

PNL 935
NOV 11 1981

A-77-11
IV-6

U. S. Uranium Mining Industry: Background Information on Economics and Emissions

C. A. Breda
L. A. Deitz
E. G. Johnson
J. K. Young

RECEIVED
ENVIRONMENTAL PROTECTION
AGENCY
APR 11 1984
GENERAL DOCKET
SECTION

March 1984

Prepared for
the Environmental Protection Agency
under Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute



PNL-935

CONTENTS

1.0	SUMMARY.....	1.1
2.0	INTRODUCTION.....	2.1
3.0	INDUSTRY DESCRIPTION.....	3.1
3.1	COMMODITY CHARACTERISTICS.....	3.1
3.1.1	Uranium Uniqueness.....	3.1
3.1.2	Terminology.....	3.6
3.1.3	Chemistry.....	3.7
3.2	DEPOSIT-TYPE DESCRIPTIONS.....	3.9
3.3	MINING PROCESSES.....	3.12
3.3.1	Underground Mining.....	3.13
3.3.2	Open-Pit Mining.....	3.15
3.3.3	Solution Mining.....	3.16
3.4	WASTE MANAGEMENT.....	3.16
3.4.1	Airborne Waste.....	3.16
3.4.2	Liquid Wastes.....	3.18
3.4.3	Solid Wastes.....	3.19
3.4.4	Reclamation.....	3.19
3.5	MINING INDUSTRY STATISTICS.....	3.24
3.6	INDUSTRY EMISSION REGULATIONS.....	3.27
3.6.1	Underground Exposure.....	3.27
3.6.2	Emission to Atmosphere.....	3.29
3.7	INDUSTRY GROWTH POTENTIAL.....	3.30
3.8	UNDERGROUND URANIUM MINE STUDY.....	3.34
3.8.1	Study Mine Selection and Background.....	3.34

3.8.2	Study Mine Site Characterization.....	3.40
4.0	ECONOMIC PROFILE.....	4.1
4.1	DEMAND.....	4.1
4.1.1	Key Determinants.....	4.1
4.1.2	Trends in Energy Consumption.....	4.5
4.1.3	Uranium Pricing.....	4.8
4.1.4	Elasticity of Demand.....	4.16
4.2	SUPPLY.....	4.17
4.2.1	Key Determinants.....	4.17
4.2.2	Interindustry Organization and Market.....	4.20
4.2.3	Trends in Production and Supply.....	4.25
4.2.4	Facility Utilization--Operating Capacity, Production Lifetime.....	4.28
4.2.5	Productivity and Employment Trends.....	4.32
4.2.6	Imports/Exports.....	4.35
4.3	FINANCIAL CHARACTERISTICS.....	4.38
4.3.1	Capital Requirements.....	4.38
4.3.2	Financial Data.....	4.42
5.0	BASELINE FORECAST.....	5.1
5.1	REACTOR FUEL DEMAND FORECAST.....	5.1
5.2	DEMAND/OTHER USES.....	5.2
5.3	ORE PRODUCTION FORECAST.....	5.2
6.0	RADIONUCLIDE EMISSIONS TO AIR.....	6.1
6.1	TECHNIQUES FOR MONITORING ^{222}Rn EMISSIONS FROM UNDERGROUND URANIUM MINES.....	6.1
6.1.1	Radon Measurements.....	6.3
6.1.2	Calibration of Radon Monitoring Instruments.....	6.15

6.1.3	Vent Flow Measurements.....	6.16
6.2	EMISSIONS CONTROL DESCRIPTIONS.....	6.17
6.2.1	Stacks.....	6.18
6.3	^{222}Rn EMISSIONS TO AIR FROM UNDERGROUND URANIUM MINES.....	6.23
6.3.1	Methodology of Calculations.....	6.23
6.3.2	Calculation Process.....	6.28
6.3.3	Results and Discussion.....	6.30
6.3.4	Conclusions.....	6.30
7.0	REFERENCES.....	7.1
APPENDIX A	GLOSSARY OF MINING TERMS.....	A.1
APPENDIX B	PRODUCTIVITY FACTOR CALCULATION.....	B.1
APPENDIX C	STUDY MINE DATA SHEETS.....	C.1
APPENDIX D	STUDY MINE LOCATION AND DATA MAPS.....	D.1
APPENDIX E	ASSOCIATED MINE FACILITIES DESCRIPTIONS.....	E.1
APPENDIX F	PRESIDENT REAGAN'S STATEMENT OF NUCLEAR ENERGY POLICY.....	F.1
APPENDIX G	FINANCIAL ANALYSIS.....	G.1

FIGURES

3.1	Grade of Uranium Ore Processed.....	3.5
3.2	Uranium Prices Compared to Uranium Production Costs and to Prices of Other Commodities.....	3.6
3.3	Schematic Cross-Section of a Wyoming-Type Role Uranium Deposit.....	3.12
4.1	History of U ₃ O ₈ Prices.....	4.15

TABLES

3.1	Ancient Versus Modern Metals and Fuels.....	3.2
3.2	Characteristics of Uranium.....	3.3
3.3	Uranium Content of Selected Materials.....	3.9
3.4	Most Common Uranium Minerals.....	3.10
3.5	Quarried Stone for Erosion and Sediment Control.....	3.23
3.6	Distribution of 1982 Uranium Production by Mining Method.....	3.25
3.7	Distribution of 1982 Uranium Production by State.....	3.25
3.8	Uranium Ore Produced from Mines and Received at Mills and Buying Stations.....	3.26
3.9	Ore Processed and Concentrate Produced in 1982.....	3.26
3.10	Comparison of 1982 and 1981 Drilling by State.....	3.27
3.11	Number of Reactors Starting Commercial Operation.....	3.31
3.12	Categorization of MSHA Uranium Mines.....	3.35
3.13	Uranium Mines in Study Group.....	3.37
3.14	Employee-hours, FTE Workers, and Estimated Production.....	3.41
3.15	Average Persons Per Household.....	3.43
3.16	Population.....	3.44
3.17	Indian Population and Total Relocation Costs.....	3.45

3.18	Land Ownership Percentages P/M/G.....	3.46
3.19	Estimated Value of Private Land.....	3.49
3.20	Aggregate Assessment/Sales Price Ratios.....	3.51
3.21	Local Real Estate Estimates for Grazing and Residential Property.....	3.52
3.22	Annualized Cost of Controlling Land to 2 km.....	3.54
4.1	Uncertainties Affecting Demand Projections.....	4.3
4.2	Projections of Installed Nuclear Capacity Presented at Annual Uranium Industry Seminar.....	4.6
4.3	Current Projection of Installed Nuclear and Total Electric Utility Capacity by DOE/EIA.....	4.7
4.4	Previous Projection of Installed Nuclear and Total Electric Generating Capacity by ERDA.....	4.7
4.5	Circulars 3 and 4: Price Schedule for Colorado Plateau Uranium From Carnotite and Roscoelite Ores.....	4.9
4.6	Circular 5 and Circular 6: Schedule of Prices for Uranium Ore.....	4.10
4.7	Average Value of Ore.....	4.12
4.8	AEC Domestic Concentrate Purchases: Amount, Cost and Average Price..	4.13
4.9	Historical Exchange Values.....	4.14
4.10	Current Nuclear Fuel Cycle Activities.....	4.21
4.11	Uranium Ore Produced from Mines and Received at Mills and Buying Stations.....	4.26
4.12	U.S. Uranium Processing Plants: Operating as of January 1, 1983.....	4.30
4.13	Conventional Mill Status Summary for 1982.....	4.30
4.14	Average New Mine.....	4.31
4.15	Estimates of Labor Productivity in Uranium Mining.....	4.33
4.16	Changes in Output Per Man in Open-Pit and Underground Mines.....	4.34
4.17	Employment in the Uranium Industry.....	4.35
4.18	Deliveries of Uranium to DOE Enrichment Plants by Domestic Customers	4.36

4.19	U.S. Imports and Exports of Uranium for Commercial Uses.....	4.39
4.20	Capital Investment for the Domestic Uranium Industry.....	4.41
4.21	Financial Information for Three Uranium-Mining Companies.....	4.43
5.1	Annual U.S. Uranium Demand in Tons $U_3O_8 \times 10^3$	5.1
5.2	Annual U.S. Uranium Production in Tons $U_3O_8 \times 10^3$	5.3
5.3	Annual Ore Production.....	5.3
6.1	Manufacturers of Radon Analysis Equipment.....	6.6
6.2	Exhaust Borehole Stack Cost Final Estimate.....	6.20
6.3	Increased Cost of Production Resulting from Adding Ventilation Stacks on Exhaust Boreholes.....	6.23
6.4	Summary of Radon Emissions from Underground Mine Vents.....	6.24
6.5	Current Status of Mines Monitored in 1978-1979 Survey of Jackson et al (1979, 1980).....	6.26
6.6	Uranium Ore Produced from Underground Mines and Fractional Radon Emission Rate Factors.....	6.28
6.7	Measured and Predicted ^{222}Rn Emission Rates.....	6.31

1.0 SUMMARY

A review of the U.S. uranium mining industry has revealed a generally depressed industry situation. The 1982 U_3O_8 production from both open-pit and underground mines declined to 3,800 and 6,300 tons respectively with the underground portion representing 46% of total production.

U.S. exploration and development has continued downward in 1982. Many programs have been curtailed or abandoned, drilling has declined, and total industry expenditures have dropped. Of 15 major oil companies active early in 1982, only 7 remain in the uranium business and at reduced levels. The total number of conventional uranium production sources in 1982 was down to 139 underground mines and 24 open-pit mines. Drilling was down 56% from 1981 to 61 million feet. Total 1982 industry capital investment declined to \$163 million or 39% of 1981 expenditures.

Employment in the mining and milling sectors has dropped 31% and 17% respectively in 1982. Capacity utilization at mills was 45% in 1982 with only 14 mills still operating by year end out of 20 at the beginning of the year. Many mines were at 50% capacity or on standby status. The depressed nature of the U.S. uranium mining industry can be attributed mainly to a weakened demand for uranium fuel and a low commodity price caused by oversupply.

Representative forecasts were developed for reactor fuel demand and U_3O_8 production for the years 1983 and 1990. Reactor fuel demand is estimated to increase from 15,900 tons to 21,300 tons U_3O_8 respectively. U_3O_8 production, however, is estimated to decrease from 10,600 tons to 9,600 tons respectively. This projected decrease in U_3O_8 production can be attributed to a predicted increase in imports and a predicted continuation of inventory liquidation. In 1983, imports are estimated at 28% of uranium used in the U.S., increasing to an estimated 37.5% in 1990.

A field examination was conducted of 29 selected underground uranium mines that represent 84% of the 1982 underground production. Data was gathered regarding population, land ownership and private property valuation. Out to 2 km total population was 618 persons. Average land ownership was 22% private, 17% mining company and 61% government. The value of land and structures was

estimated at \$9,378,270 out to 2 km. The annual cost to control land out to 2 km was estimated at \$3,012,000 equivalent to a \$0.29 per pound U_3O_8 increase in the cost of production based on 1982 production.

An analysis of the increased cost to production resulting from the installation of 20-meter high exhaust borehole vent stacks was conducted. For a most likely case, increased cost would be \$0.493 to \$0.881 per ton of ore or \$0.062 to \$0.242 per pound of U_3O_8 .

An assessment was made of the current and future ^{222}Rn emission levels for a group of 27 uranium mines. It is shown that ^{222}Rn emission rates are increasing from 10 individual operating mines through 1990 by 1.2 to 3.8 times. But for the group of 27 mines as a whole, a reduction of total ^{222}Rn emissions is predicted due to 17 of the mines being shutdown and sealed. The estimated total ^{222}Rn emission rate for this group of mines will be 105 Ci/yr by year end 1983 or 70% of the 1978-79 measured rate and 124 Ci/yr by year end 1990 or 83% of the 1978-79 measured rate.

2.0 INTRODUCTION

As a result of a lawsuit filed by the Sierra Club against the Environmental Protection Agency (EPA) in the state of California on June 16, 1981, a court order has dictated that the EPA publish proposed regulations regarding radionuclide emissions from underground uranium mines. The EPA had earlier listed such emissions as hazardous air pollutants under provisions of the Clean Air Act as amended in 1977. In preparing these proposed emission regulations, the EPA required certain background information of the uranium industry as a whole as well as of specific active and recently inactive uranium mines. This background information aided the EPA in both the development and support of these proposed regulations.

In regards to underground uranium mines, the EPA proposed a radionuclide emission standard which restricts the increase in the annual average concentration of ^{222}Rn in any unrestricted area around a mine to 0.2 picocuries per liter. Several methods for meeting this standard were suggested which include:

1. reducing the operating time of the mine,
2. increasing the exhaust borehole vent stacks effective heights, and
3. controlling additional land around the mine vents--out to 2 km.

This report, in providing the EPA with essential background information, has basically a four-fold objective:

1. to assess the economic background of the uranium industry and describe its present status,
2. to provide as best as possible a forecast of fuel demand and ore production for the years 1983 and 1990,
3. to review emissions data from underground uranium mines; document radon measurement/monitoring techniques; assess the magnitude of emissions from a sample of underground mines using projected ore production data; determine production cost increases resulting from the proposed vent stack height increase to 20 meters,

Descriptions of uranium mining processes are provided in the following sections. Underground mining techniques are discussed first since they are the emphasis of this report. Descriptions of open-pit and solution mining methods are provided for comparison.

3.3.1 Underground Mining

The basic phases in underground mining include exploration, development, production, and closure. In the life of a mine, however, phase operations are often carried out concurrently.

Exploration

Because uranium tends to occur in irregular deposits, extensive exploration work is necessary to delineate the ore (Charles River Associates, Inc. 1977). Usually the first phase of searching for ore is the reconnaissance survey. Any geologic features or geophysical measurements that might indicate a mineral deposit are further investigated using trenching and sampling techniques. In deeper lying deposits, extensive drilling is required to appraise the deposit (Stout 1980).

Development

For most underground mines extensive preproduction development is required before production can begin. Principal steps in the development of an ore body includes 1) development drilling and 2) primary mine development.

Development drilling delineates the ore body further and assesses ore grade and amenability to ore processing. Potential locations for shafts are determined and a plan is established for mining a deposit. Information gathered during this period is required to decide whether the mine can be economically developed (Charles River Associates, Inc. 1977).

Primary mine development includes sinking of main shafts, construction of haulage ways, slopes and ventilation shafts, installation of underground equipment, and construction of surface facilities and access roads. A ventilation system is also constructed.

The first step of primary mine development is the sinking of concrete-lined mine shafts using mechanical shaft muckers. Most underground mines use

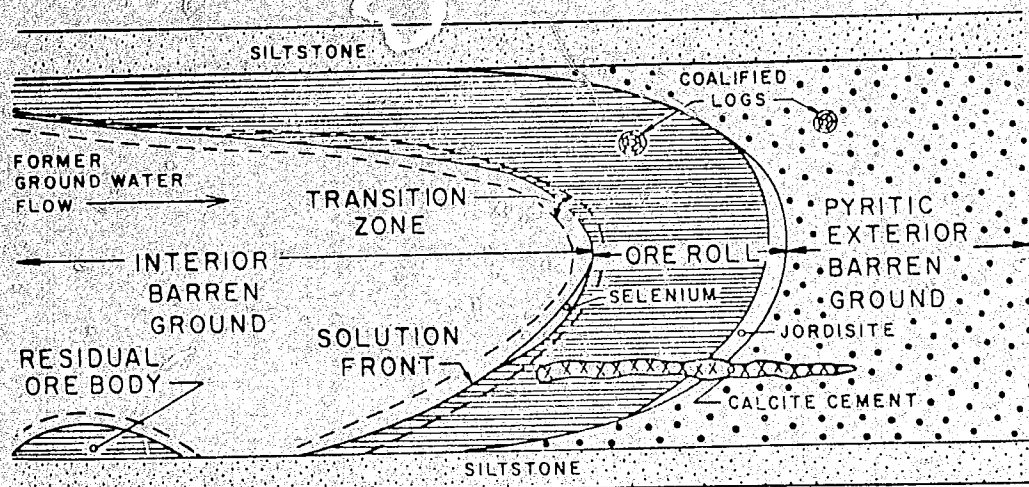


FIGURE 3.3. Schematic Cross-Section of a Wyoming-Type Roll Uranium Deposit

Source: Cheney and Ista, 1980

3.3 MINING PROCESSES (a)

Conventional mining techniques are utilized in the United States to extract most uranium-bearing ore. Uranium is primarily mined using underground and open-pit methods. A third form of extraction which is much less traditional is referred to as solution mining.

The choice of mining method is based on mechanical and spatial characteristics of the deposit. As a rule of thumb, open-pit mining is generally considered to be uneconomical beyond a depth of 300 feet. In the past, underground mining was favored for the Colorado Plateau regions because of the greater depths of ore occurrence. Wyoming was the site of most surface mining because of the shallow deposits and poorly consolidated overburden. Solution mining is used to recover low-grade ores that may not be economically recoverable using other methods.

(a) A glossary of mining terms is included in Appendix A to assist the reader in understanding the mining processes.

4. and to conduct field surveys to gather data on population densities, land ownership, land values, and site characteristics around selected mines; plus determine production cost increases resulting from the land control option of the proposed regulations.

Chapter 3 begins with an overview of uranium--its commodity and ore-deposit characteristics. This is followed by other broad descriptions of the uranium mining industry including mining processes, waste management, regulations, general production statistics plus a statement on the industry's growth potential. Chapter 3 is concluded with a detailed description of the field surveys performed on 29 selected mines in our study group. This description includes the production cost analysis involving the land control option.

Chapter 4 provides an economic profile of the uranium industry which is divided into demand, supply, and financial topics. Once the background is soundly developed, fuel demand and ore production forecasts are given in Chapter 5.

Finally, a detailed review of emissions data, resulting in an assessment of the projected magnitude of emissions from a sample of underground uranium mines is provided in Chapter 6. Here also is found the production cost analysis involving increased exhaust borehole vent stack height.

3.0 INDUSTRY DESCRIPTION

This section will develop several general issues relating to the uranium industry and then focus on a specific study of underground uranium mines. The general topics will introduce the reader to the commodity and deposit-type characteristics of uranium, then continue on through a discussion of mining processes and mine waste disposal/reclamation. Industry statistics on production coupled with a discussion on regulations will lead to an assessment on the industry's growth potential.

The specific underground uranium mine study is a vital and major part of this report. Field trips were undertaken to a total of 31 uranium mines in five states to gather important data on population distribution, land status and land value. This data was needed by the Environmental Protection Agency for the development of proposed new radionuclide emission standards for underground uranium mines. A detailed discussion is given on the methodology of study, mine selection, data gathering and the results of the study.

3.1 COMMODITY CHARACTERISTICS

3.1.1 Uranium Uniqueness

A description of the uranium mining industry should begin with an understanding of the specific characteristics of the commodity of uranium itself. Is uranium unique in comparison to other metal or fuel commodities? A review of the uses of uranium, its principle industry characteristics and comparisons of these and other characteristics to different metals and fuels will help in answering the questions on the uniqueness of uranium.

Uranium has the distinction of having a dual nature--it is both a modern metal and fuel. Only plutonium carries that same distinction. This duality might suggest a unique niche for uranium in the marketplace, but a closer examination of the specifics of uranium will show otherwise.

Aucoin (1982) has categorized the ancient versus modern metals and fuels (Table 3.1) and discusses the properties and uses of uranium. Uranium is the youngest metal and fuel with basically only three modern uses:

TABLE 3.1. Ancient Versus Modern Metals and Fuels

<u>Ancient Metals</u>	<u>Modern Metals</u>	<u>Ancient Fuels</u>	<u>Modern Fuels</u>
• copper	• aluminum	• coal	• natural gas
• gold	• bismuth	• wood	• petroleum (crude oil)
• iron	• cobalt		• uranium
• lead	• columbium		
• mercury	• magnesium		
• silver	• manganese		
• tin	• molybdenum		
• zinc	• nickel		
	• tantalium		
	• titanium		
	• tungsten		
	• uranium		

Source: Aucoin (1982)

1. fuel to power nuclear reactors
2. atomic weapons
3. specific scientific purposes such as in radiation shielding.

Of these three functions, fuel for nuclear reactors can be considered the major use of uranium and the basis of a domestic uranium industry. Uranium thus has basically one application in this one market--that of electric power generation.

Aside from nuclear power, let us look at the major industry characteristics of uranium. Aucoin (1982) gives a list of twelve characteristics of uranium which he states is in no particular order of priority (Table 3.2). Of these twelve characteristics, Aucoin discusses some of the outstanding ones which can be compared to other commodities such as:

- High unit value. All of the precious metals (e.g., gold, silver) have this distinction.
- High political sensitivity. This can describe all of the strategic metals (e.g., the platinum group metals) plus petroleum and gas.

