Corp.
Homestake Mining Co.
Inexco Oil Co.
Kerr-McGee Corp.
Marathon Oil Co.
Mobil Oil Corp.
National Passenger Service Corp.
Newmont Mining Corp.
Phelps Dodge Corp.
Phillips Petroleum Co.
Pioneer Natural Gas Co.
Ranchers Exploration & Development Co.
Reserve Oil & Minerals Corp.
Rio Grande Industries, Inc.
Rio Tinto - Zinc Corp. Ltd.
Royal Dutch/Shell Group
Santa Fe Industries, Inc.
Southern Pacific R.R.
Standard Oil of California
Standard Oil of Indiana
Standard Oil of Ohio
Studebaker - Worthington, Inc.
Sun Oil Co.
Tenneco, Inc.
Texaco, Inc.
Union Carbide Corp.

Table D-1 (continued)

COMPANIES SUBPOENAED

Union Oil of California
Union Pacific Corp.
United Nuclear Corp.
Utah International, Inc.
Westinghouse Electric Corp.

Table D-2

Additional Uranium Companies Contacted

Total - 87
*Contacted - 42
**-Responded-18
E-Engaged in uranium exploration itself or as operator of a joint venture
E-JV-Engaged in uranium exploration through a joint venture where it is not the operator

*	American Smelting & Refining Co.	
	Archer and Associaties	E
	Atlantic Minerals Corp.	E-JV
	Atomic Fuel Corp.	
	Berge Exploration	
	Bethlehem Steel	E-JV
**	Bokum Resources	E
*	Buttes Oil & Gas Co.	
**	Cabot Corp.	E-JV
**	Callahan Mining	
	Calvin Blade Enterprises	
	Canso Oil & Gas, Inc.	E
	Centennial Development Co.	E-JV
*	Consolidated Oil & Gas, Inc.	
*	Continental Materials Corp.	E-JV
	Cordero Mining	E-JV
	Dennison Mines U. S.	E-JV
	DeVilliers Nuclear Corp.	E
*	Duval Corp.	E-JV
*	Earth Resources Corp.	E
**	Earth Sciences	E
	Enerdyne Corp.	
**	Energy Resources Corp.	E
	Everest Exploration Co.	E-JV
**	Felmont Oil Corp.	E
*	Four Corners Exploration Co.	
	Framco (French)	E
*	Freeport Minerals	
**	Frontier Resources, Inc.	E
	Geo Industries	E
	Great Basins Petroleum Corp.	E-JV
*	Golden Cycle Corp.	
**	Hecla Mining Co.	E
	Houston Natural Gas and Oil Co.	E-JV
	Houston Oil & Minerals Corp.	
**	Hydro Nuclear Corp.	
*	Idaho Mining Corp.	E
	J & P Corp.	E-JV
	J Group (Japanese)	E-JV
**	Keradamex, Inc. (Canadian)	E

Table D-2 cont'd.

	Kern County Land Co. (Tenneco)	
**	Koch Exploration Co.	E-JV
	Lodestar Uranium, Inc.	E-JV
*	Lonestar Producing Co. (Utility)	E-JV
*	Louisiana Land Exploration	
	Marline Oil Co.	E-JV
	Mineral Energy Co.	
**	Minerals Engineering Co.	E
	Mono Power (So. Cal. Edison)	E-JV
	Montana Nuclear Corp.	
*	Mountain West Mines	
	M. P. Grace	E
	Natural Resources Development Co.	E-JV
**	NEDCO	
**	New Mexico & Arizona Land Co. (St. Louis and San Francisco Railway)	E
	Newpark Resources Land Co.	E
	Niagara Mohawk	E-JV
	Nubeth Joint Ventures	
	Nuclear Dynamics Co.	E
*	Nuclear Resources, Inc.	E-JV
*	Occidental Minerals Corp.	
	PNC (Japanese)	E-JV
*	Power Resources Corp.	E
	PUK (French)	E-JV
**	Sabine Royalty Corp.	E
	Sante Fe Industries	E
*	St. Joe Minerals	
	Silverbell Industries	E-JV
*	Standard Metals Corp.	E
*	Strategic Minerals Exploration Co.	
**	Superior Oil Co.	E-JV
	Total CMN (French)	E-JV
*	Trend Exploration Co.	E-JV
	TVA	E-JV
	Texas Eastern	E-JV
	Texas Utilities Fuel Co.	E-JV
	Thunderbird Petroleum	E-JV
**	U.S. Energy Corp.	E
	U.S. Steel	E-JV
	Uranium Production Co.	
	Uranerz (German)	E
	Urangasellschaft (German)	E-JV
	Uravan Minerals, Inc.	E-JV
*	U. V. Industries	
**	Webb Resources, Inc.	E
	Westan Kaycee	E-JV
*	Western Standard Corp.	E
*	Wold Nuclear Co.	

Table D-2 (con'd.)

Additional Companies Listed by ERDA as Engaging in Uranium Exploration But Who Are Not Major Reserve Holders (These Companies Were Not Contacted)

Central Power and Light	E
Cerro Power and Light	E
Dennison Mines	E
Felmont-Northern States Power	E
Fritz-Ericson	E
F. B. Binder	E
Geomet Mining Company	E
Hauptman, Ivan J.	E
John Schumaker	E
Kirkwood Oil Company	E
Minerals Associates	E
Oklahoma Public Service	E
Rampart Exploration Corporation	E
Uranex USA, Inc.	E
Woodard, Charles	E

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