- No substitutes. Another metal with this quality is manganese in its use in steel making. Manganese serves as a scavenger in removing sulfur, phosphorous and some oxygen from a molten steel batch. Of the six major ferroalloy elements, only manganese can remove sulfur. Without manganese, good steel could not be made (Dykstra and Tatnall 1976).
- Stockpiling ease. Most of the metals have similar bulk storage characteristics.
- Supply concentration. The commodity of cobalt is equally highly concentrated in its production. In 1981, five countries produced 88% of the free world cobalt, with one country producing 59%. Three countries have 69% of the free world cobalt reserves.

TABLE 3.2. Characteristics of Uranium

1. Uranium usage has a moderately high projected growth rate.
2. Uranium has a high unit value.
3. Uranium has a very high political sensitivity.
4. Uranium has only one application or use.
5. The uranium-producing industry is totally demand-driven, demand is relatively price-inelastic.
6. Uranium demand forecasts are constantly being revised.
7. Uranium is a metal produced by mining.
8. Uranium users are deeply involved in exploration and production.
9. Uranium is easy and inexpensive to transport and store.
10. Uranium resources are unevenly distributed among a relatively few countries.
11. The uranium industry is diverse and is not highly organized.
12. Uranium has not as yet exhibited predictable cyclical behavior.

Source: Aucoin (1982)

Thus, uranium has many qualities in the marketplace that cannot be considered unique.

In considering the physical characteristics of uranium, as per number 7 on the list, uranium is a metal produced by mining. Grade and size of an uranium ore deposit are the two most important factors in its mining profitability. However, this fact is not unique to uranium. Grade and size relate to all metallic mining ventures. High grade ores and large tonnage ore bodies make the ideal situation, but unfortunately nature doesn't always provide such bonanzas. An ore body is usually one or the other. For example, the Rössing uranium deposit in South West Africa is a large tonnage igneous hosted ore body whose uranium mineralization is a disseminated, very low grade ore. Similarly, copper ores of today come from very low grade porphyry systems where the grade is now less than one percent copper. Mining of such lower grade ores has been made possible due to changing economic variables including the economics of scale of these mines, and new technologies. Figure 3.1 depicts the grade of uranium ore (in % U_3O_8) processed from 1966-1981. The trend has been one of steady decline. In comparison, the average grade of copper ore has been declining from about 5% in 1900 to less than 0.7% today (Aucoin 1982).

A comparison of uranium prices to uranium production costs and to prices of other commodities can also be made to test the position of uranium in terms of being unique. Figure 3.2 from Aucoin (1982) depicts this for the period 1972-1981. Indexes are used versus dollars where 1972=100 as the base index. Prices for silver, copper, and aluminum are New York spot quotes, while uranium is the NUEXCO Exchange value for U_3O_8 . Aucoin describes the U_3O_8 production cost curve as representing "the weighted average U.S. cost, including the effects of inflation (labor and materials escalation), productivity increases and/or decreases at both mines and mills, environmental and safety regulations, and declining ore grades plus fluctuating mill recoveries." The GNP Implicit Price Deflator is also plotted for comparison.

Of the many points the plot depicts, an important comparison can be made between the similar behavior of uranium and silver spot prices (as opposed to a

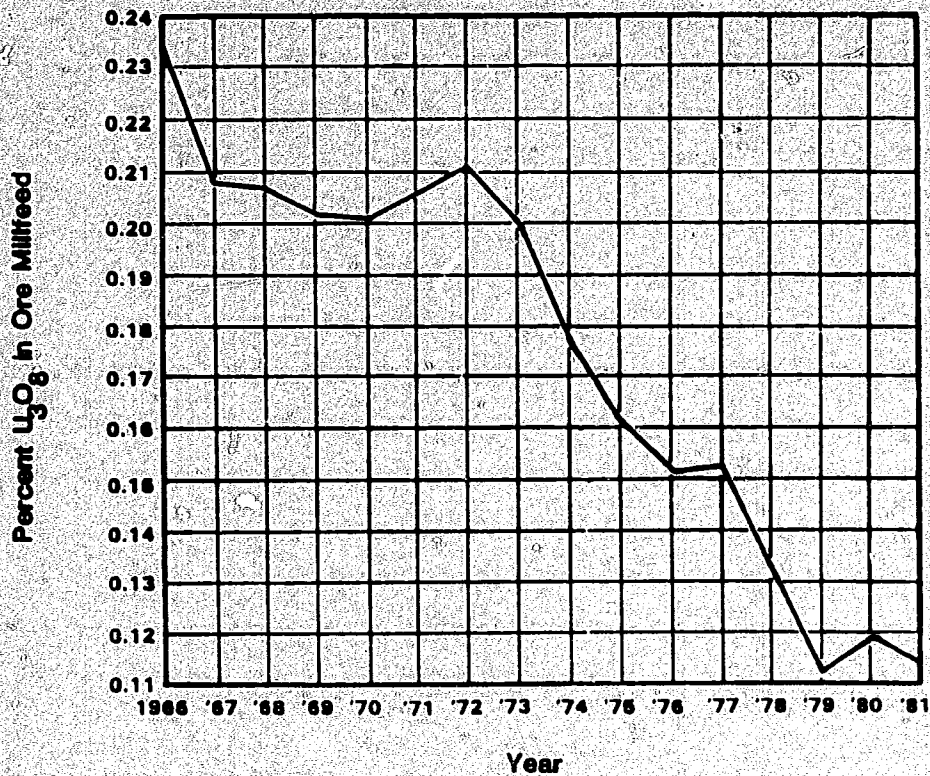


FIGURE 3.1. Grade of Uranium Ore Processed

Source: Aucoin, 1982

contrast with aluminum or copper). The pricing of silver is described by Aucoin (1982) as "a tremendously complex hodge-podge of industrial demand, monetary policy, hoarders, investors, and speculators, sales from the U.S. federal stockpile, plus consumer taste in jewelry." Uranium prices can and have been influenced by these same factors i.e., speculators, hoarders, investors, industrial demand and its fluctuation, and government control and regulation. Uranium then is not unique in these terms of price behavior.

Through the review of uranium use, industry and other characteristics it has been shown that uranium is not a totally unique commodity. It may be "unique" in that it is a metal and fuel whose nearly exclusive commercial market is in power generation, but in a breakdown comparison, its many industrial and economic characteristics are similar to other commodities. The fact

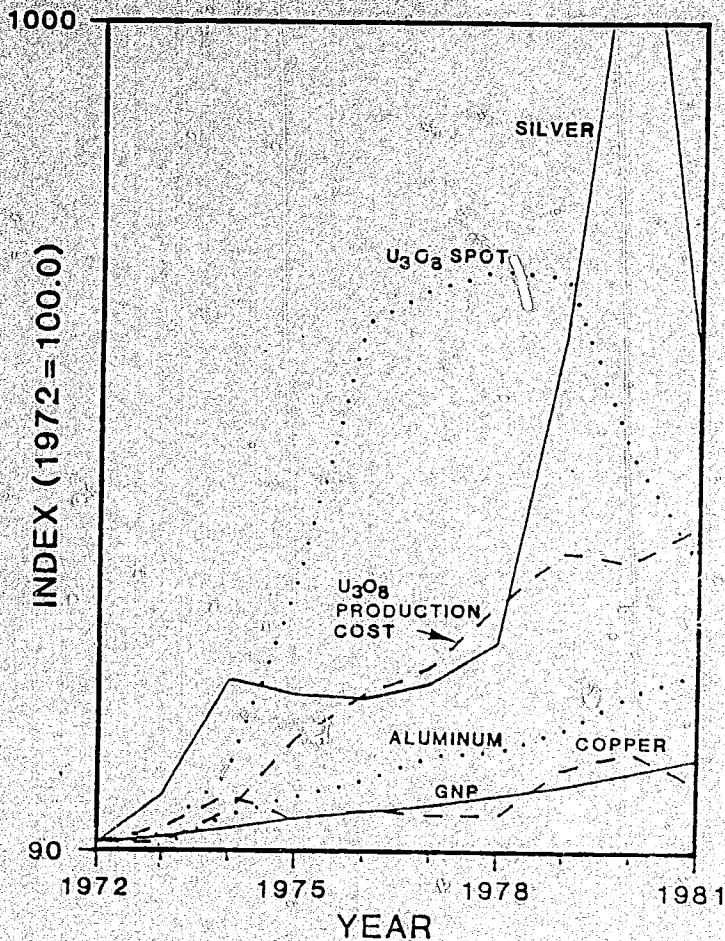


FIGURE 3.2. Uranium Prices Compared to Uranium Production Costs and to Prices of Other Commodities

Source: Aucoin, 1982

that uranium is a metal makes for its similarity in exploration, production and mining and economics among other metals. Among metals then, it is not unique at all. Uranium can only be considered unique in its specialized governmental controls and trade patterns.

3.1.2 Terminology

Having an understanding of the characteristics of uranium as a commodity, a description of uranium terminology common to the commercial industry is necessary. The term "uranium" refers to several aspects of the substance such

as: uranium the element, mineralization, reserves, ore, concentrate, yellowcake, U_3O_8 , UF_6 , UO_2 , natural, enriched and depleted uranium.

In describing the chemical nature of uranium, elemental uranium refers to the atomic form. It is the heaviest of the naturally occurring elements with an atomic weight of 92. There are two naturally occurring isotopes, ^{235}U and ^{238}U . The first one, ^{235}U , is the fissile isotope, capable of splitting after the absorption of a neutron. The later, ^{238}U , is the fertile isotope, being convertible to the fissile plutonium. Natural uranium is characterized by the specific ratio of the two isotopes $^{235}U/^{238}U$. The natural composition is about 0.71 % ^{235}U by weight (Thrush 1968). Enriched uranium has this ratio increased above its natural percentage for use as a nuclear reactor fuel (Thrush 1968). Depleted uranium is that uranium from the tails of the enrichment process with less than 0.71 % ^{235}U by weight (Thrush 1968).

In considering the physical concentration of uranium, both geologically and in processing, we refer to the terms mineralization, ore, reserves, concentrate and refined compounds. Uranium mineralization is simply its existence in certain geologic environments without reference to any specific economic parameters. Ore is that material mined containing uranium-bearing minerals with the intent to process for the extraction of its uranium content. Reserves are those ore deposits exploitable under certain economic conditions. Uranium concentrate or yellowcake is the processing (concentrating) product. It is a fine powder containing mainly three compounds of uranium (Thrush 1968):

ammonium diuranate	$(NH_4)_2U_2O_7$
sodium diuranate	$Na_2U_2O_7$
triuranium octoxide	U_3O_8

Two refined compounds include UF_6 and UO_2 . UF_6 , uranium hexafluoride, is the process fluid in the gaseous diffusion refining process. UO_2 , uranium dioxide, is a brown black powder in crystalline or pellet form used to pack nuclear-fuel rods (Thrush 1968).

3.1.3 Chemistry

Describing the chemical aspects of uranium as discussed in Merritt (1971), finds that the average crustal concentration to be 2-4 parts per million (ppm).

This is comparable to the concentrations of other elements such as molybdenum, tungsten, arsenic and beryllium. Uranium averages 6 ppm in those igneous rocks higher in their silica content, while igneous rocks lower in silica content and higher in magnesium, aluminum and iron contain less than one ppm uranium. There are some varieties of igneous rocks in the Colorado Front Range that are high in their alkali, and low in their calcium content that have up to 100 ppm uranium.

Merritt (1971) says that uranium oxidizes readily, and in that state is quite soluble, thus having the potential for being highly distributed in nature via solutions. The uranyl ion is soluble in solutions of both acidic or carbonate-bicarbonate character and will form stable complexes with the ions of sulfate and carbonate under high temperatures and pressures. These conditions are often found in the hydrothermal solutions that accompany magmatic intrusions.

Uranium in solution may be mobilized by circulating ground waters throughout rock formations. Special physical characteristics of these rock formations along with special chemical conditions can cause the uranium to become concentrated. The concentration of uranium by precipitation from the solutions may be caused by many factors including a lowering of the temperature and pressure, reducing conditions, ion exchange, neutralization, chemical replacement and so forth. Of these factors, Merritt says that the forming of uranium minerals is caused most importantly by the reduction of the soluble UO_2^{++} ion from the hydrothermal and ground water solutions.

Uranium can occur in a variety of host-materials as the list from Merritt (1971) shows (Table 3.3). The concept of "cyclical migration" is important in explaining uranium's presence in many of these environments. Basically, this involves redissolving, redistributing and reprecipitation of the uranium into new environments. Later metamorphism may alter again the nature of the uranium mineralizations.

A table of the more common uranium minerals is shown (Table 3.4). The great number of uranium minerals, 155 confirmed and probable species where uranium is the important elemental constituent, is due mainly to the polyvalence of uranium and its relatively high solubility of the hexavalent form.

TABLE 3.3. Uranium Content of Selected Materials

<u>Rock Description</u>	<u>Percent U₃O₈</u>
High-grade veins	30-70
Vein ores	0.2-1.0
Sandstone ores	0.05-0.4
Pegmatitic ores	0.05-0.1
Uraniferous phosphates	0.005-0.03
Gold ores (South Africa)	0.015-0.06
Chattanooga Shales (U.S.)	0.006
Marine black shales	0.001-0.02

Source: as adapted from Merritt (1971)

3.2 DEPOSIT-TYPE DESCRIPTIONS

There are many "types" of uranium deposits being economically mined today. It is difficult, to classify these many ore deposits because the economic geology and scientific knowledge of uranium is not yet perfectly understood. And, as this knowledge of uranium and the origins of these ore deposits increases, classification schemes presently in place are continually subject to revision.

However, in light of these difficulties, many classification schemes for uranium deposits are currently being used. These schemes are based on descriptive, lithologic or temporal means of organization. For convenience, the descriptive method will be used here in outlining the basic uranium deposit

TABLE 3.4. Most Common Uranium Minerals

Type	Name	Chemical Composition
Oxides	Uraninite	$(U^{+4}_{1-x}, U^{+6}_x)O_{2+x}$
	Pitchblende	Variety of uraninite
Nb-Ta-Ti complex oxides	Brannerite	$(U, Ca, Fe, Th, Y)(Ti, Fe)_2O_6$
Silicates	Coffinite	$U(SiO_4)_{1-x}(OH)_{4x}$
	Uranophane	$Ca(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5 H_2O$
Phosphates	Autunite	$Ca(UO_2)_2(PO_4)_2 \cdot 10-12 H_2O$
	Torbernite	$Cu(UO_2)_2(PO_4)_2 \cdot 12 H_2O$
Vanadates	Carnotite	$K_2(UO_2)_2(VO_4)_2 \cdot 1-3 H_2O$
	Tyuyamunite	$Ca(UO_2)_2(VO_4)_2 \cdot 5-8 H_2O$

Source: as adapted from Merritt, 1971

types. The descriptive method uses terms such as "sandstone type" which convey various descriptive geological characteristics. This method is also useful in that revisions need not be made to the classification scheme as increased knowledge changes the theories on origins of these deposits.

There are ten general uranium deposit types as outlined by Cheney and Ista (1980):

- Witwatersrand type
- Blind River type
- Sandstone type
- Rossing type
- Pegmatitic type
- Surficial Uranium Deposit type
- Athabasca type
- Jabiluka type
- Veins in two mica granites types
- Other vein types

Of these ten, the Sandstone type is the most important for consideration here. About 95% of the uranium produced in the United States comes from two important subdivisions of the sandstone type uranium deposit - the Wyoming subtype and Colorado Plateau subtypes (Cheney and Ista 1980).

These two deposit sub-types occur in continental arkosic sandstones derived from granitic rocks of older Precambrian age. The uranium ore usually occurs when a conglomerate or sandy facies (e.g. former stream channel) grades into a finer grained siltstone or mudstone. Mineralized horizons are commonly overlain by felsic volcanoclastic rock units. Uranium mineralization usually consists of uraninite and coffinite which act as cementing agents in the sandstone. Pyrite is also present. These minerals are commonly found in or next to coalified plant materials (Cheney and Ista 1980).

A common form of a uranium ore deposit is called the "roll" deposit. Figure 3.3 is a schematic cross-section of a typical Wyoming type uranium roll deposit. As the figure shows, the sandstone strata hosting the uranium ore is generally bounded by impermeable siltstones. These ore bodies have reached cross-sectional widths up to 25 meters in the Gas Hill district in Wyoming (Cheney and Ista 1980).

The next section will discuss the mining processes involved in extracting ore from these roll-type and other uranium deposits.

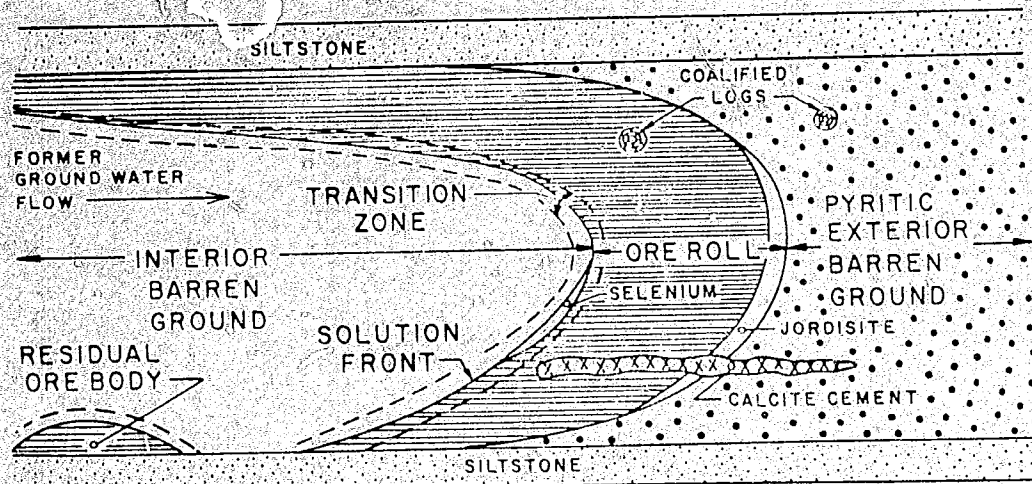


FIGURE 3.3. Schematic Cross-Section of a Wyoming-Type Roll Uranium Deposit

Source: Cheney and Ista, 1980

3.3 Mining Processes(a)

Conventional mining techniques are utilized in the United States to extract most uranium-bearing ore. Uranium is primarily mined using underground and open-pit methods. A third form of extraction which is much less traditional is referred to as solution mining.

The choice of mining method is based on mechanical and spatial characteristics of the deposit. As a rule of thumb, open-pit mining is generally considered to be uneconomical beyond a depth of 300 feet. In the past, underground mining was favored for the Colorado Plateau regions because of the greater depths of ore occurrence. Wyoming was the site of most surface mining because of the shallow deposits and poorly consolidated overburden. Solution mining is used to recover low-grade ores that may not be economically recoverable using other methods.

(a) A glossary of mining terms is included in Appendix A to assist the reader in understanding the mining processes.

Descriptions of uranium mining processes are provided in the following sections. Underground mining techniques are discussed first since they are the emphasis of this report. Descriptions of open-pit and solution mining methods are provided for comparison.

3.3.1 Underground Mining

The basic phases in underground mining include exploration, development, production, and closure. In the life of a mine, however, phase operations are often carried out concurrently.

Exploration

Because uranium tends to occur in irregular deposits, extensive exploration work is necessary to delineate the ore (Charles River Associates, Inc. 1977). Usually the first phase of searching for ore is the reconnaissance survey. Any geologic features or geophysical measurements that might indicate a mineral deposit are further investigated using trenching and sampling techniques. In deeper lying deposits, extensive drilling is required to appraise the deposit (Stout 1980).

Development

For most underground mines extensive preproduction development is required before production can begin. Principal steps in the development of an ore body includes 1) development drilling and 2) primary mine development.

Development drilling delineates the ore body further and assesses ore grade and amenability to ore processing. Potential locations for shafts are determined and a plan is established for mining a deposit. Information gathered during this period is required to decide whether the mine can be economically developed (Charles River Associates, Inc. 1977).

Primary mine development includes sinking of main shafts, construction of haulage ways, slopes and ventilation shafts, installation of underground equipment, and construction of surface facilities and access roads. A ventilation system is also constructed.

The first step of primary mine development is the sinking of concrete-lined mine shafts using mechanical shaft muckers. Most underground mines use

vertical shaft entry except those constructed during the early war period. Lower cost adits and inclined shafts can provide entry to deposits in areas of high relief. Shafts are generally located at the end and in the center of mine property (Charles River Associates, Inc. 1977).

Shafts allow horizontal access to ore-bearing veins. From the shafts, cross-cuts are driven through the width of the ore deposit. From the cross-cuts, two drifts are driven along the length of the vein. One drift undermines the ore bed and the other directly follows the bed. Each drift system comprises a horizon. When the distances between horizons is considerable, sub-drifts are driven to decrease the size of blocks to be extracted.

A ventilation system must also be incorporated. Ventilation raises are constructed between the cross-cuts, drifts, subdrifts, and horizons. While working a horizon, the ore drift of the overlying level is the ventilation drift for exhausting the contaminated air. When mining a horizon, only the last ventilation connection is used for feeding fresh air to the miners. All other connections are stopped.

After the shafts and tunnels are constructed, the ore body is further delineated by longhole drilling. Exploratory boreholes in the hanging and footwalls of the deposit are used to determine the presence of mineralization in the entire width of the bed (Bykouskii, et al. 1977).

Production

Extraction (called stoping) of an ore body begins once development is complete. The general sequence in extracting uranium ore is to drill out a blasting round, load the explosives and blast, bardown any loose material, install rock bolts for back support, excavate broken rock, and slush or tram the ore to the nearest stope exit (Dames and Moore 1980). Ore is hoisted to the surface, stockpiled and blended to the proper grade, and transported to the mill (Heeb, et al. 1980).

There are several methods of stoping employed, but room and pillar or modifications thereof are generally used. Room and pillar and modified room and pillar are methods of cutting up a deposit by excavating a grid of rooms

separated by pillars of uniform cross-section (Battelle Columbus Laboratories 1976). Many grid lay-outs are used including both rib and square pillars with checkerboard spacing. As pillars are extracted upon retreat, the mined-out area caves and it is abandoned (Stout 1980).

Closure

When ore depletion causes a project to become unprofitable, mine closure procedures are put into effect. Such closing procedures are presently being used at the Kerr-McGee Puerco mine as described in the company's environmental report. Valuable underground equipment is salvaged and a concrete plug is poured at the collar of the production shaft to seal the mine. The area of the ore stockpile is cleaned and all structures removed. The disturbed areas are relaid with topsoil and reseeded (New Mexico Energy and Mineral Department 1979).

3.3.2 Open-Pit Mining

The basic phases in open-pit mining are the same as for underground mining. The exploration phase described in Section 3.3.1 is identical since mining methods are not chosen until after this phase is completed. The development phase consists of removing overburden and development drilling. Ore is removed during the production phase followed by closure and reclamation. Reclamation procedures are discussed in Section 3.4.4.

The first step in open-pit mining is the removal of overburden with scrapers or power shovels. Blasting and ripping is usually required to loosen the topsoil. When the orebody is exposed, it is cleaned of waste with tractor scrapers and bulldozers. After blasting and ripping of the ore, the ore is mined with a backhoe and loaded onto trucks for hauling to the mill.

Mining starts before the whole ore body is exposed by dividing the mine into areas. Overburden from the first mined area is stripped and placed on the surface. Overburden from succeeding areas is used to backfill areas where mining has been completed. At the cessation of operations, the overburden is covered with topsoil and reseeded (Battelle Columbus Laboratories 1976).

3.3.3 Solution Mining

A third form of uranium extraction is referred to as solution mining. The two principal forms, in-situ and heap leaching, can be used to recover uranium from low-grade ores. In-situ means leaching the ore in the geological formation in which it occurs. In heap leaching, a leach solution is applied to heaps of ore on drain tiles (Charles River Associates, Inc. 1977).

Currently in-situ mining projects for uranium use a sodium or ammonium carbonate solution for leaching of the ore (Battelle Columbus Laboratories 1976). The leach solution is injected through several outer wells and recovered in a center well. In order to contain the leachate, the ore zone should have impermeable material underlying and overlying the ore-bearing zone (New Mexico Energy and Mineral Department 1979). Recovered solutions carry from 50 to 150 ppm U_3O_8 (Dames and Moore 1980).

Heap leaching requires weeks or even years and chemical reagents such as sulfuric, nitric, or hydrochloric acid are generally used domestically. Bacterial leaching is utilized in the Elliot Lake region of Canada (Charles River Associates, Inc. 1977).

3.4 WASTE MANAGEMENT

Wastes generated during mining can be categorized as airborne, liquid, and solid. Wastes are generated at all phases of a mining project. Most wastes are expelled to the environment untreated and generally cause only short-term environmental impacts. Ore stockpiles, mine water-evaporation ponds, and mined-out pits must be reclaimed at the cessation of operations. The following sections discuss the waste-generating processes for all phases of a mining project. Finally, surface reclamation techniques are discussed since it is the major waste-management procedure required in a mining project.

3.4.1 Airborne Wastes

Various air pollutants are generated during the life of a mine. Effluents generated as a result of the operation of machinery, the construction of roads, and the drilling, blasting, blending, and loading of ore and are released to the atmosphere untreated. Airborne effluents consist of dust, combustion gases, radon gas and radon daughters.

Effluents generated from these processes can be minimized using standard techniques. Excavated rock, loaded mine cars and trucks, and roadways can be wetted down to reduce dust emanation (Heeb, et al. 1980). Speed of travel should be lessened on unpaved roads (Battelle Columbus Laboratories 1976). Engine gases can be catalytically decomposed and, in some cases, atomized sprays are used to remove part of the dust from the air after loading and blasting (Heeb, et al. 1980). Although most of the effluents from these processes are minimized rather than treated, the impacts of these effluents on air quality is slight, local, and short-term (Battelle Columbus Laboratories 1976).

The ventilation-air exhaust boreholes in underground mines are another significant source of airborne wastes. Ventilation holes exhaust dust, radon, and radon daughters from the mine workings. Dilution with the atmosphere is currently used to control the concentration of contaminants in the environment (Heeb, et al. 1980). Also, limited use of fabric or fiber filtration units clean primary air inside the mine for use in remote areas (Floyd C. Bossard and Associates 1983).

Personnel at Battelle Columbus Laboratories recently overviewed radon control measures in underground mines. Currently no process or device is being used to reduce radon at the shaft, but several possible methods have been proposed. Processes include electrostatic precipitation and filtration, gas centrifuging, cryogenics, and chemical removal methods. Stacks installed at exhaust points would also assist in dilution.

Control methods that reduce mine levels of contaminants, also tend to reduce atmospheric discharge of wastes. Methods include bulkheading of closed-off areas and the establishment of appropriate pressure differentials in the sealed-off area so that contaminants do not escape. Water is used to suppress dust in various areas of the mine. Backfilling of mined-out areas not only provides ground support, but also reduces ventilation requirements. Sealants and diffusion barriers applied to mine walls (intake airways, shops, lunch-rooms, and mined-out areas) can also significantly reduce radon contamination levels.

3.4.2 Liquid Wastes

Mine water is the main liquid effluent leaving an underground or open-pit mining facility. Mine water is produced by the flow of both surface runoff and subsurface water into pits or mine workings. In underground mines, sump pumps are used to dewater workings. Inceptor wells located at mine perimeters can also aid in the dewatering process of underground workings (Thomsen 1983). Ground water from underground mines is pumped to holding ponds on the mine surface. In surface mines, the water flows by gravity to a holding pond in the mine pit where it is allowed to evaporate or seep into the ground.

Water from underground mines is usually treated before it is discharged to the environment. Mine water is pumped to a holding pond on the surface and treated using ion exchange methods to remove uranium. Water from the ion exchange circuit is then treated with barium chloride and discharged to a second holding pond. Radium precipitates out and the water evaporates. At the cessation of operations, the tailings are covered and reclaimed (Heeb, et al. 1980).

In some cases, mine water is discharged to the environment without treatment. The effluent can transform dry washes and ephemeral streams to perennial streams disrupting local topography and biota. Local surface waters can be contaminated, and seepage may contaminate aquifers (Battelle Columbus Laboratories 1976).

Groundwater contamination from underground operations also occurs after mining ceases when sump dewatering has stopped. The inactive mine fills with water until the original water level is reestablished. The water is contaminated through contact with mine rubble. To reduce contamination, a number of mines in New Mexico recover uranium from flooded mines through ion exchange. Barren liquid is returned until original conditions are restored in the aquifer (Thomsen 1983).

Effluents from solution mining are not produced until the project is completed. Leach solution is recycled until the end of operation. Upon completion of the project, the solutions are evaporated in tanks or lined ponds. The dry residue is packaged and shipped to active mill tailings disposal sites (U.S. Nuclear Regulatory Commission 1980).

3.4.3 Solid Wastes

Solid wastes from underground mining are treated using standard reclamation practices. Wastes consist of rocks and overburden excavated from pits, shafts, haulage drifts, and ventilation boreholes. There is also residue from mine water holding and treatment and dried-out ore stockpiles (Heeb, et al. 1980). Standard reclamation practices include covering with topsoil or spoils and stabilizing with vegetation or riprap.

3.4.4 Reclamation

The objective of reclamation is to reconstitute the disturbed area in such a manner that when operations cease, the land is suitable for alternative uses. Because they disturb much greater areas, surface mines are of much greater concern than underground or solution mines. Some reclamation is required in all cases, however.

The main objective in reclaiming mine spoils is not to reduce the escape of radioactivity as it is in milling. With mine spoils, structural stability must be achieved in order for vegetation to become established. Spoils are usually in piles and must be graded and terraced to minimize erosion and retain rainfall.

Spoils are then covered with topsoil or treated with chemicals if vegetation is required. Riprap can also be used to minimize erosion. The following paragraphs outline the general procedures for stabilizing disturbed sites.

Revegetation

Vegetation is a naturally occurring protectant against erosion for any land surface. But in the case of uranium mines, establishing suitable plant species will require careful planning due to the arid climates of the sites. The revegetation procedure includes site preparation, soil treatment, seeding, and irrigation.

Site preparation involves grading and topsoil placement. A proper topsoil is selected and transported to the site by haul trucks or bulldozers. At the site, bulldozers are used to backfill and rough grade the spoils to blend with the surrounding topography; some operations use draglines or scrapers. In all cases, slopes should not exceed 3:1 according to personnel at Century West Engineering, Bend, Oregon. Motor patrols, bulldozers, or tractor-pulled drags

or floats are commonly used to fine grade the spoils. Fine grading readies the spoil surface for topsoil placement by removing low places and small humps and ridges. Surface rocks are also removed by handpicking or front-end loaders. After a suitable spoils surface is obtained, the topsoil is uniformly placed on the fine-graded spoils, usually with scrapers (Persse 1977).

Revegetation should follow topsoiling as soon as possible to prevent erosion according to personnel at Century West Engineering, Bend, Oregon. Soil preparation includes both physical (discing, plowing, etc.) and chemical (fertilizers, mulch) methods. Harrowing discs scarify the soil to allow better penetration of fertilizers and plant seeds. To enrich the soil, nitrogen or phosphorous-based fertilizers may be added in dry form using a broadcast spreader. If soil acidity must be corrected, liming agents are added with spinner-type spreaders mounted on trucks. In many cases discing must follow lime application. If lime rates exceed 10 to 20 mt/ha, split applications with parts being plowed under is recommended (Mays and Bengtson 1978).

The most common methods of planting seed are drilling, broadcasting, and hydroseeding. Grass and legumes should be drilled using a drill seeder equipped with depth bands and cultipacker wheels. The seeder-cultipacker wheels are aligned to cut furrows. The drill behind the wheels puts seeds in the furrows while another set of wheels, offset from the drill, cover and compact the soil in one operation. Drill rows are ordinarily placed 20 to 40 cm apart at a depth of 6 to 20 mm.

Broadcast seeding is generally used for small, inaccessible areas or areas that are seeded immediately after grading. After roughening the area by harrowing or discing, seeds are applied with a fan or airblast seeder. An aircraft can sometimes be used for broadcast seeding if soil surfaces are rough enough for wind and water action to cover the seed. A cultipacker, harrow or disc, or a sheeps foot roller can also be used for covering the seed.

Seeds can also be planted using a hydroseeder which mixes it with water and sprays. Hydroseeding alone has not usually produced good strains of vegetation in semiarid regions. However, good results are obtained when hydrofertilizing or mulching follows drilling or broadcast seeding.

Trees and shrubs are sometimes planted as seeds, but this is risky. A higher degree of success is obtained from planting small plants either bare-rooted or potted in biodegradable containers. After hardening the plants for several weeks, tubings are usually planted by hand (Persse 1977). Since mulching improves soil filtration and reduces evaporation, it is particularly advantageous for establishing perennial species in areas of low rainfall. Wood chips, wood fiber, manure, and sewage sludge all can be utilized as mulch for revegetation purposes. Straw, hay, and sawdust are applied with a specifically designed blower or spread by hand. Wood fiber, manure, and sewage sludge are applied in a water slurry (hydromulching). Straw is probably the most effective and widely-used mulch.

Common methods of holding straw in place are crimping, discing, or rolling into the soil; covering with a net or wire; or spraying with a chemical tackifier. Crimping is accomplished by a weighted tractor-drawn carriage which forces blunt notched discs into the soil. A specially-designed roller equipped with studs is utilized for rolling or "punching." The roller may be tractor-drawn on gentle slopes. However, on steep slopes with top-of-the-slope access, a flat-bed truck equipped with a winch can be utilized to raise and lower the roller. Both crimping and rolling require soft soils to allow the teeth to penetrate. But rolling can be used on much steeper slopes than a crimper can.

Nets constructed from woven kraft paper, plastic fabric, poultry netting, concrete-reinforcing wire, and even jute can be anchored to hold straw in place. The most common mulching method, however, is the use of a tackifier. This method is useful for hard soils and steep slopes with limited access. Asphalt emulsions and wood fiber-flue mixtures are applied over the straw, or simultaneously with the straw-blowing operation. Hydromulching techniques are frequently utilized (Kay 1978).

Irrigation to start a vegetative cover is usually required in arid climates, especially for the first growing season. Once the seed has germinated and the plants have been established, irrigation schedules can be gradually cut back. By the end of the second or third growing season, the system is no longer required.

Drip irrigation is a new technique predominately used to establish sparse tree and shrub cover in arid environments. With drip irrigation, a small volume of water (1-2 gal/hr) is delivered to each plant along with fertilizers by means of an emitter. For practicality, each emitter spacing is limited to 4 x 4 feet. Maintenance includes installation and care of filters and inspection and flushing of plugged emitters. Tensiometers are used to adjust irrigation schedules to weather conditions and plant requirements.

Sprinkler irrigation is a universal technique for supplying supplemental water. This method provides broad, uniform area coverage, but water requirements are more than double requirements for drip irrigation. Fertilizers can be injected into the water system, too (Bengston 1979).

Low-cost water harvesting methods can be used to enhance growth and survival of vegetation. Water collecting areas lined with paraffin or black polyethylene rubber asphalt increase runoff and concentrate moisture around seedlings.

Long-term maintenance of the reclaimed area includes fertilization with nitrogen if necessary, inspection, and possible reseeding of areas that fail to thrive.

Riprap

Riprap can also be used to stabilize the spoils at uranium mine sites, especially in arid climates or areas where surface runoff is high. Riprap is basically a rock material which varies in size from small cobbles to large boulders weighing several tons. The different grades and sizes of riprap are defined in Table 3.5.

Riprap is usually procured from quarries. The quarry floor is drilled and blasted to obtain large chunks of rock. The rock material is loaded on haul trucks and transported to a crushing and grading facility. If the quarry floor is below the water table, pumps maintain a dry floor by circulating water to a settling pond. Settling pond water is often used for the wash plant which classifies the fine rock material. Water is not essential for riprap manufacture, however.

TABLE 3.5. Quarried Stone for Erosion and Sediment Control (a)

NCSA No.	Graded Riprap Stone		
	Size inches (sq. openings) Avg. (b)	Wave Height (c) ft	Velocity (d) (ft/sec)
R-1	3/4	--	2.5
R-2	1 1/2	0.3	4.5
R-3	3	0.5	6.5
R-4	6	1.0	9.0
R-5	9	1.5	11.5
R-6	12	2.0	13.0
R-7	15	2.5	14.5
R-8	24	4.0	--

- (a) The table assumes a stone dry density of 165 pounds per cubic foot.
- (b) "Average size" is that size exceeded by at least 50% of the total weight of the tonnage shipped; i.e., 50% of the tonnage shall consist of pieces larger than the "average" size (normally 1/2 the specified nominal top size).
- (c) Wave Height is the vertical distance from wave crest to wave trough. The wave height given in the table is the average height of the 1.3 highest waves in the incident wave train.
- (d) The stream velocity is the velocity at mid-stream or at a point 10 feet from the bank, whichever is closest to the bank.
- Source: as adapted from National Crushed Stone Association, 1978.

From the quarry the large stone pieces are transported by haul trucks to a separation facility located nearby. A typical facility would contain a vibrating grizzly, screens, and feeders. As the rock material moves along the grizzly, progressively larger stones drop through openings onto vibrating feeders. The vibrating feeders transport the rock material to screens for successive grading. Graded riprap drops to the ground. Front-end loaders and haul trucks transport the riprap to stockpiles. The riprap is then loaded onto haul trucks or rail cars and transported to the mine site (Robertson 1979).

Other sources of riprap include river beds and naturally occurring gravel deposits. The processing procedure would be very similar; however, drilling and blasting would not be required. The riprap would be loaded onto front-end

loaders. If graded riprap is desired, portable crushing and classifying equipment located nearby would then manufacture the technically acceptable riprap. Pitrun riprap is simply excavated and hauled to the site.

Management requirements for riprap covers includes: 1) periodic inspections, 2) repair of damaged areas, and 3) removal of unwanted vegetation.

As with revegetation, some preparation is needed before the riprap cover can be placed on the uranium mill tailings. First, the site must be graded and whenever possible, the slope should not exceed 3:1. In the case of large riprap, sand-like bedding material is placed on the top of the covered tailings. The sandy material stabilizes the large stones and insures the long-term integrity of the riprap cover. Small cobblestone riprap would probably not require bedding material, however.

When the site is prepared, riprap is dumped onto the spoils. bulldozers or, in some cases, laborers spread the riprap to meet predetermined design requirements.

3.5 MINING INDUSTRY STATISTICS

Uranium ore is extracted by various mining methods, but as described previously, primarily from underground and open-pit mines. As reported by the Department of Energy (1983), there were 139 underground and 24 open-pit uranium mines reported in operation in 1982 accounting for a combined 75% of uranium production. Solution and "other" mining methods accounted for about 25% of production in 1982 (Table 3.6).

The 1982 distribution of uranium ore production by state is given in Table 3.7. Production continues to be primarily from the western United States, mainly New Mexico, Wyoming, and Texas. The amount of uranium produced from all underground uranium mines and received at mills and buying stations in 1982 equaled 2,809,000 tons ore or 6,200 tons U_3O_8 . This underground ore production represented about 34% of the 1982 total receipts of 8,313,000 tons ore (Table 3.8).

TABLE 3.6. Distribution of 1982 Uranium Production by Mining Method^(a)

<u>Source</u>	<u>Number of Sources</u>	<u>Thousand Tons U₃O₈</u>	<u>Percent of Total Production</u>
Underground Mines	139	6.3	46
Open-Pit Mines	24	3.8	29
Solution Mining	18	1.5	11
By-Product	5	1.6	12
Others: Heap Leach, Mine Water, and Low-Grade Stockpiles	10	0.2	2
Totals	196	13.4	100

(a) Table based on information from 182 operating and 14 unmined sources.

Source: U.S. DOE, 1983.

TABLE 3.7. Distribution of 1982 Uranium Production by State^(a)

<u>State</u>	<u>Thousand Tons U₃O₈</u>	<u>Percent of Total Production</u>
New Mexico	3.8	28
Wyoming	2.7	20
Texas	2.2	17
Others: Arizona, Colorado, Florida, Idaho, Utah, and Washington	4.7	35
Totals	13.4	100

(a) Table based on information from 182 operating and 14 unmined sources.

Source: U.S. DOE, 1983.

In other terms, the DOE (1983) reported that total U.S. production of uranium concentrate equalled 14,430 tons U₃O₈. Of this total, 10,115 tons came from ore, while 3,315 tons came from other sources. This total concentrate production is down 30% (or 5810 tons) from the 1981 level of 19,240 tons (Table 3.9).

Uranium drilling declined as well in 1982. Uranium companies drilled only 6.1 million feet in 1982, down 8 million feet or 56% from the 1981 level of 14.1 million feet (Table 3.10).

TABLE 3.8. Uranium Ore Produced from Mines and Received at Mills and Buying Stations^(a)

Year	Total Receipts		(Thousand Tons) Open-Pit Production		Underground Production	
	Ore	U ₃ O ₈	Ore	U ₃ O ₈	Ore	U ₃ O ₈
1982	8,313	10.1	5,504	3.9	2,809	6.2

(a) This represents mined ore only; does not include production from mine water, in-situ leach liquor, heap-leach solutions, by-products, and miscellaneous low-grade ore from old mine dumps.

Source: U.S. DOE, 1983.

TABLE 3.9. Ore Processed and Concentrate Produced in 1982

State	Ore Processed		Concentrate Produced (Tons U ₃ O ₈)		
	Millions of Tons	Contained Tons U ₃ O ₈	From Ore	Other ^(a)	Total
New Mexico	2.11	3,755	3,650	255	3,905
Wyoming	3.89	2,550	2,440	80	2,520
Arizona, Colorado, Florida, Louisiana, Texas, Utah, and Washington	2.75	4,215	4,025	2,980	7,005
Totals	8.75	10,520	10,115	3,315	13,430

(a) Includes U₃O₈ in concentrate obtained by solution mining, heap leaching, and as a by-product from other activities.

Source: U.S. DOE 1983.

One uranium industry statistic remained the same in 1982 as it was in 1981. The average grade of ore processed was 0.12% U₃O₈. However, the recovery of U₃O₈ from ore processed was 96% up 2% from the year before (U.S. DOE 1983).

TABLE 3.10. Comparison of 1982 and 1981 Drilling by State

<u>State</u>	<u>1982 Drilling (Millions of Feet)</u>	<u>1981 Drilling (Millions of Feet)</u>
Wyoming	1.8	3.8
Texas	1.2	3.9
New Mexico	0.6	1.5
Utah	0.6	1.9
Colorado	0.8	1.0
Others ^(a)	1.1	2.0
Totals	6.1	14.1

(a) For 1982, includes Alaska, Arizona, California, Michigan, Minnesota, Montana, Nebraska, Nevada, Oklahoma, Oregon, South Dakota, Virginia, Washington, and undisclosed locations. Eighty-eight percent of this drilling was done in the states of Arizona, Nebraska, and South Dakota.

Source: U.S. DOE, 1983.

3.6 INDUSTRY EMISSION REGULATIONS

Radioactive emissions from underground uranium mines, i.e., radon daughter products found in mine atmospheres have been identified as a health risk to miners and individuals situated near mining operations (McGinley, 1975). McGinley (1975), discusses that these radioactive emissions have been the assumed cause of lung cancer at a higher than expected incidence rate among underground uranium miners. These emissions discharged to the above-ground atmosphere are also thought to be a health concern for individuals living proximal to such operations. There has been an evolution of standards governing radioactive exposure/emissions. These standards deal with two aspects: 1) the exposure to the underground uranium miner, 2) and the emission limit to the above ground atmosphere.

3.6.1 Underground Exposure

McGinley (1975) states that around 1960, a systematic monitoring of radon-daughter concentrations in underground uranium mines was implemented by state agencies and major mining companies and standards were developed. The United States Public Health Service (USPHS) in 1959, the American Standards

Association (ASA) (now known as the American National Standards Institute (ANSI)) and the United States Atomic Energy Commission (AEC) in 1960 recommended that an exposure standard be set for underground uranium mines based on a maximum permissible radon-daughter concentration of one working level (WL) in the mine atmosphere.^(a) This standard stated that when any working area showed a working level between 1.0 and 3.0, a determination was to be made of the weighted average exposure to workers. If a greater than 10.0 WL was measured, immediate action was necessary to reduce the exposure to workers and correct conditions. The average exposure level for the industry was 7 WL in 1957 with a drop to 2.1 WL by 1966 (McGinley 1975).

The Federal Radiation Council (FRC) was established in 1959 (Public Law 82-373) to provide guidance for federal agencies in regards to formulating radiation standards and enforcing programs in conjunction with the states involved in such mining. The FRC published in September 1967, a recommendation of no more than six working level months (WLM) exposure to a miner over a 3 month consecutive period and no more than 12 WLM in any 12 month consecutive period. It was recommended also that actual exposures were to be kept lower than this standard when at all practical and that records of exposure to individuals were to be kept.

A prior standard proposed by the Department of Labor earlier in the same year (May, 1967) called for a much lower 0.3 WLM. After much debate and study, a final standard as recommended by the FRC was adopted limiting exposure to 4 WLM as of July 1, 1971 (McGinley, 1975). It is listed in the Code of Federal Regulations (CFR) under 30 CFR 57 - "Safety and Health Standards - Metal and Non-Metal Underground Mines." This standard has remained unchanged as of May, 1983 as indicated in the Code of Federal Regulations, List of CFR Sections Affected, May, 1983.

As described by Breslin (1981), there are three federal agencies that are involved in Mine Health and Safety and in overseeing this exposure standard. They are the Bureau of Mines (BOM) the Mine Safety and Health Administration

(a) A working level is defined as any combination of radon-daughters in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy (McGinley, 1975).

(MSHA) and the National Institute for Occupational Safety and Health (NIOSH). The BOM is responsible for research and development on mine safety and control of the mine environment. MSHA is responsible for enforcement and promulgation of mine health and safety standards. NIOSH is responsible for research on the health of miners and the recommendation of health standards.

3.6.2 Emission to Atmosphere

With the establishment of the Environmental Protection Agency (EPA), the FRC was abolished and its responsibilities transferred to the EPA. The EPA on December 27, 1979, listed radionuclides as a hazardous air pollutant under provisions of the Clean Air Act, Section 112. Congress in 1977, had amended this act to consider such air borne emissions of radioactive materials and directed the EPA to determine whether emissions of radioactive pollutants cause or contribute to air pollution. After listing radionuclide emissions as hazardous, the EPA began efforts for their regulation in coordination with the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE). Prior to these provisions in the Clean Air Act of 1977, these emissions were mostly unregulated or regulated under the earlier Atomic Energy Act,^(a) (Federal Register, 1983).

The Sierra Club filed suit against the EPA in California on June 16, 1981. The club alleged that it was the nondiscretionary duty of the EPA to propose standards for radionuclides within 180 days after listing them as hazardous pollutants. The suit resulted in a court order on September 30, 1982. It stated that the EPA must publish proposed regulations, with a notice of hearings, within 180 days of the order (Nuclear News, 1983a).

(a) Under authority of the Atomic Energy Act of 1954, as amended; Reorganization Plan No. 3 of 1970 and as listed in the Federal Register, Vol. 42, p. 4860, January 13, 1977, there are environmental radiation protection standards for nuclear power operations. These standards apply to radiation doses received by public members in the general environment resulting from operations which are part of a nuclear fuel cycle. Nuclear fuel cycle here excludes mining operations by definition. However, this standard limits the annual dose equivalent not to exceed 25 millirems to the whole body, effective December 1, 1979 (40 CFR 190).

The EPA has identified four types of facilities as sources of radionuclide emissions, which includes underground uranium mines. They have proposed standards for the emissions from these sources. The standard for underground uranium mines proposes to restrict the increase in annual average concentration of ^{222}Rn in any unrestricted area around a mine. The restriction is 0.2 picocuries per liter ($\mu\text{Ci}/\ell$) (Federal Register, 1983). An unrestricted area means any area not under the control of the mining company or government agency (Federal Register, 1983).

It is noted in the Federal Register (1983) that the EPA has concluded that there is presently no practical control technology to effectively reduce ^{222}Rn emissions to air from underground uranium mines. However, the 1977 amendments to the Clean Air Act allow the EPA to set design, equipment, work practice, or operational standards for such hazardous materials as radionuclides when an emission standard may not be achievable (White, et al., 1979).

Thus, the EPA has suggested various methods for meeting the proposed emission standard. As listed in the Federal Register (1983), they are:

- 1.Reducing the operating time of the mine,
- 2.Increasing the stacks effective heights,
- 3.Controlling additional land around the mine vents - out to 2 km.

The least expensive method for meeting the proposed standard is expected to be controlling land within 2 km (Federal Register, 1983).

3.7 INDUSTRY GROWTH POTENTIAL

Presented in Table 3.11 are the number of reactors that began commercial operation in each year from 1974 through 1982. After 1977, the rate of reactor startups has dropped significantly. In 1978, the last reactor was ordered and since 1972 more than one hundred reactors have been canceled. In 1982, "14 reactors were delayed (had their construction schedules stretched out); 18 more representing 22019 megawatts capacity--were canceled" (Raloff 1983).

TABLE 3.11. Number of Reactors Starting Commercial Operation

<u>Year</u>	<u>Number of Reactors</u>
1974	13
1975	8
1976	3
1977	8
1978	2
1979	2
1980	2
1981	4
1982	2

Source: Nuclear News, February 1983d.

As stated previously, of the three main uses of uranium, fuel for nuclear reactors can be considered the major use of uranium and the basis for a domestic uranium industry. The continued existence of this uranium industry thus is directly dependent on the existence of a domestic nuclear power industry. The present nuclear power industry faces many problems that threaten its own expansion. In summing up the major problems, Carl Walske, president of the Atomic Industrial Forum, has been quoted by Science News magazine (Raloff 1983) as saying "that the nuclear power industry's top ... problems are money ..., regulation, public acceptance and waste disposal." Similarly, the U.S. Department of Energy, Energy Information Administration (1983) has summarized its views on the conditions necessary in the nuclear power industry for a long-term resurgence in new nuclear power orders to be possible. These include:

- The need for new electric generating capacity clearly increases.
- Nuclear power remains competitive with alternative generation sources, such as coal.
- Utility financial practices and utility rate structures are modified to reduce debt equity and cash-flow burdens of new nuclear construction.

- Uncertainties surrounding nuclear generating plants are resolved, including the predictability of the nuclear licensing process, nuclear safety regulations, reactor siting, and long-term uranium availability.
- The nuclear waste disposal problem is resolved, particularly the construction of a Federal repository for the long-term disposition of highly radioactive wastes.

Given below are a few examples and details of these problems/conditions in the nuclear power industry as quoted from recent literature.

- In a report released January 21, 1983 by the National Economic Research Associates, Inc. (NERA) entitled The Current Economics of Electric Generation from Coal in the U.S. and Western Europe, "NERA has concluded that nuclear has an advantage of 15 to 25% over coal east of the Mississippi and west of the Rockies, but adds that the uncertainties surrounding future nuclear costs are so great that it will likely tend to make utilities favor coal-fired units for new orders" (Nuclear News, 1983b).
- Continuing on this topic, Lewis J. Perl, senior vice president of NERA, states that "nuclear's decline is due to several factors ... largely economics in origin. Both capital and operating costs have escalated rapidly in the past five years. If this continues, nuclear's small advantage over coal will completely evaporate" (Catalano 1983b).
- The lifetime of nuclear reactors has typically been estimated to be about 30 years and some plants have already operated 20 years. There is now great concern that the average life of all reactors will not be 30 years. In the same report cited above, NERA states that "the nuclear advantage would be eliminated if the lifetime of nuclear plants turns out to be shorter than has been previously anticipated (20 instead of 30 years)." (Nuclear News, 1983b)

- According to Lee Catalano, Industry News Editor for Power Magazine, "capacity factors [of operating commercial reactors] have not been as high as expected. At 60%, they are about 10% under the expert's predictions." (Catalano 1983a). Economically, this tends to reduce nuclear power's cost advantage over other competing electric sources such as coal-fired plants.
- The average lead time for construction of a reactor in the U.S. has "historically been eight years although in contrast, the anticipated average lead time for reactors now under construction is 10 to 12 years" (Bonny and Fulton 1982). Utilities borrow to finance construction, and with higher interest rates and longer lead times construction costs have also increased.
- On the waste disposal issue, in April of this year a "unanimous U.S. Supreme Court ... rul[ed] that California and other states may ban future plants until the federal government creates permanent disposal sites for radioactive wastes ... Already seven states besides California have passed moratorium legislation" (Newsweek, May 2, 1983)

Not only do all the problems that affect the nuclear power industry affect the uranium industry, but the domestic uranium industry has problems unique unto itself.

- Paul C. DeVergie and others of the U.S. Department of Energy in the Grand Junction Area Office state that:

"In terms of constant 1981 dollars, the current price is close to the all-time low value which occurred in 1972. Yet, the real cost of uranium production continues to rise, engendered to a considerable degree by increasingly stringent environmental regulations. Substantial portions of the investments made to develop the large uranium deposits discovered in the 1970s have resulted in little or no actual production. Additional expenditures

will be needed to maintain or reopen completed or partially completed mine development workings if they are to be used in the future. As a result of these conditions, uranium production, investments, exploration activities, and industry employment have dropped very sharply during the past 2 years and are projected to decline even further in the future" (DeVergie et al. 1982).

- Lastly, "U.S. producers ... are adjusting to the industry's reduced requirements. More reactors have been canceled here, and production costs are the highest anywhere. ... Foreign producers have stepped into the U.S. market. Presently, about 28% of all uranium in the U.S. is imported, and this figure is expected to increase" (Catalano 1983a). Thus, domestic producers are losing market share in a declining market that is characterized by large and increasing inventories.

3.8 UNDERGROUND URANIUM MINE STUDY

A group of 29 underground uranium mines was chosen for study in regards to population, land status and land value surrounding their sites. This group represents approximately 84% of the 1982 domestic underground uranium production.^(a) The methodology used in selecting this representative group of 29 underground uranium mines, plus the procedure used in estimating its percent of industry production will be discussed. Also, a description of uranium miner productivity and estimates of mine-specific production, plus a detailed characterization of population, land status and land value will be presented in the following sections.

3.8.1 Study Mine Selection and Background

The 29 mines in this study were selected based on mine type, operating status and cumulative employee-hours as reported by the U.S. Department of Labor-Mine Safety and Health Administration (MSHA) (1982) listing. The MSHA

(a) Calculated using 3rd quarter, 1982, statistics from the Department of Labor-Mine Safety and Health Administration (MSHA).

list was first broken down according to mine type and operating status. Only those underground mines (code 01-"type") that were listed as active (code 01-"status"), or known to be recently inactive, were considered. For this group, 105 mines total, employee-hours worked were then converted to a full-time equivalent (FTE) worker number.^(a)

These 105 mines were then categorized according to operating status and FTE. Operating status was either active or temporarily inactive and the FTE breakdown was greater than 25, 25-10, 9-1, and 0.9-0 FTE (Table 3.12). From this categorization, the 30 mines falling under the greater than 25 FTE and 25-10 FTE were selected as the initial underground uranium mine study group.

TABLE 3.12. Categorization of MSHA Uranium Mines

Mine Status	Full-Time Equivalents ^(a) (FTE)			
	>25	25-10	9-1 ^(c)	0.9-0 ^(c)
(Total number mines in each category)				
Active	20	5	29	25
Temporarily inactive	3 ^(b)	2 ^(b)	6	15

(29 selected for study group, see Table 3.13 for identification)

- (a) 1 FTE = 2000 man hours.
- (b) These were indicated as "active" in the MSHA list. Personal opinion at time chart was made indicated "inactive" (no production) status.
- (c) It was not known that ventilation was applied full-time to all of these mines.

A later modification of the selection scheme, however, resulted in the total dropping to 29 mines. This modification combined two of the mines into one entity (Hacks Canyon #1 and #2), added two mines (Pigeon and Kanab North) due to their proximity and similarity to the Hacks Canyon area, and dropped one mine (Bill Smith) due to information that the mine was flooded.^(b) And

- (a) One FTE equals 2000 man hours.
- (b) Since data on the mine was collected during a field excursion in the area, the data is included in this report, but as supplemental information only. It has not been included into the final tabulation totals.

finally, data for the Schwartzwalder was not included in the final tabulated totals. (a) This decision not to include the Schwartzwalder data was made by the EPA because the mine was considered not to be typical of the U.S. uranium mining industry due to its deposit type (vein-type versus sandstone-type) and location (mountain resort area near metropolitan Denver, Colorado). Without the Schwartzwalder and Bill Smith, the study group number totals 29 (Table 3.13).

Information for each of the 29 study mines is summarized on individual synopsis sheets in Appendix C. All sources of information on these sheets are referenced. Location maps are also given in Appendix D, showing all occupied dwellings, mine shaft locations, and population distributions.

Percentage of Industry Production

The estimated percentage of 1982 underground uranium production represented by these 29 study mines (84%) was calculated from the MSHA employee-hours data. This data is available quarterly from the Health and Safety Analysis Center, Denver, Colorado. Even though actual production statistics are not generally publicly available on a mine-by-mine basis, estimates of a production percentage can be made using employee-hour statistics. This estimate of the percentage of industry production as represented by the 29 study mines should be representative of the actual production percentage if certain assumptions are clearly stated as follows:

- 1) Worker productivity is relatively constant between mining locations.
- 2) The MSHA data gives the best data as to the "operating status" of a particular underground uranium mine unless other higher confidence information indicates differently.
- 3) The MSHA employee-hours for mines of status 1, 2, and 3 (active, temporarily inactive, or permanently closed, respectively) will be used in the calculation, but under the following scheme:

(a) Since data on the mine was collected during a field excursion in the area, the data is included in this report, but as supplemental information only. It has not been included into the final tabulation totals.

TABLE 3.13. Uranium Mines in Study Group

<u>MINE</u>	<u>COMPANY</u>	<u>LOCATION</u>
<u>Arizona</u>		
Hack Canyon	Energy Fuels Nuclear, Inc.	T37N, R5W, Sec. 26, Mohave Co., Arizona
Pigeon	Energy Fuels Nuclear, Inc.	T38N, R2W, Sec. 5, Coconino Co., Arizona
Kanab North	Energy Fuels Nuclear, Inc.	T38N, R3N, Sec. 17, Mohave Co., Arizona
<u>Colorado</u>		
Sunday	Union Carbide Corp.	T44N, R18W, Sec. 13, San Miguel Co., Colorado
King Solomon	Union Carbide Corp.	T48N, R17W, Sec. 19, Montrose Co., Colorado
Deremo-Snyder	Union Carbide Corp.	T42N, R20W, Sec. 2, San Miguel Co, Colorado
<u>New Mexico</u>		
Mt. Taylor	Gulf Mineral Resources	T13N, R8W, Sec. 24, Cibola Co., New Mexico
Old Church Rock	United Nuclear Corp.	T16N, R16W, Sec. 17, McKinley Co., New Mexico
Church Rock NF	United Nuclear Corp.	T17N, R16W, Sec. 35, McKinley Co., New Mexico
Church Rock #1	Kerr-McGee Corp.	T17N, R16W, Sec. 35, McKinley Co., New Mexico
Church Rock East	Kerr-McGee Corp.	T17N, R16W, Sec. 36, McKinley Co., New Mexico
Kerr-McGee Sec. 30 East	Kerr-McGee Corp.	T14N, R9W, Sec. 30, McKinley Co., New Mexico
Kerr-McGee Sec. 30 West	Kerr-McGee Corp.	T14N, R9W, Sec. 30, McKinley Co., New Mexico
Kerr-McGee Sec. 19	Kerr-McGee Corp.	T14N, R9W, Sec. 19, McKinley Co, New Mexico
Kerr-McGee Sec. 35	Kerr-McGee Corp.	T14N, R9W, Sec. 35, McKinley Co., New Mexico
Kerr-McGee Sec. 36	Kerr-McGee Corp.	T14N, R9W, Sec. 36, McKinley Co., New Mexico

TABLE 3.13. (Cont'd)

Homestake Sec. 23	Homestake Mining Co.	T14N, R10W, Sec. 23, McKinley Co., New Mexico
Homestake Sec. 25	Homestake Mining Co.	T14N, R10W, Sec. 25, McKinley Co., New Mexico
Nose Rock	Phillips Petroleum Co.	T19N, R11W, Sec. 31, McKinley Co., New Mexico
Mariano Lake	Gulf Mineral Resources	T15N, R14W, Sec. 12, McKinley Co., New Mexico
<u>Utah</u>		
Velvet	Atlas Corp. - Minerals Division	T31S, R25E, Sec. 3, San Juan Co., Utah
Tony M. (Lucky Strike)	Plateau Resources, LTD.	T35S, R11E, Sec. 16 & 21, Garfield Co., Utah
Wilson-Silverbell	Union Carbide Corp.	T32S, R26E, Sec. 15 San Juan Co., Utah
Lisbon	Rio Algom Corp.	T29S, R24E, Sec. 21, San Juan Co., Utah
LaSal	Union Carbide Corp.	T29S, R24E, Sec. 1, San Juan Co., Utah
Hecla	Union Carbide Corp.	T29S, R24E, Sec. 6, San Juan Co., Utah
<u>Wyoming</u>		
Big Eagle	Pathfinder Mines Corp.	T27N, R92W, Sec. 2 & 11, Fremont Co., Wyoming
Golden Eagle	Silver King Mines	T36N, R73W, Sec. 14, Converse Co., Wyoming
Sheep Mountain	Western Nuclear, Inc.	T28N, R92W, Sec. 22, Fremont Co., Wyoming
<u>Supplemental Data</u>		
Schwartzwalder (a)	Cotter Corp.	T2S, R71W, Sec. 25 Jefferson Co., Colorado
Bill Smith (b)	Kerr-McGee Corp.	T36N, R74W, Sec. 36, Converse Co., Wyoming.

(a) Given as data supplemental only because the mine type and location are not considered typical of the uranium industry.

(b) Data given as supplemental only because of reported mine flooding.

- a. For those study mines that are known to be "not producing" or that have become "inactive" or "closed" prior to 1982, MSHA employee-hours will not be used and considered to the zero (hence zero production).
- b. For all other underground mines, employee-hours will be used for only those of status 1, status 2 (becoming "inactive" sometime in 1982) and status 3 (becoming "closed" sometime in 1982).

The formula for calculating the estimated percentage of production is estimated as follows:

$$\frac{P}{100} = \frac{\Sigma SMH}{\Sigma MH} = \frac{\Sigma SMPR}{\Sigma MPR} \quad (3.1)$$

where

P = percent of total underground uranium production represented by study mines

SMH = employee-hours for study mines

MH = total employee hours for all underground mines

SMPR = uranium production for study mines

MPR = uranium production from all underground mines

Based on the MSHA data (3rd quarter, 1982), a value of 84% of total 1982 underground production from the 29 study mines is calculated as follows:

$$0.84 = \frac{3,602,498 \text{ hr}^{(a)}}{3,602,498 \text{ hr}^{(a)} + 219,655 \text{ hr}^{(b)} + 202,140 \text{ hr}^{(c)} + 274,055 \text{ hr}^{(d)}} \quad (3.2)$$

- (a) All study mines reporting 3rd quarter hours except Pigeon, Nose Rock, Golden Eagle and Sheep Mountain mines. These four exceptions are either not yet producing or were closed prior to 1982. Refer to Table 3.14.
- (b) All other underground mines with status 1 and status 2 (becoming inactive sometime in 1982). The Schwartzwalder mine is listed separately from this category since it is reported in Table 3.14 as supplemental data.
- (c) All other underground mines with status 3 (becoming closed sometime in 1982). The Bill Smith mine (supplemental data Table 3.14) drops out due to closure since 1979.
- (d) Swartzwalder mine, status 1, reported separately since reported in Table 3.14 as supplemental data.

Table 3.14 lists the 3rd quarter 1982 employee-hours used for each of the 29 study mines in this calculation.

Mine-Specific Production

As well as estimating the production percentage represented by these 29 mines, the annual productions on a mine-by-mine basis can also be estimated using the same employee-hour data plus a worker productivity factor. It should be emphasized that an assumption is made here that worker productivity is relatively constant between mining locations. This may not necessarily be the case on a mine-specific basis due to varying worker population throughout the country.

A productivity factor of 2.44 tons U_3O_8 per FTE uranium worker per year (underground uranium mines), calculated from DOE (1983) and MSHA (U.S. Dept. of Labor 1982) data, can be used to estimate annual productions.^(a) The annual production is estimated as follows:

$$APS_i = (CH)_i (F) \quad (3.3)$$

where APS = 1982 annual production in tons U_3O_8 for each study mine i
CH = cumulative employee-hours for 1982 for each study mine i
F = factor of employee productivity.

Table 3.14 lists the 4th quarter, 1982, cumulative employee-hours for each study mine, the FTE worker equivalent and the estimated mine production.

3.8.2 Study Mine Site Characterization

The 29 mine sites of the study group were each visited during the months of January and February, 1983, by a field team from Battelle Pacific Northwest Laboratories. For each mine site, information was gathered concerning population status, land status, and value of surrounding land out to 5 kilometers from the site. Any associated facilities of major importance and surrounding land characteristics were also noted in the field. Results are tabulated in Tables 3.15, 3.16, 3.17, and 3.18, and Appendix E.

(a) Refer to Appendix B for detailed calculations.

TABLE 3.14. Employee-hours, FTE workers, and Estimated Production

Mine	3rd Qtr., 1982 Employee-hours (a)	4th Qtr., 1982 Employee-hours (a)	4th Qtr., 1982 FTE Worker Equivalent (b)	Estimated 1982 Production (tons U-308) (c)
Arizona				
Hack Canyon (#1 & #2)	91,292	113,799	56.9	138.8
Pigeon	8,823	13,948	7.0	0(d)
Kanab North	0	0	0	0
Colorado				
Sunday	59,196	75,231	37.6	91.7
King Solomon	53,926	68,544	34.3	83.7
Deremo-Snyder	81,109	105,316	52.7	128.6
New Mexico				
Mt. Taylor	504,130	592,447	296.2	722.7
Old Church Rock	50,275	51,535	25.8	63.0
Church Rock NE	288,807	310,020	155.0	378.2
Church Rock #1	292,236	318,751	159.4	388.9
Church Rock East	124,404	130,469	65.2	159.1
Kerr-McGee Sec. 30 East	176,733	215,665	107.8	263.0
Kerr-McGee Sec. 30 West	200,394	238,846	119.4	291.3
Kerr-McGee Sec. 19	191,064	229,450	114.7	279.9
Kerr-McGee Sec. 35	295,792	351,838	175.9	429.2
Kerr-McGee Sec. 36	169,580	200,666	100.3	244.7
Homestake Sec. 23	280,687	376,578	188.3	459.5
Homestake Sec. 25	118,446	122,347	61.2	149.3
New Mexico				
Nose Rock	35,378	45,041	22.5	0(d)
Mariano Lake	60,693	66,403	33.2	81.0(e)

TABLE 3.14. (contd)

Mine	3rd Qtr., 1982 Employee-hours (a)	4th Qtr., 1982 Employee-hours (a)	4th Qtr., 1982 FTE Worker Equivalent (b)	Estimated 1982 Production (tons U ₃ O ₈) (c)
<u>Utah</u>				
Velvet	76,165	92,977	46.5	113.5
Tony M	205,166	248,116	124.1	302.8
Wilson-Silverbell	22,316	29,726	14.9	36.4
Lisbon	100,270	132,245	66.1	161.3
LaSal	115,710	147,393	73.7	179.8
Hecla	21,348	26,589	13.3	32.5
<u>Wyoming</u>				
Big Eagle	22,759	29,977	15.0	36.6
Golden Eagle	78,217	98,611	49.3	0(d)
Sheep Mountain	70,952	92,328	46.2	0(d)
TOTALS	3,795,868(g)	4,524,856(g)	2,262.5(g)	5,215.5(g)
<u>Supplemental Data</u>				
Schwartzwalder (f)	274,055	358,319	179.2	437.3
Bill Smith (f)	31,959	40,326	20.2	0(d)

(a) Includes only those hours reported by the mining company; does not include hours reported by contractors.

(b) 1 FTE worker = $\frac{\text{cumulative employee-hours}}{2000 \text{ hours}}$

(c) Calculated by using 2.44 tons U₃O₈ per FTE worker per year. See Appendix B for this productivity calculation. These are estimates only using industry average productivity and employee-hour data. Actual production may vary due to specific conditions at each mine.

(d) Zero production is reported for this mine in 1982 even though employee-hours are given. The mine is either not yet producing or is shut down prior to 1982. Consequently, the 3rd quarter company employee-hours for this mine are not included in the calculation of percentage of industry production as represented by the 29 study mines.

(e) A 1982 production figure is reported even though the mine was closed sometime in 1982. Production occurred up until then and most likely afterwards as well, as cleanup of ore and reclamation continued throughout the remainder of the year.

(f) Hours not included in total hours of study mine group because these mines were dropped from the group for reasons cited in the text. Number of mines total 29.

(g) Represents 84% of the underground uranium industry.

TABLE 3.15. Average Persons Per Household
(1980 Census)

<u>State</u>	<u>County</u>	<u>Average Persons/Household</u>
New Mexico	McKinley	3.73
	Valencia/Cibola	3.17 (4.35 Indian)
Utah	San Juan	4.04
	Garfield	3.00
Colorado	Dolores	2.84
	San Miguel	2.55
	Montrose	2.84
	Jefferson	2.82
Wyoming	Fremont	2.98
	Converse	2.99
Arizona	Coconino	3.15
	Mojave	2.63

Source: U.S. Department of Commerce,
Bureau of Census, 1980.

Population Status

As described earlier, the EPA has suggested that one possible method of meeting the proposed radionuclide emission standard would be to restrict habitation within a zone around the mine site by controlling land out to 2 km. Having control over surrounding land in this manner would require present residents to relocate. The EPA requested an on-site field study be conducted to determine the number of residents within a 5 km radius of each mine site. The latest 1980 Bureau of Census statistics were used to supplement the field study. This included population estimates for any small towns and villages located within a 5 km zone, and the number of people per household for each particular county and state. In addition, information was obtained from the USPHS Indian Hospital in Gallup and Crownpoint, NM. Table 3.15 is the census data incorporated into this study.

TABLE 3.16. Population

Mine	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
<u>Arizona</u>						
Hack Canyon	1	1	1	1	1	1
Pidgeon	0	0	0	0	0	0
Kanab North	0	0	0	0	0	0
<u>Colorado</u>						
Sunday	0	0	0	0	0	0
King Solomon	0	0	0	0	0	0
Deremo-Snyder	0	5	21	49	67	83
<u>New Mexico</u>						
Mt. Taylor	0	100	317	336	336	336
Old Church Rock	9	9	70	139	187	364
Church Rock NE	0	11	22	26	31	31
Church Rock #1	0	11	22	27	31	31
Church Rock East	0	0	9	57	70	131
Kerr-McGee Sec 30 East	3	3	3	3	3	3
Kerr-McGee Sec 30 West	0	5	5	5	5	6
Kerr-McGee Sec 19	0	0	0	4	4	4
Kerr-McGee Sec 35	0	0	0	0	0	0
Kerr-McGee Sec 36	0	0	0	0	0	0
Homestake Sec 23	0	0	0	3	3	4
Homestake Sec 25	0	0	0	0	0	0
Nose Rock	0	0	0	0	26	35
Mariano Lake	13	44	75	196	274	352
<u>Utah</u>						
Velvet	0	0	0	0	0	0
Tony M	0	0	0	0	0	0
Wilson-Silverbell	0	0	0	12	20	23
Lisbon	0	0	0	4	44	44
LaSal	0	0	53	101	194	194
Hecla	16	16	20	40	73	73
<u>Wyoming</u>						
Big Eagle	0	0	0	0	0	0
Golden Eagle	0	0	0	6	6	6
Sheep Mtn.	0	0	0	0	0	12
TOTALS	42	205	618	1009	1375	1733
<u>Supplemental Data</u>						
Schwartzwalder ^(a)	3	3	63	102	136	147
Bill Smith ^(b)	0	0	0	0	0	6

(a) Data given as supplemental only because the mine type and location are not considered typical of the uranium industry. Data gathered during a field excursion to the area.

(b) Data given as supplemental only because of reported mine flooding. Data gathered during a field excursion in the area.

TABLE 3.17. Indian Population and Total Relocation Costs

Site	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
Old Church Rock	9	9	70	139	187	364
Church Rock NE	0	11	22	26	31	31
Church Rock #1	0	11	22	27	31	31
Church Rock East	0	0	9	57	70	131
Kerr-McGee Sec 30 East	0	0	0	0	0	1
Homestake Sec 23	0	0	0	3	3	4
Nose Rock	0	0	0	0	26	35
Mariano Lake	<u>13</u>	<u>44</u>	<u>75</u>	<u>196</u>	<u>274</u>	<u>352</u>
TOTALS	22	75	198	448	622	949
Total Relocation Costs (\$)	396,000	1,350,000	3,564,000	8,064,000	11,196,000	17,082,000

TABLE 3.18. Land Ownership Percentages, P/M/G^(a)

Mine	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
<u>Arizona</u>						
Hack Canyon	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100
Pidgeon	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100
Kanab North	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100	1/0/99
<u>Colorado</u>						
Sunday	0/0/100	0/0/100	0/0/100	3/1/97	8/1/91	10/1/89
King Solomon	0/0/100	0/2/98	0/5/95	0/3/97	0/3/97	0/3/97
Deremo-Snyder	84/0/16	87/0/13	84/0/16	89/0/11	85/0/15	81/0/19
<u>New Mexico</u>						
Mt. Taylor	75/19/6	58/26/16	55/16/29	45/13/42	39/10/51	39/7/54
Old Church Rock	0/0/100	0/0/100	0/0/100	0/0/100	2/0/98	3/0/97
Church Rock NE	0/0/100	0/7/93	0/23/77	0/13/87	0/8/92	0/5/95
Church Rock #1	0/0/100	0/7/93	0/23/77	0/13/87	0/8/92	0/5/95
Church Rock East	0/0/100	0/7/93	0/6/94	3/4/93	5/2/93	3/1/96
Kerr-McGee Sec 30 East	11/89/0	4/91/5	2/70/28	4/78/18	10/79/11	13/77/10
Kerr-McGee Sec 30 West	11/89/0	24/76/0	17/72/11	16/69/15	22/666/12	27/57/16
Kerr-McGee Sec 19	0/100/0	23/77/0	46/39/15	45/39/16	32/37/31	29/38/33
Kerr-McGee Sec 35	0/100/0	0/85/15	8/59/33	14/55/31	10/57/33	14/52/34
Kerr-McGee Sec 36	5/42/53	14/22/64	27/14/59	36/8/56	36/5/59	39/3/58
Homestake Sec 23	74/0/26	68/0/32	61/6/33	50/18/32	47/17/36	53/12/35
Homestake Sec 25	100/0/0	85/0/15	59/0/41	58/1/41	50/2/48	43/10/47
Nose Rock	0/50/50	0/50/50	0/45/55	0/41/59	0/38/62	0/35/65
Mariano Lake	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100

TABLE 3.18. (contd)

Mine	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
<u>Utah</u>						
Velvet	14/0/85	10/0/90	6/0/94	12/0/88	24/0/76	27/0/73
Tony M	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100	0/0/100
Wilson-Silverbell	80/0/20	95/0/5	95/0/5	94/0/6	91/0/9	81/0/19
Lisbon	0/0/100	0/0/100	6/0/94	17/2/81	21/2/78	16/1/83
LaSal	8/0/92	25/0/75	34/0/66	41/0/59	34/0/66	26/0/74
Hecla	25/0/75	25/0/75	48/0/52	37/0/63	28/0/72	21/0/79
<u>Wyoming</u>						
Big Eagle	0/100/0	0/88/12	0/80/20	0/8/92	0/5/95	1/3/96
Golden Eagle	60/20/20	89/7/4	85/3/2	94/1/5	91/1/8	90/1/9
Sheep Mtn.	30/45/25	18/42/40	5/28/69	2/18/80	4/11/85	12/8/80
AVERAGES	20/22/58	22/20/58	22/17/61	23/13/64	22/12/66	22/11/67
<u>Supplemental Data</u>						
Schwartzwalder ^(b)	100/0/0	100/0/0	100/0/0	100/0/0	100/0/0	100/0/0
Bill Smith ^(c)	1/0/99	15/0/85	34/0/66	43/5/52	54/8/38	64/7/69

(a) P = private, M = mineowner, G = government, federal, state, local and Indian lands

(b) Data given as supplemental only because the mine type and location are not considered typical of the uranium industry. Data gathered during a field excursion to the area.

(c) Data given as supplemental only because of reported mine flooding. Data gathered during a field excursion in the area.

Population estimates (Table 3.16) were based on occupied dwelling counts and the noted information from the Bureau of Census USPHS Indian Hospital. Population was estimated for zones at 1/2, 1, 2, 3, 4, 5 km radii from the mine site. Occupied dwelling units were identified and plotted onto the largest scale United States Geological Survey topographic quadrangle maps available or any other detailed map available such as United States Forest Service national forest district maps, United States Bureau of Mines surface-minerals management status maps, or United States Geologic Survey county series topographic maps.

Once plotted, the total estimated number of people per zone was calculated by using the people per household statistic for the particular county and state multiplied by the number of total occupied dwellings per zone. Table 3.16 represents cumulative totals for each increasing zone distance.

In several cases, two or more mines were located within the 5-km radius. When this occurred, the total area around the sites was allocated to the nearest mine. Refer to page D.5 in Appendix D for a simple case of two intersecting mine sites (Deremo-Snyder/Wilson-Silverbell). A more complex case is shown on page D.8 for the Ambrosia Lake Mining District (7 mine cluster).

A special note needs to be made concerning Indian population around eight of the mines in New Mexico. Refer to Table 3.17. Indian population was broken out of the totals due to special consideration regarding Indian relocation and buyout of Indian property.

Land Status

The EPA requested that the land status be identified, i.e., what percentage of the land in each zone around the mine is owned by private individuals, the mining company, or government agencies (Table 3.18). This involved reviewing public information (plats and records) at respective county tax assessors' offices. In most cases, information regarding surface ownership was available in an easy-to-use format, either being plotted on a base township and range map or other reference. However, in some instances in the highly developed mining districts of western Colorado and eastern Utah, information concerning ownership of patented and unpatented mining claims was very ill-organized. Detailed examination of deed books and other submitted mining maps and documents was required in these cases. General land status information was also available from the USFS and USBM. We aggregated federal, state, local, and Indian lands in the government ownership category; these can be separated if needed.

Land Valuation Methodology

The EPA requested that private land values be determined for lands within the 5 km radius of each mine site (Table 3.19). Land values were determined by using several data sources: 1) information from the respective county and

TABLE 3.19. Estimated Value of Private Land (a), \$

Mine	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
<u>Arizona</u>						
Hack Canyon	NA (b)	NA	NA	NA	NA	NA
Pidgeon	NA	NA	NA	NA	NA	NA
Kanab North	NA	NA	NA	NA	NA	= 100 acres of patented mining claims
<u>Colorado</u>						
Sunday	NA	NA	NA	48,000	208,000	384,000
King Solomon	NA	NA	NA	NA	NA	NA
Deremo-Snyder	79,700	260,370	922,640	1,852,870	3,028,940	4,432,770
<u>New Mexico</u>						
Mt. Taylor	39,600	391,500	2,523,700	2,834,200	3,227,400	3,918,800
Old Church Rock	NA	NA	NA	NA	543,300	1,443,100
Church Rock NE	NA	NA	NA	NA	NA	NA
Church Rock #1	NA	NA	NA	NA	NA	NA
Church Rock East	NA	NA	NA	122,200	355,600	355,600
Kerr-McGee Sec 30 East	35,000	35,000	35,000	53,500	147,560	239,960
Kerr-McGee Sec 30 West	31,100	132,200	147,800	157,900	194,800	235,100
Kerr-McGee Sec 19	NA	194,400	844,800	1,229,400	1,405,100	1,532,800
Kerr-McGee Sec 35	NA	NA	37,000	137,800	168,000	336,000
Kerr-McGee Sec 36	3,400	23,500	124,300	326,000	588,000	977,800
Homestake Sec 23	217,800	528,000	994,100	1,158,700	1,485,200	2,361,800
Homestake Sec 25	295,600	622,200	987,800	1,478,000	1,632,200	1,645,600

TABLE 3-19. (Contd)

Mine	0-1/2 km	0-1 km	0-2 km	0-3 km	0-4 km	0-5 km
Nose Rock	NA	NA	NA	NA	NA	NA
Mariano Lake	NA	NA	NA	NA	NA	NA
<u>Utah</u>						
Velvet	5,500	16,000	36,000	172,800	603,200	1,048,000
Tony M	NA	NA	NA	NA	NA	NA
Wilson-Silverbell	39,090	186,350	535,750	1,667,150	2,861,590	3,968,740
Lisbon	NA	NA	50,000	306,000	810,540	810,540
LaSal	4,000	228,430	920,880	1,427,800	2,484,530	2,534,530
Hecla	36,820	147,260	380,000	691,000	965,850	1,000,540
<u>Wyoming</u>						
Big Eagle	NA	NA	NA	NA	NA	NA
Golden Eagle	35,400	209,000	796,200	2,121,000	3,584,000	5,231,000
Sheep Mtn.	18,000	42,300	42,300	42,300	150,000	898,000
TOTALS	841,010	3,016,510	9,378,270	15,835,820	24,443,810	33,354,680
<u>Supplemental Data</u>						
Schwartzwalder ^(c)	880,000	3,400,000	15,200,000	33,600,000	58,400,000	89,200,000
Bill Smith ^(d)	600	35,330	317,430	901,710	2,008,640	5,151,430

(a) Includes structures on private land only.

(b) NA = not assessed. All land owned by either the mine owner or public.

(c) Data given as supplemental only because the mine type and location are not considered typical of the uranium industry. Data gathered during a field excursion to the area.

(d) Data given as supplemental only because of reported mine flooding. Data gathered during a field excursion in the area.

state tax assessors' offices, 2) detailed assessed valuations from these offices and applying applicable assessment valuation to selling price ratios obtained from the U.S. Department of Commerce, Bureau of Census (1978b), 3) estimates from local real estate agents, and 4) local newspapers. The valuations were based on surface usage and rights only, since the mineral values would remain intact.

In each state and county visited, full market values were sought for private lands and dwellings. Unfortunately, each state's assessment procedures and regulations vary. Thus, to simplify matters and to offer uniformity in calculations, aggregate assessment/sales price ratios were used. Table 3.20 lists these ratios for the five states visited. As a verification measure, local real estate agencies and newspapers were checked in each state to get an approximate value of the local ranch and residential properties. Table 3.21 lists these local real estate and newspaper estimates.

Land value calculations were then made for each parcel using two basic methods: 1) using full assessment data and applying appropriate ratios or 2) using quoted local land values and multiplying by the number of acres and/or dwelling units. After determining values for methods 1 and 2, the higher value was selected for use in this study. Citing the Mt. Taylor mine near the village of San Mateo in Cibola County, New Mexico, as an example, will clarify the calculation process.

TABLE 3.20. Aggregate Assessment/Sales Price (Market Value) Ratios

<u>State</u>	<u>Acreage (ratio in %)</u>	<u>Residential Property (ratio in %)</u>
Arizona	not available	12.0
Colorado	11.9	18.5
New Mexico	9.0	18.5
Utah	10.3	13.0
Wyoming	5.8	10.1

Source: U.S. Department of Commerce, Bureau of the Census, 1978.

TABLE 3.21. Local Real Estate Estimates for Grazing and Residential Property

State	Acreage Grazing	Residential Property, No Dwelling	Residential Property, Occupied Dwelling
New Mexico	\$240/acre	\$2100/acre (San Mateo area, Cibola county, New Mexico only)	\$30,000/residential unit; \$32,700/church or school unit (San Mateo area, Cibola county, New Mexico only)
Wyoming	\$300/acre	NA ^(a)	\$50,000/residence unit
Colorado	\$250/acre for mountain property \$300/acre flat valley property	NA	used assessed value and assessment valuation to selling price ratio
Utah	\$250/acre for mountain property \$300/acre flat valley property	NA	used assessed value and assessment valuation to selling price ratio

(a) Not applicable

The Mt. Taylor mine lies within 1 km of the village of San Mateo which has an estimated population of 311. The mining company operating the Mt. Taylor mine has purchased much of the private land surrounding its mining activities, owning about 7% of all property within 5 km of its shaft. Of the remaining property, about 39% is privately owned.

After determining the percentage of land ownership, full assessment data from the county tax assessor's office was reviewed for the 39% privately owned land. The number of acres out to 5 km for each of the following was determined: 1) acres of grazing land and 2) acres of residential property. In addition, the total number of occupied residences, churches and schools was determined. On a sector by sector, radius by radius accounting scheme, values were determined for each property by using the full assessment and ratio method. Then, values were calculated for these same properties by using the real estate/newspaper data method. In this example, higher values resulted from the later method. Note that in these particular calculations, residential

property is broken out into that property with and without an occupied dwelling. In the Mt. Taylor mine area, the real estate/newspaper data method values were higher than the assessment and ratio method values in all cases.

Indian Relocation Costs. As with the special breakout of Indian population (Table 3.17), a special consideration was made regarding land control costs of Indians. Since property is part of Indian reservations and/or Indian allotted lands, an outright buyout may not be feasible or possible. Rather a relocation of the Indian people along with a purchase of existing dwellings and new housing/property acquisition is considered. Table 3.17 gives the costs of relocating the Indian population. Such a relocation scheme is presently underway by the Federal government, involving the Hopi and Navajo tribes in the southwestern United States. Information supplied by the Navajo and Hopi Relocation Commission in Flagstaff Arizona (1981) indicates an average Indian relocation cost of about \$18,000 per person. Details of this data are as follows^(a):

\$71,000 average for site and housing cost

This average figure includes a \$66,000 maximum allowance for new housing for a family of four or more, or \$50,000 maximum for a family of 3 or less, a site preparation cost encompassing \$750 for a tribal archeological survey, \$1,500 - \$2,000 for sewage, and \$2,000 for a water cistern. No administration costs are reflected in this average site-housing figure.

\$5,000 bonus per head-of-household

This bonus is being offered to the Hopi and Navajo Indians as an incentive to move.

\$500 moving expense per head-of-household

This is a one time cash payment for moving expense. the client can choose between the cash or a reimbursement of actual moving expenses. In all cases to date, the \$500 has been taken.

(a) Information from Buck McGee, Chief Housing Acquisition and Relocation officer, Navajo and Hope Relocation Commission, Flagstaff, Arizona.

0 to \$1,000 additional search/processing expenses per head of household. This variable expense covers traveling expenses incurred during the search and processing for the relocation.

The average persons per household on the Hopi/Navajo reservation is 4.35. From this data, an estimate of the per capita relocation cost can be made as follows:

\$16,500	site and housing
\$ 1,200	bonus incentive
\$ 300	moving and search expenses
<u>\$18,000</u>	total relocation expense per capita.

Estimated Cost of Controlling Land. The estimated annual cost of controlling the land out to 2 km for all mines, except the Schwartzwalder and Bill Smith is \$3,012,000 (Table 3.22). This estimate is based on the following assumptions:

Fraction of total value in land	.80
Fraction of total value in structures	.20
Interest rate applied to land value	.10
Fixed charge rate applied to depreciable costs based on 5 years life	.30
Per capita relocation expenses (non-Indian)	\$5,000
Per capita relocation expenses (Indian)	\$18,000

TABLE 3.22. Annualized Cost of Controlling Land to 2 km

	<u>Total Cost</u>	<u>Annualized Cost</u>
Total private land value	\$9,378,270	
Land (80%)	7,502,616	\$750,000
Structures (20%)	1,875,654	563,000
Relocation expenses		
Non-Indian (420 people)	2,100,000	630,000
Indian (198 people)	3,564,000	<u>1,069,000</u>
		\$3,012,000

Increase in U₃O₈ Production Costs. The estimated increase in U₃O₈ costs to control land out to 2 km is \$0.29 per pound U₃O₈. This is obtained by dividing the \$3,012,000 annual cost by the estimated yearly production from mines in our population study (10,416,000). The mines in our study are estimated to produce 84% of the 1982 production of U₃O₈ from all underground mines (12,400,000) (DOE, 1983).

If we include the Schwartzwalder, the additional cost per pound of U₃O₈, spread across all U₃O₈ production represented in our study, is increased to \$0.50 per pound U₃O₈ as follows:

<u>Annualized Cost</u>	
Increased Land Value	\$ 1,216,000
Increased Structures Value	912,000
Increased Relocation Expenses (non-Indian)	<u>95,000</u>
	\$ 2,223,000

The increased cost, if applied only to the Schwartzwalder production would of course, be much higher on a unit cost basis.

Associated Facilities

As part of the on-site field examination, other land uses and associated facilities were noted around the mine vicinities. Generally, the primary uses for lands surrounding most mine sites are for mining, mineral exploration, stock grazing, and unconfined recreation. Vegetation is usually sparse, consisting of low shrubs, range grasses and occasional trees.

One important exception to this general site description is the Schwartzwalder mine near Denver, Colorado. The population, land status and land value data is not included in the final tabulation because the mine is not considered by the EPA to be typical of the uranium industry. This uranium deposit is of the vein-type versus the dominant disseminated, sedimentary/sandstone-type. Also the Schwartzwalder is located near a large metropolitan area where land can be subdivided or purchased for mountain resort homes. This makes land values extremely high compared to the average per acre

price of range land at other sites. In addition, the mine is located in an isolated mountainous region. For these reasons, the Schwartzwalder mine is not included in this study.

Each area was also reviewed regarding its status under the BLM Intensive Wilderness Inventories. These BLM reports were last issued in 1980-81, giving detailed descriptions of state-wide study areas along with state-wide plotted maps. Appendix E gives the mine-by-mine summary of land use and associated facility information, grouped by state.

4.0 ECONOMIC PROFILE

This section will provide an economic profile of the uranium industry, as broken down into three major categories: 1) demand, 2) supply, and 3) financial characteristics. Industry-wide issues are addressed and analyzed in order to understand the mechanisms involved in the uranium market place. This understanding is necessary for proper interpretation and appreciation of industry forecasts made later in this report.

4.1 DEMAND

4.1.1 Key Determinants

This section on the components of demand will begin with an overview of the present nuclear policy, and then proceed to discuss the key determinants of demand.

Nuclear Energy Policy

The outlook of the uranium industry is related to the future of nuclear power, and the nuclear power industry is directly influenced by government energy policy. Thus, an overview of the present policy will set the stage for further discussion of demand determinants.

President Reagan gave his statement of nuclear energy policy on October 8, 1981 (complete statement given in App. F). As described by Hanrahan (1982), Deputy Director of the Office of Policy, Planning and Analysis for the Department of Energy, "this Administration's national energy policy is quite different from any we have had in recent years. Instead of treating energy as an isolated entity, this Administration recognizes its role as a key commodity that is part of the overall economy. Energy policy is, therefore, treated in the context of an overall plan to revitalize the economy, and is one part of the President's Program for Economic Recovery". Limiting the government's intervention is recognized as important while the private sector increases its role in energy production and consumption.

Hanrahan (1982) continues by emphasizing that the Administration is dedicated to free market principles; that a shift has been made in our national energy policy away from Federal planning and control and toward a free enterprise system. This shift has been towards removal of price and allocation controls. In summing, the emphasis of this Administration's energy policy is toward "energy security" with production and preparedness as key elements. The role of the marketplace is considered critical.

Demand Determinants

The key determinants of uranium demand and thus the outlook for the uranium industry are primarily and directly related to the future of nuclear power. However, the current and forecasted capacity of nuclear reactors is not solely responsible in building the demand equation. The demand for uranium is further complicated by many other uncertainties and variables that are beyond the control of users (utilities and others) and producers. Kovisars (1979) has compiled a list of such uncertainties affecting uranium demand projections. (Table 4.1)

The Uranium Institute (Bonny & Fulton, 1982) has expressed the demand for uranium in mathematical terms:

$$\text{Demand} = \text{Consumption} + \text{Designed Change in Inventory} \quad (4.1)$$

where

$$\text{Consumption} = f(\text{GWe, Capacity Factor, Uranium Utilization}) \quad (4.2)$$

In their demand forecasts, two basic methodologies are used: 1) a calculation based on nuclear reactor fuel requirements and, 2) a calculation based on estimates of enrichment capacities. The determinants of uranium demand will be discussed as related to forecasting such demand based on nuclear power capacities. The elements of the demand equation will be keyed out and described in greater detail.

TABLE 4.1. Uncertainties Affecting Demand Projections

Growth of World Economies

- stability
- goals of developed vs. LDC countries

Development of Energy Usage

- elasticity of energy vs. income/economic performance
- technical and conversion variables

Interfuel Competition

- energy economics
- resource base for development
- hydrocarbon alternatives
- political/social pressures
- electrical share of total energy usage

Nuclear Power Capacity Growth

- system load factors
- coal/nuclear economics
- political/social constraints
 - nonproliferation concerns
 - waste disposal
 - radiation health

Reactor Design

- uranium fuel cycle
 - LWR
 - HWR
 - gas-cooled
- alternative fuels
 - thorium cycle
 - mixed-oxide reactors
 - breeder
- once-through vs. closed cycle
- capacity factor
 - availability
 - utilization

Enrichment Criteria

- unenriched; low-enriched; high-enriched fuel
- enrichment plant design
 - diffusion
 - centrifuge
 - jet-nozzle
 - laser
- tails assay level
- contracting-delivery practice and requirements

Recycling

- availability
- scale and timing

Inventory Decisions

- working inventories
- user inventories
- government inventories

Source: Kovisars (1979)

Nuclear Power Capacity. The first issue of discussion is nuclear power capacity. This topic covers the GWe portion of the demand equation. Sharp reductions in forecasts of nuclear power capacity have prevailed recently (see Section 4.1.2). These reductions have resulted from technical, economic and political/social factors.

The strongest factor or constraint on the development of nuclear power as cited by the Uranium Institute (1979; and Bonny & Fulton, 1982) are economic factors, especially the general economic growth of the economy. The growth rate has been considerably lower than assumed since the nuclear industry was founded. This translates into a lower overall electrical demand and thus a lower nuclear power share of that total. Another economic factor is high interest rates. High rates can force utilities to delay or cancel construction of new nuclear power plants due to the high cost of capital.

The Uranium Institute (1979) cites opposition to nuclear power as the second most important factor or constraint on nuclear power development. The whole question of nuclear acceptability and safety has resulted in many obstacles to the nuclear industry in implementing already planned programs as well as new plans.

Capacity Factor and Uranium Utilization. Assuming a viable and growing nuclear power capacity, variations in operating parameters of reactors and enrichment plants can have a profound effect on uranium demand. Topics here cover the "capacity factor" and "uranium utilization" components of the demand equation given earlier.

The capacity or load factor of nuclear reactors refers to the average capacity utilized in a year, expressed as a percentage of the plant's design capacity. A 65% load factor is assumed. The higher the factor, the greater will be the amount of fuel used up, and thus the greater will be the demand (Uranium Institute, 1981). The capacity factor can change due to environmental regulations, operating experience and/or technological developments. These changes could probably have as much as a 10% effect on the demand level--in either direction (Bonny and Fulton, 1982).

Changes in the level of uranium utilization can also have an effect on uranium market developments. Beginning at the enrichment stage, the tails assay could have a dramatic effect on demand. The tails assay is described as the concentration of fissile U-235 remaining in the reject stream at the government enrichment facility (Uranium Institute, 1981). This assay is an operating decision which has a direct impact on the uranium feed requirements. Tails assays have ranged between 0.18 and 0.38%. The elasticity of feed requirements to the tails assay level is about 0.35. So for a 25% change in the tails assay (e.g., from 0.20 to 0.25%), uranium feed will increase by about 9% (Kovisars, 1979).

Assuming a particular tails assay, fuel load characteristics become the next issue in uranium utilization. Fuel load refers to the amount of uranium required to operate a given nuclear reactor (Uranium Institute, 1981). This amount could change as fuel technology improves. Increasing fuel burn-up reduces uranium consumption during a reactor's lifetime. However, the main concern of utilities which used to be to minimize uranium consumption is now changing to other goals. These goals include increasing reactor operating flexibility, minimizing costs of the total fuel cycle, and/or improving the ease and economics of spent fuel management (Bonny and Fulton, 1982). These different goals can have both individual and combined effects on uranium requirements.

Other Factors. Other important influences on demand include: stock piling or inventory (by government and utilities), reprocessing of spent fuel policy, development of alternative fuel cycles and reactor designs, processing lead times, nuclear reactor construction lead times, and import/export issues.

4.1.2 Trends in Energy Consumption

Projections of installed nuclear capacity have been made yearly by a variety of government and private sources. Table 4.2 shows the projections presented at the Annual Uranium Industry Seminars in Grand Junction, Colorado for the years 1975 through 1981.

TABLE 4.2. Projections of Installed Nuclear Capacity (GWe) Presented at Annual Uranium Industry Seminar

Seminar Year	Source	Projected for end of year	
		1985	1990
1975	ERDA ^(a) (Hanrahan, 1975)	high/mod-mod/low-low 205-185-160	high/mod-mod/low-low 385-340-285
1976	ERDA (Hanrahan, 1976)	high-mid-low 166-145-127	high-mid-low 290-250-195
1977	DOE ^(b) (Brown and Williamson, 1977)	with NEP ^(c) 127 without NEP 127	with NEP 195 without NEP 210
1978	DOE/EIA ^(d) (Clark and Reynolds, 1978)	high-mid-low 122-111-100	high-mid-low 192-172-157
1979	EIA 7/79 EIA 10/79 (Clark and Reynolds, 1979)	high-mid-low 118-114-102 high-mid-low 113-106-95	high-mid-low 171-152-142 high-mid-low 155-140-129
1980	EIA Spring 80 OURE ^(e) 6/80 (Staggs, 1980)	high-mid-low 109-98-86 high-mid-low 105-96-85	high-mid-low 139-127-121 high-mid-low 140-129-125
1981	OUEA ^(f) (Staggs, 1981)	high-mid-low 99-90-80	high-mid-low 126-122-117

- (a) Energy Research and Development Administration
- (b) Department of Energy
- (c) National Energy Policy
- (d) Energy Information Administration
- (e) Office of Uranium Resources and Enrichment
- (f) Office of Uranium Enrichment and Assessment

The early projections have been optimistic. All projections of capacity installed by 1985 and 1990 were decreased by at least fifty percent between 1975 and 1981. In fact the high nuclear growth projections for 1990 have fallen by more than two thirds.

Current DOE/EIA projections for installed nuclear capacity and total electric utility capacity are shown in Table 4.3. For comparison Table 4.4 shows similar forecasts made in 1975 by the Energy Research and Development Administration. The tables show a moderate decrease in the projections of total electric generating capacity over the past seven years. But, the interesting figures are those of the projected nuclear capacity as a percentage of the total generating capacity. A decrease in the projected values of over fifty percent is indicated for both the 1985 and 1990 forecasts. Thus, it is clear that the reductions in the projections of installed nuclear capacity are not, for the most part, due to a lowering of the forecast for total electric utility capacity; but in fact are due to the problems as discussed in Section 3.7.

TABLE 4.3. Current Projection (1983) of Installed Nuclear and Total Electric Utility Capacity (in gigawatts) by DOE/EIA

Capacity	Year	
	1985	1990
Nuclear	77.94	113.93
Total	721.48	805.93
Nuclear as % of Total	10.8	14.1

Source: DOE/EIA, 1983. A.5.3, Case A: Middle World Oil Price.

TABLE 4.4. Previous Projection (1975) of Installed Nuclear and Total Electric Generating Capacity (in gigawatts) by ERDA

Capacity	Year	
	1985	1990
Nuclear (moderate/low)	185	340
Total (moderate/low)	800	1040
Nuclear as % of Total	23.1	32.7

Source: Hanrahan, 1975. Tables 2 & 3 Moderate Growth-Low Case.

4.1.3 Uranium Pricing

Uranium prices and the mechanics behind price formation have developed over a four decade span. The uranium market, which began under total government control has now transferred into a private market. Following is a discussion of the development of the uranium market and its pricing policy, beginning with the Atomic Energy Commission (AEC) programs, and concluding with the current private market situation. Market pricing mechanisms will form the conclusion.

Prices Under AEC

The AEC began a uranium procurement program in 1948 by guaranteeing ore prices and negotiating concentrate prices in individual contracts with uranium mills. The period 1948-1962 was known as the "incentive period". Ore prices were guaranteed as published in a series of circulars. As discussed in Charles River Associates, Inc. (1977), circulars 3 and 4 stated that the government would give a facilities and development allowance and a premium for high grade ore containing above 0.15-0.25% U_3O_8 in addition to a base price (Table 4.5). These prices were effective through mid-1948 when Circular 5 was issued.

Circular 5 provided for higher base prices. Also the development allowance was extended to lower-grade ores. Revisions came in 1951 as Circulars 5 (revised) and 6 (Table 4.6). These increased the base prices and allowances again and added a production bonus. The goal of the AEC was to encourage a wide search for new and lower grade deposits. Circular 5 (revised) was so designed to offer prices favoring lower grade ores. It was effective through March 1962. The production bonus of Circular 6 expired in March, 1960. Table 4.7 reflects the average value of ore purchased beginning 1957 (data not available prior to 1957).

Concentrate prices paid by the AEC for the same period are shown in Table 4.8. They rose between the years 1948 and 1953, after which they declined through 1962.

In 1956, the AEC announced a new fixed price of \$8.00 per pound concentrate to go into effect in 1962. The price, although below the price being paid in 1956, still proved to be an incentive for exploration and production.

TABLE 4.5. Circulars 3 and 4: Price Schedule for Colorado Plateau Uranium From Carnotite and Roscoelite Ores

Content Percent U ₃ O ₈	Price Per Short Tone of Ore					Total Price Per Pound U ₃ O ₈ ^(d)
	Base Price	Development Allowance ^(a)	Premium	Facilities Allowance ^(b)	Total Price ^(c)	
0.10	\$0.60				\$0.60	\$0.30
0.11	1.32				1.32	0.60
0.12	2.16				2.16	0.90
0.13	3.12				3.12	1.20
0.14	4.20				4.20	1.50
0.15	4.50	\$1.50			6.00	2.00
0.20	6.00	2.00		\$2.00	10.00	2.50
0.25	7.50	2.50	\$0.25	2.50	12.75	2.55
0.30	9.00	3.00	0.50	3.00	15.50	2.58
0.40	12.00	4.00	1.00	4.00	21.00	2.63
0.50	15.00	5.00	1.50	5.00	26.50	2.65
0.75	22.50	7.50	4.00	7.50	41.50	2.77
1.00	30.00	10.00	6.50	10.00	56.50	2.83
1.25	37.50	12.50	9.00	12.50	71.50	2.86
1.50	45.00	15.00	11.50	15.00	86.50	2.88
1.75	52.50	17.50	14.00	17.50	101.50	2.90
2.00	60.00	20.00	16.50	20.00	116.50	2.91

- (a) To be spent only for maintaining and increasing the development reserves of uranium ores.
- (b) To be spent only for reopening and equipping closed mines and increasing the production facilities of mines in operation.
- (c) Excludes a haulage allowance of 6 cents per mile to a maximum of 100 miles and prices for vanadium contained in the ores.
- (d) Calculated: Total price per short ton ore ÷ (2000 lbs/short ton x U₃O₈ content, percent) = Total price per pound contained U₃O₈.

Source: BOM, Minerals Yearbook, "Uranium, Radium and Thorium," 1948, p. 1269 as found in Charles River Associates Inc., 1977. p. 9-17.

In late 1958, the AEC then announced an allocation program designed to limit its purchase obligations at the \$8.00 price.

The next AEC procurement program (1962-1966) saw the end of guaranteed minimum ore prices. Table 4.7 shows the average value of ore through this period.

During this 1962-1966 period, concentrate purchased by the AEC remained at the \$8.00 per pound U₃O₈. As stated above, the \$8.00 value was announced in 1956 and went into effect in 1962 (refer to Table 4.8).

TABLE 4.6. Circular 5 (Revised) and Circular 6: Schedule of Prices For Uranium Ore^(a) (dollars)

Grade of Ore (Percent U ₃ O ₈)	Price Excluding Initial Production Bonus: ^(b)		Price Including Production Bonus on Initial 10,000 Pounds U ₃ O ₈ ^(c)	
	Per Ton of Ore	Per Pound Contained U ₃ O ₈	Per Ton of Ore	Per Pound Contained U ₃ O ₈
.10	\$ 4.00	\$ 2.00	\$ 7.00	\$ 3.50
.11	4.84	2.20	8.58	3.90
.12	5.76	2.40	10.32	4.30
.13	6.76	2.60	12.22	4.70
.14	7.84	2.80	14.28	5.10
.15	9.00	3.00	16.50	5.50
.16	10.24	3.20	18.88	5.90
.17	11.56	3.40	21.42	6.30
.18	12.96	3.60	24.12	6.70
.19	14.44	3.80	26.98	7.10
.20	16.00	4.00	30.00	7.50
.21	16.95	4.04	31.65	7.54
.22	17.90	4.07	33.30	7.57
.23	18.85	4.10	34.95	7.60
.24	19.80	4.13	36.60	7.63
.25	20.75	4.15	38.25	7.65
.26	21.70	4.17	39.90	7.67
.27	22.65	4.19	41.55	7.69
.28	23.60	4.21	43.20	7.71
.29	24.55	4.23	44.85	7.73
.30	25.50	4.25	46.50	7.75
.31	26.45	4.27	48.15	7.77
.32	27.40	4.28	49.80	7.78
.33	28.35	4.30	51.45	7.80
.34	29.30	4.31	53.10	7.81
.35	30.25	4.32	54.75	7.82
.36	31.2	4.33	56.40	7.83
.37	32.15	4.34	58.05	7.84
.38	33.10	4.36	59.70	7.86
.39	34.05	4.37	61.35	7.87
.40	35.00	4.38	63.00	7.88
.45	39.75	4.42	71.25	7.92
.50	44.50	4.45	79.50	7.95
.60	54.50	4.54	96.50	8.04
.70	64.50	4.61	113.50	8.11
.80	74.50	4.66	130.50	8.16
.90	84.50	4.69	147.50	8.19
1.00	94.50	4.73	164.50	8.23
2.00	194.50	4.86	334.50	8.36
3.00	294.50	4.91	504.50	8.41
4.00	394.50	4.93	674.50	8.43
5.00	494.50	4.95	844.50	8.45
6.00	594.50	4.95	1,014.50	8.45
7.00	694.50	4.96	1,184.50	8.46
8.00	794.50	4.97	1,354.50	8.47

TABLE 4.6. (Contd)

Grade of Ore (Percent U ₃ O ₈)	Price Excluding Initial Production Bonus: ^(b)		Price Including Production Bonus on Initial 10,000 Pounds U ₃ O ₈ ^(c)	
	Per Ton of Ore	Per Pound Contained U ₃ O ₈	Per Ton of Ore	Per Pound Contained U ₃ O ₈
9.00	\$894.50	\$ 4.97	\$1,524.50	\$8.47
10.00	994.50	4.97	1,694.50	8.47

- (a) All prices exclude haulage allowances of 6 cents per mile to a maximum of 100 miles and payments for vanadium ores.
 (b) Includes base price, grade premium and mine development allowance.
 (c) Bonus not to exceed a maximum of \$35,000 per property.

Source: Calculated from Circular 5 (revised), reprinted in GAO, op. cit., in JCAE, Hearings, 1962, p. 300, and information in BOM, Minerals Yearbook, "Uranium," 1951, pp. 1305-1306. As found in Charles River Associates Inc., 1977, pp. 9-19 to 9-21.

Special "stretch-out" arrangements were offered by the AEC through 1970. This allowed mills to defer concentrate deliveries scheduled for 1963-1966 until 1967-1968. The AEC then agreed to purchase additional amounts equal to the deferred amounts during 1969-1970. By this time a private market for uranium had developed and the AEC procurement policies showed less importance in determining U₃O₈ prices. (Charles River Associates, Inc., 1977).

Private Market Prices

The private uranium market began in the late 1960s. Its beginning was characterized by depressed prices, but after mid-1973, a marked upswing in market conditions caused prices to rise rapidly. Table 4.9 gives NUEXCO exchange values beginning August 1968 to December, 1982. These commercial prices are also shown graphically (Figure 4.1) in both actual and 1982 dollars. AEC prices (active and 1982 dollars) are also plotted for comparison. The table and figure show how prices began to increase in 1973 and then sharply in 1974 and 1975.

Increased contracting in 1976 caused another sharp increase in price. More contracts were signed in the first half of 1976 than in all of 1975. (Gordon, 1977). The price per pound U₃O₈ was \$41.00 for spot delivery at

TABLE 4.7. Average Value of Ore

Year ^(a)	Dollars Per Ton of Ore ^(b)	Dollars Per Pound Contained U ₃ O ₈ ^(c)
1957	22.36	4.19
1958	22.50 ^(d)	4.15
1959	20.38 ^(d)	4.08
1960	19.04 ^(e)	4.02
1961	18.44 ^(e)	4.00
1962	19.61 ^(e)	4.05
1963	20.04 ^(e)	4.05
1964	20.52 ^(e)	4.08
1965	19.23 ^(e)	4.04
1966	17.81 ^(e)	3.90
1967	15.25 ^(e)	3.90
1968	14.50	3.87
1969	16.02	3.97
1970	14.68	3.50
1971	15.57	3.71

- (a) Prior to 1957, production data were classified and no annual data are reported in the Minerals Yearbooks. The BOM did not estimate this series for earlier years when the data became available in 1955 and 1956. Value of ore production/shipments is not reported separately, in a form comparable to earlier years, after 1971.
- (b) Derived by dividing ore production (or ore shipped) into estimated ore value. The calculations are based on unrevised production data.
- (c) Derived by dividing total value of ore by recoverable U₃O₈ content of ore (in pounds), prior to adjustment for milling recovery rates.
- (d) F.O.B. mines.
- (e) Based on quantity of ore shipped, rather than ore production.

Sources: Derived from data on ore production and total ore value provided by the AEC to the BOM, and reported in BOM, Minerals Yearbook, "Uranium," 1957 through 1971. As Found in Charles River Associates, Inc., 1977, pp. 9-14 to 9-15.

TABLE 4.8. AEC Domestic Concentrate Purchases: Amount, Cost and Average Price

Fiscal Year	Tons U ₃ O ₈	Cost to AEC (in \$10 ⁶)	Average Price/lb. U ₃ O ₈ (in \$)	AEC Purchases as Percent of Total Concentrate Production (percent of tons U ₃ O ₈)(b)
1948	116	1.7	7.14	
1949	115	2.0	8.53	
1950	323	5.9	9.11	
1951	639	12.9	10.10	
1952	824	18.6	11.28	
1953	968	23.9	12.35	
1954	1,435	35.2	12.27	
1955	2,125	52.1	12.25	
1956	4,179	96.2	11.51	
1957	7,505	157.4	10.49	
1958	10,078	190.5	9.45	
1959	15,029	274.1	9.12	
1960	16,394	287.0	8.75	
1961	17,646	299.8	8.50	
Sub-Total	77,646	1,457.2	Average 9.42	
1962	17,244	281.0	8.15	
1963	15,752	246.2	7.82	
1964	12,607	201.7	8.00	
1965	11,240	179.8	8.00	
1966	10,178	162.8	8.00	99%
Sub-Total	67,021	1,071.6	Average 7.99	
1967	8,902	142.4	8.00	83
1968	7,937	127.0	8.00	66
1969	7,124	99.6	6.99	60
1970	4,010	46.0	5.74	32
1971(a)	1,295	14.3	5.54	20
Sub-Total	29,268	429.4	Average 7.34	
TOTAL	173,655	2,958.2	Average 8.52	

(a) Through December 1970 in Fiscal year 1971.

(b) Purchases in a given fiscal year refer to the receipt of concentrate by the AEC in accordance with contract provisions. They do not refer to the amounts "contracted for" by the AEC in any given year.

Source: ERDA, Statistical Data of the Uranium Industry, GJO-100. January 1976, p. 11. As found in Charles River Associates, Inc., 1977, pp. 9-11 to 9-12.

TABLE 4.9. Historical Exchange Values
(U.S. Dollars/lb U₃O₈)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1968	--	--	--	--	--	--	--	6.35	6.35	6.40	6.45	5.50
1969	--	6.35	6.10	6.10	6.25	6.25	6.20	6.20	6.15	6.15	6.15	6.20
1970	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.20	6.15	6.15	6.15	6.15
1971	6.20	6.20	6.20	6.20	6.15	6.05	6.00	5.95	5.95	5.95	5.95	5.95
1972	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
1973	5.95	6.00	6.10	6.20	6.45	6.50	6.50	6.50	6.50	6.50	6.75	7.00
1974	7.70	7.90	8.00	9.00	9.50	10.50	11.50	12.00	12.50	14.00	14.75	15.00
1975	16.00	16.00	18.00	20.00	21.00	23.00	24.70	26.00	26.00	28.50	30.00	35.00
1976	35.20	37.00	39.25	40.00	40.00	40.00	40.00	40.40	41.00	41.00	41.50	41.00
1977	41.35	41.50	41.60	41.60	42.00	42.25	42.25	42.25	42.40	42.75	43.20	43.20
1978	42.90	43.25	43.25	43.25	43.40	43.40	43.40	43.10	43.25	43.00	43.25	43.25
1979	43.25	43.25	43.25	43.25	43.25	43.00	42.70	42.70	42.20	42.20	41.00	40.75
1980	40.00	38.00	35.00	32.00	32.00	31.50	31.50	30.00	28.50	28.00	28.00	27.00
1981	25.00	25.00	25.00	25.00	25.00	24.25	23.50	23.50	23.50	23.50	23.50	23.50
1982	23.00	23.00	22.50	20.75	20.50	19.25	18.75	17.00	17.00	17.50	19.75	20.25

Source: Niexco Exchange values as found in Nuclear News Magazine, Nuclear Fuel Newsletters, and Niexco price quotes.

yearend 1976. However, many producers were not benefiting from this price increase due to locked-in contracts at earlier lower prices. This occurred at a time when exploration and production costs were increasing. (Charles River Associates, Inc., 1977).

1977-1978 saw relatively stable prices with the NUEXCO exchange value increasing to \$43.20 by yearend 1977 and \$43.25 in 1978. The outstanding feature in the 1977 uranium market, as described by White (1978), was buyers' concern about security of supply. Buyers were convinced that the best hedge against supply disruptions was to purchase and hold inventory, either as U₃O₈ concentrate or as reserves in the ground. The continued stability in 1978 reflected a balance in the market place. However, 1979 saw the beginning of erosion of the exchange value for U₃O₈ concentrate. Between 1979-1981

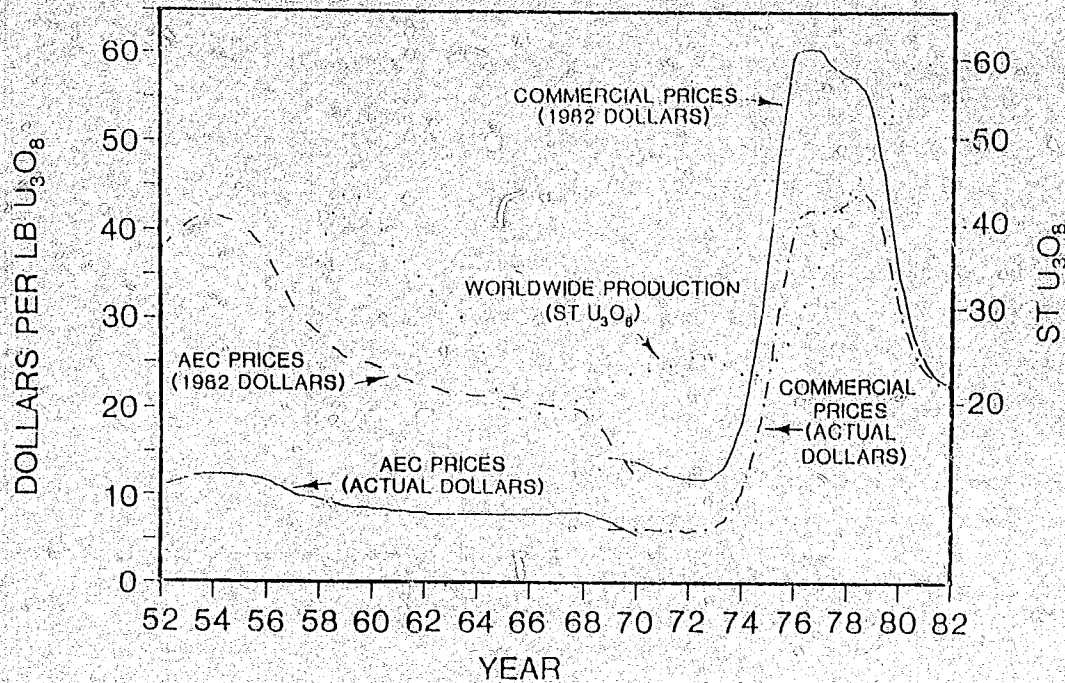


FIGURE 4.1. History of U₃O₈ Prices

Source: Hahne, F. L. III, 1982. "Future Uranium Prices," paper presented at Uranium Colloquium V, Grand Junction Colorado, Oct. 6-7, 1982.

inclusively, the constant dollar decrease was 20%, 45% and 25% respectively. The downward spiral finally ended in September, 1982 at \$17.00 per pound U₃O₈. Yearend 1982 saw a slight rebound to \$20.25 per pound U₃O₈.

The decline, as described by White, (1979, 1980, 1981, 1982, 1983), was due to an imbalance between production and consumption. In 1980, material available for sale was often in excess of purchase requests by ratios of 4:1 or more. In 1981, production committed for delivery under existing supply contracts exceeded actual reactor consumption by almost 100%. This resulted in buyer inventories increasing by nearly 50 million pounds U₃O₈ in 1981. And finally, in 1982, the continued price decline resulted from an aggressive selling campaign by both U.S. and non-U.S. utilities and producers. The pressure from this great inventory liquidation caused prices to break sharply from a somewhat stabilized yearend 1981 price.

Pricing Mechanisms

Having discussed the uranium market and uranium price development, closing remarks will be made on market pricing techniques or mechanisms. Basically, market pricing refers to that mechanism by which two parties attempt to deal with an uncertain future uranium price situation by setting forth procedures to arrive at a contract price that reflects market conditions at the time of delivery. This mechanism usually operates for intermediate and long term contracts versus spot sales.

Many contract approaches have been tried and used by buyers and sellers. The first such contract which helped to give market pricing credibility in the U.S., was termed a negotiated approach and occurred between the Tennessee Valley Authority and Rio Algom (a Canadian firm) in 1974. It was a 12 year agreement involving 17 million pounds of U_3O_8 .

In the negotiated approach, price negotiations are begun prior to an agreed upon year of delivery. The lead negotiating time can be from several years to only months prior to delivery. Objectives are established, negotiation sequences are laid out, and if necessary, experts are used to expedite results. There are several variations on this approach, differing mainly in form and manner of price setting.

A second major market pricing mechanism is the reference approach. Here, the market price is determined based on published and public reference sources for prices. These include the NUEXCO exchange value, Metals Week, American Metal Market, U.S. Department of Energy price data, the NUKEM Price Quote, and the Uranium Price Information Service data by the Nuclear Assurance Corporation. There are also several variations of the reference approach.

4.1.4 Elasticity of Demand

In the short and intermediate terms, the demand for uranium is relatively price-inelastic (Aucoin, 1982). That is, the demand is insensitive to the price of the commodity. This inelasticity stems from the fact that there are no substitutes for uranium as a fuel in the present nuclear fission-type reactor. Present demand for uranium is directly linked to the fuel requirements of those reactors that are presently on-line.

Future demand will depend on both those reactors that are under construction and completed and those being planned. The number of planned reactors will depend on the demand for nuclear-powered electricity which is linked to the overall growth of electrical demand and cost of alternative energy sources.

The reductions in projected nuclear power capacity are in part due to the many problems facing the industry as discussed in Section 3.7. Two important points are emphasized here that will effect utilities' future nuclear ambitions, and thus the outlook for uranium demand. These are: 1) the future financial conditions of the utilities and 2) the relative costs and acceptability of competing energy sources including other nuclear technology (Bock, 1978). Because of long lead times for power facility construction, a utility's financial coverage is usually lowered and its financial rating reduced, thus resulting in a higher cost of capital acquisition. Among the competing energy sources, coal is viewed as the chief alternative to nuclear power.

Returning to the present, once a nuclear power plant is constructed, an adequate fuel supply is vital for operation. The relative cost of fuel is small compared to construction and finance costs. Once construction is started or completed, the cost of the fuel supply is no issue. It must be secured at any cost. Thus, demand becomes insensitive to price or is inelastic.

In the long run however, demand for uranium may not be totally inelastic. This is due to choices made by utilities on future energy sources for electricity generation versus the nuclear option in light of the utilities' perceptions of future uranium fuel prices and other reasons cited above.

4.2 SUPPLY

4.2.1 Key Determinants

Making estimates of future uranium supply beyond the short-term is as uncertain as forecasting demand. Reliable or accurate estimates can be made only when the entire market is understood from the economic, physical, social, and political aspects. These aspects are composed of many key determinants that dictate how the industry will respond to market forces of demand. These key determinants will be discussed as they relate to uranium supply.

As described by Bonny and Fulton (1982) supply is a function of two basic economic factors--price and cost. This can be written as:

$$\text{production} = f(\text{uranium price, mining costs}). \quad (4.3)$$

This relationship can be complex. When market prices for uranium are low for a lengthy period relative to production costs, some high-cost mines are forced to work higher grade ores. As well, they must become more cost efficient by implementing cost-saving strategies. Some mines may be forced to extend production capabilities in order to reduce unit costs (Uranium Institute 1981).

The uranium industry has shown its ability to respond to market forces. Increased demand for uranium and price incentives have spurred production at sufficient rates. However, because of such a rapid build-up of supply capacity over the last decade, oversupply has resulted. This oversupply has upset the supply/demand balance and since 1979, prices have plummeted by as much as 45% per year (refer to Section 4.1.4--Uranium Pricing). What was once an expanding industry is now one of a series of mine/mill suspensions and closures.

Such economic forces are perhaps the most important factors in determining future uranium production and supply. There must be a production incentive plus a perception of a long-term uranium market in order for producers to plan future operations. The size of the market will depend on the overall rate of economic growth and the associated growth in demand for electricity. The market will also depend on the ability of utilities to finance new nuclear power plants.

Current financial conditions in the mining industry are very important as well when looking at future supply. This is so because today's company profits will be used in part to finance future exploration and operations. However, during periods of low market prices, management may not make favorable exploration/investment decisions. Shortage of financial resources and expertise could result; a situation which could be hard to reverse later. Also, because of long lead times required for facility development, future demand may not be met adequately even if exploration/investment decisions were favorable at some later date (Uranium Institute 1981).

There are certain short-term characteristics that are important in understanding the uranium supply market. These are the physical constraints on production. They include mine/mill operating characteristics and the size and nature of the uranium ore deposits. Short-term increases or decreases in production are flexible within the limits of these constraints.

At the underground mine, increasing output is more difficult than for an open-pit operation because of problems resulting from limited haulage, hoisting and ventilation capacity, and from using inflexible underground mining methods (Uranium Institute 1981). Skilled labor shortages due to mine remoteness and exposure-related health concerns are also constraints to expansion.

At the mill, capacity utilization and recovery rates are important. Increased mill output can be achieved by a step-up in utilization, either up to or exceeding designed capacity, for short periods. Increased throughput, however, tends to negatively effect the uranium recovery rate (Uranium Institute, 1981).

The physical nature of deposits also determines the rates at which uranium can be produced. Ore grade is a given of nature, but cut-off grade may be raised to increase production (by having a higher uranium concentration in the ore) and lower unit cost. However, high grading will eventually effect the longer-term ore mining schedule and shorten the mine's life.

The combined effects of all these economic and physical constraints on the future supply of uranium are: longer lead times for developing new projects, a slower rate of production build-up towards design capacity, and continually higher extraction costs (Uranium Institute 1979). But while these constraints have a marked influence on supply, other nontechnical factors effect the market as well.

Other constraints encompass political and social issues. Government intervention in the uranium mining and milling industry has increased over the years due in large part to these issues. As described by the Uranium Institute (1981) these include: environmental impacts of uranium mining and milling operations, land and mineral rights of local population groups, ownership and foreign participation, nuclear non-proliferation policies, and the effects of uranium imports upon the uranium mining industry.

4.2.2 Interindustry Organization and Market

The Nuclear Fuel Cycle

The existing nuclear industry or the nuclear fuel cycle is characterized by "front-end" and "back-end" activities (see Table 4.10). The front-end of the cycle refers to all activities which result in the production of fabricated fuel elements. Front-end operations include exploration, mining, milling, aqueous conversion, enrichment, and fabrication. Power production is the focus of the nuclear fuel cycle. The back-end of the cycle currently refers to the interim-storage of spent fuel assemblies. Reprocessing of spent fuel has been deferred because of complex technical/political issues. Effective implementation of recycling spent fuel is unlikely until the late 1980's or later (EIA 1977).

Ownership in the nuclear fuel cycle is very diversified with a declining number of independent producers. Entrants include petroleum firms, minerals companies, utilities, and in the case of enrichment, the federal government. Joint ventures play an important role in many front-end activities (DOE 1982).

Several factors have contributed to the integrated nature of the uranium industry. Major incentives include the AEC weapons program, nuclear power generation, the development of self-supply ventures, and the cancellation of nuclear projects. The following sections discuss the influence of these events on the structure of the nuclear supply industry. Examples of vertical and horizontal integration are also provided.

AEC Weapons Program

Several of the front-end operations developed as a result of the AEC weapons program in the 1950s and 1960s. Most supply facilities were owned by small independent firms. Custom manufacture of uranium products was not uncommon to meet the unique needs of weapons testing.

The end of the weapons program left the uranium supply industry in dismal condition. In 1958, AEC announced that no reserves developed before November would be eligible for procurement. The AEC then stretched out its purchase program to prevent collapse of the industry (EPRI 1977). Market activity almost halted and many development programs were abandoned (EIA, 1977).

TABLE 4.10. Current Nuclear Fuel Cycle Activities

Activity	Ownership	Description
Exploration and Development	Private and Federal	Uranium mineralization is delineated and accessed. Major steps include land acquisition, surface drilling, and reserve development.
Mining	Private Producers	Ore is removed from sand or limestone rock using underground or surface methods. It is transported in bulk by truck or rail to nearby milling facilities (Schneider 1979).
Milling	Private Producers	Uranium ore is converted to a concentrated ammonium diuranate powder called yellowcake. Yellowcake consists of 74.2 wt% U as uranium diuranate (Schneider 1979).
Conversion	Private Producers	Uranium concentrate is converted to the volatile compound UF ₆ and shipped as a solid to enrichment facilities. The processes used are the hexafluor process and the "wet" process. The fissionable isotope U-235 is 0.7% of the total uranium content (Schneider 1979). Plants are located in Metropolis, Illinois, and Sequoyah, Oklahoma (AEC 1974).
Enrichment	DOE owned but operated by private industry under contract	UF ₆ is isotopically enriched in U-235 to the range of 2 to 4% for use a reactor fuel. The UF ₆ is shipped as a solid to fuel fabrication plants. In addition to the enriched UF ₆ product, the gaseous diffusion plant produces UF ₆ depleted in U-235 called tails. The current assay of tails is 0.25% U-235. The tails are stored as solid UF ₆ at the plant for future use. Plans are located in Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky (Schneider 1979).

TABLE 4.10. (contd)

Activity	Ownership	Description
Fuel Fabrication	Private Processors	<p>Fuel fabrication plants manufacture fuel assemblies from UF₆. The UF₆ is converted to UO₂. The UO₂ is pelletized and interred to the desired density and loaded into fuel rods. Of the ten commercial plants licensed in 1971, only three produced completed reactor fuel assemblies. Four other plants used enriched UF₆ feed to produce UO₂ powder or pellets. The three used UO₂ powder or pellets to produce fuel assemblies. When necessary, powdered UO₂ is transported in steel pails by truck (AEC 1974).</p>
Power Plants	Public Utilities	<p>Reactors produce electricity from the fissionable U-235 isotope in fuel assemblies. As of Dec. 31, 1982, there were 95 PWRs, 49 BWRs, and 3 other nuclear power plants domestically in operational or constructional phases (Nuclear News 1983). In a PWR, the heat produced by the nuclear reaction is removed by a pressurized water system. Heat exchangers transfer heat from the pressurized water to produce steam. A BWR boils water, directly to produce steam for the generators.</p>
Spent Fuel Storage	Utilities	<p>Spent fuel is usually stored at reactor sites. At the end of 1977, approximately 3000 pounds of spent fuel was discharged of which 10% was reprocessed, 15% was stored at reprocessing facilities, and the remainder was stored at the utility. All reprocessing of spent fuel terminated in 1971 (EIA 1977).</p>

In 1965 through 1970, exploration became active again. During this period, oil and mineral companies actively purchased or merged with small independent producers. Control was probably gained by accident as a result of oil and gas drilling. Plans for nuclear power projects could also have provided incentives for these investments despite oversupply and low prices. By 1972, oil companies held 50% of proven reserves.

As large mining and exploration firms appeared, many mine/mill complexes were constructed. Major oil and mining companies currently active in milling include Kerr-McGee, Exxon, Getty Oil, and ARCO.

Oil and mineral firms entering front-end fuel cycle activities is an example of horizontal integration. Horizontal integration occurs when a company produces more than one product or merges with a competitor (EPRI 1977).

Nuclear Power Generation

Nuclear power development required the construction of fabrication plants, nuclear reactors, and back-end facilities. Major public utilities and corporations were responsible for reactor projects. Large diversified corporations constructed fabrication plants. Projects were heavily regulated and highly technical with significant environmental, financial, and legal responsibilities. Entry by small firms was virtually impossible because of the complexity of the facilities.

By 1974, nuclear power was a commercial reality but aggressive exploration efforts were still not underway. The market changed to a buyer's market, and the price for uranium tripled in a matter of two years. Low contract prices, however, set a few years previous were not conducive to aggressive exploration efforts. Exploration efforts were also inhibited by uncertainties in nuclear requirements. Variations in enrichment and recycle policies alone could have resulted in a 40% spread in potential demand for uranium (Stoller 1977). Factors affecting the demand for uranium are shown in Table 4.1.

Shortages were expected if exploration efforts were not pursued since future demand was in excess of known reserves. Exploration and reserve development require lead times of at least 10 and 6 years, respectively. Long lead times and the rapid growth of the projected power industry made these activities potential limiters of uranium supply (Doiron 1978).

Utility Self-Supply Programs

A utility requires a guaranteed supply of nuclear fuel to be a reliable source of power. In fact, state regulatory commissions were demanding that lifetime supplies of uranium be assured before approving a reactor project. Utilities were encouraged to participate in exploration and development to assure long-term supply and price control (Stoller 1977).

A utility entering a supply sequence to lower costs and assure supply is an example of vertical integration. By 1980, about 40% of all American nuclear electric utilities had participated in uranium supply ventures. In some cases, the utility took only a limited role by financing the venture, while the minerals company was responsible for planning the program (Mommson 1980).

The earlier a participant enters a supply chain, the higher the risks. Risks include barren drilling, technical problems, delays, poor production, high costs, or complete failure. These risks are far beyond those of normal procurement. Money spent on barren reserves must be included in overall production costs.

Power Plant Delays Cancellations

Over the last few years, uranium supply has again become a buyer's market. Forecasts for nuclear power demand had decreased to 40% of 1978 levels and several nuclear projects have been delayed or cancelled (Heiks 1982). Development efforts of the late 70s resulted in over-capacity, large inventories, and low profits (Nuclear News, 1982).

Many utilities feel their performance in supply activities has not been good. Many have dropped out and utility commissions are discouraging supply ventures, since sufficient capacity currently exists to supply fuel projections until at least 1995. Most utilities are dissatisfied with the costs of production due to heavy exploration expenditures and rising capital costs for mine development (Mommson 1980).

Effects of Integration

The level of corporate investment in the uranium industry has steadily increased over the last two decades. Both horizontal and vertical integration have significantly reduced the number of independent enterprises except as

joint partners. Exxon is an example of a large domestic enterprise with diversified energy investments. Exxon has substantial investments in coal, oil, uranium, and natural gas reserves, and most of the domestic oil refining capacity. Exxon also mines and mills uranium, fabricates fuel, and has announced plans to be one of the first private entrants into the enrichment industry.

Some officials believe that oil and mineral mergers may have detrimental effects. Exxon for example, owns oil and gas wells jointly with other large firms in the industry so that even corporate entities are not independent. When economic power is concentrated between a few large corporate entities, there are potential anti-competitive consequences. They include harmful supply conditions, abusive pricing policies, and less entrepreneurial spirit. The political leverage of such major companies could also inhibit appropriate environmental and occupational regulations. The self-interests of interdependent sellers does not always conform to the public interest of sufficient supply at a reasonable price.

Most potential benefits result from the relatively large capital budgets of major corporations. Explorations and production efforts can be expanded despite variable market conditions. Larger budget R&D efforts could also increase efficiencies (U.S. Congress 1975).

4.2.3 Trends in Production and Supply

Historical data for the uranium industry is presented in Table 4.11. The table lists ore production from mines which is received at mills and buying stations. Production is broken down between open-pit and underground mines with the average ore grade being a derived result.

Several things are obvious from the data. First, the average ore grade concentration from both types of mines has fallen with the largest decrease occurring in open-pit mines. The ore concentration taken from open-pit mines in 1982 was more than 70% less than that produced in open-pit mines during the first ten years of uranium mining in the U.S. Similarly the ore concentration from underground mines fell over the same period; but for 1982 it was more than three times the concentration from open-pit mines. Also, it can be seen that

TABLE 4.11. Uranium Ore Produced from Mines and Received at Mills and Buying Stations (a)

Year	Total Receipts			Open-Pit Production			Underground Production		
	Ore x 10 ³	Tons U ₃ O ₈ x 10 ³	Ore Conc% (Derived)	Ore x 10 ³	Tons U ₃ O ₈ x 10 ³	Ore Conc% (Derived)	Ore x 10 ³	Tons U ₃ O ₈ x 10 ³	Ore Conc% (Derived)
1948-57	11,308	32.2	0.285	3,796	9.5	0.250	7,512	22.7	0.302
1958	5,178	14.0	0.270	2,358	5.4	0.229	2,820	8.6	0.305
1959	6,935	17.4	0.251	2,206	4.4	0.199	4,729	13.0	0.275
1960	7,970	18.8	0.236	2,393	5.3	0.221	5,577	13.5	0.242
1961	8,041	18.5	0.230	2,482	5.3	0.214	5,559	13.2	0.237
1962	7,053	17.1	0.242	1,782	4.3	0.241	5,271	12.8	0.243
1963	5,948	14.7	0.247	1,879	4.4	0.234	4,069	10.3	0.253
1964	5,297	13.9	0.262	1,537	3.4	0.221	3,760	10.5	0.279
1965	4,376	10.4	0.238	1,243	3.0	0.241	3,133	7.4	0.236
1966	4,329	9.9	0.229	1,333	3.1	0.233	2,996	6.8	0.227
1967	5,272	10.7	0.203	1,593	3.2	0.201	3,679	7.5	0.204
1968	6,448	12.6	0.195	2,366	4.6	0.194	4,082	8.0	0.196
1969	5,904	12.3	0.208	2,173	5.2	0.239	3,731	7.1	0.190
1970	6,324	12.8	0.202	2,801	5.9	0.211	3,523	6.9	0.196
1971	6,279	12.9	0.205	3,284	7.0	0.213	2,995	5.9	0.197
1972	6,418	13.7	0.213	3,887	8.1	0.208	2,531	5.6	0.221

TABLE 4.11. (Contd)

Year	Total Receipts		Open-Pit Production		Underground Production				
	Tons Ore x 10 ³	Tons U ₃ O ₈ x 10 ³	Ore Conc% (Derived)	Tons Ore x 10 ³	Tons U ₃ O ₈ x 10 ³	Ore Conc% (Derived)			
1973	6,537	13.6	0.208	4,544	8.6	0.189	1,993	5.0	0.251
1974	7,027	12.4	0.176	4,216	7.3	0.173	2,811	5.1	0.181
1975	7,057	12.0	0.170	4,247	6.7	0.158	2,810	5.3	0.189
1976	8,608	13.5	0.157	4,673	6.8	0.146	3,935	6.7	0.170
1977	10,325	15.9	0.154	5,578	7.6	0.136	4,747	8.3	0.175
1978	14,342	18.8	0.131	8,237	9.6	0.117	6,105	9.2	0.151
1979	15,011	15.7	0.105	9,655	9.4	0.097	5,356	6.3	0.118
1980	16,745	20.0	0.119	10,394	10.4	0.100	6,351	9.6	0.151
1981	13,665	15.6	0.114	8,436	7.0	0.083	5,229	8.6	0.164
1982	8,313	10.1	0.121	5,504	3.9	0.071	2,809	6.2	0.221
TOTALS	210,710	389.5	0.185	102,597	159.4	0.155	108,113	230.1	0.213

(a) Source: U.S. Department of Energy (1983). Statistical Data of the Uranium Industry. Table 1-6. (Mined ore; does not include production from mine water, in-situ leach liquor, heap-leach solutions, by-products, and miscellaneous low-grade ore from old mine dumps.)

even though the ore concentration from open-pit mines is falling more rapidly than from underground mines the production is not. Since 1971 there has been a larger percentage of ore production from open-pit than underground mines. In 1982 almost two-thirds of the ore production came from open-pit mines while this amounted to less than forty percent of the years production of U_3O_8 . Finally, the information in the table reveals that only two years after a peak production of 20,000 tons of U_3O_8 in 1980 production of concentrate from domestic mines had fallen almost fifty percent. This decrease represents the steepest production drop in the history of the domestic uranium industry (as deduced from the data).

Many factors contributed to this abrupt decrease in production. In 1976 the price of U_3O_8 hit an all time high in real terms and by mid-1978 the price peaked in nominal terms at \$43.40/lb of U_3O_8 . The price began to decline in nominal terms as well about mid-1979 (Hahne 1982). This price drop continued until September 1982 when the price bottomed at \$17.00/lb of U_3O_8 (Nuclear News, 1983c), which is the lowest price in real terms since 1973. The price drop cut producer margins significantly making it unprofitable for most producers to continue mining operations and many producers found it more profitable to meet contract obligations by making purchases on the spot market than by new production.

Inventories during the period 1979 to 1981 increased from about 90 to 130 million pounds of U_3O_8 which is more than three years of projected domestic reactor demand. At the same time projections of installed domestic nuclear capacity had continued to fall (see Table 4.2). The result of this was a large inventory sell-off by utilities and others causing increased pressure on producers to reduce output.

4.2.4 Facility Utilization-Operating Capacity, Production Lifetime

Operating Capacity

The term "facility" can refer to the mining operation or milling unit. The U.S. Department of Energy reports annual statistics on the activities of both facilities. However, for the mining side, data is given as total ore in concentrate produced from all mines of each type (i.e., underground, open-pit,

other) or by state. No indication is given as to nominal mine capacity (mine-specific or generically) or percent mine utilization. Designed mine capacities can sometimes be gotten from various published documents, but information is rarely up-to-date or complete. Therefore, a detailed breakout of data on nominal and operating capacities on a mine-specific basis is not possible.

The U.S. Department of Energy (1983), however, has recently issued information on nominal capacity and percent utilization for uranium mills. These mills are generally considered to be production centers--with the capacity of the mill representing the supporting mines. As of January 1, 1983, there were 14 conventional uranium mills operating. These mills had a total rated capacity of 33,650 tons of ore per day (Table 4.12). Ore actually milled from these 14 units in 1982 equalled 21,510 tons per day for a 1982 operating level of 63.9% of capacity. In addition, there were 10 licensed mills not operating as of January 1, 1983, but which milled some ore throughout 1982. Their operating level was 16.3% of capacity. The total 1982 operating level was 45.4% of capacity (Table 4.13). The 1983 estimated total operating level is about 35% of capacity.^(a)

Specific information on mine and/or mill operating levels, as reported in company annual and Form 10-K reports, is as follows:

- Rio Algom, Ltd.--Lisbon Mine operating on a 50% rate since October 1981. The integrated mine/mill complex has a nominal mill capacity of 700 tons ore/day.
- Homestake Mining Co.--Two of their Grants, New Mexico mines have been placed on standby in 1982. The Homestake mill is operating at a reduced level of 8 days on, 6 days off since April, 1982.
- UNC, Resources, Inc.--As of April, 1982, all UNC uranium production was suspended and facilities were put on standby.
- Kerr-McGee Corp.--7 of 11 uranium mines in New Mexico are operating at reduced levels while the remaining 4 have been put on standby. Two surface mines in Wyoming have also been placed on standby.

(a) Information from, U.S. Department of Energy, Grand Junction Area Office, Colorado.

TABLE 4.12. U.S. Uranium Processing Plants: Operating as of January 1, 1983

Conventional Mills	Plant Location	Nominal Capacity	
		Tons Ore/Day	Tons U ₃ O ₈ /Year
Atlas Minerals Corporation	Mbab, Utah	1,400	
Bear Creek Uranium Company	Powder River Basin, Wyoming	2,000	
Chevron Resources company	Hobson, Texas	2,500	
Cotter Corporation	Canon City, Colorado	1,300	
Energy Fuels Nuclear, Inc.	Blanding, Utah	2,000	
Exxon Minerals Company	Powder River Basin, Wyoming	3,200	
Homestake Mining Company	Grants, New Mexico	3,400	
Kerr-McGee Nuclear Corporation	Grants, New Mexico	7,000	
Minerals Exploration Company	Red Desert, Wyoming	3,000	
Pathfinder Mines Corporation	Gas Hills, Wyoming	2,500	
Pathfinder Mines Corporation	Shirley Basin, Wyoming	1,800	
Petrochemicals Company	Shirley Basin, Wyoming	1,500	
Rio Algom Corporation	La Sal, Utah	750	
Union Carbide Corporation	Natrona County, Wyoming	1,400	
Total		33,650	9,000-13,000

Source: U.S. DOE (1983), Table VII-2 p. 42.

TABLE 4.13. Conventional Mill Status Summary for 1982

Mill Status	Number of Mills	Rated Capacity (tons ore/day)	Milled in 1982 (tons ore/day)	1982 Operating Level as Percent of Capacity
Operating on 1/1/83	14	33,650	21,510	63.9
Not Operating on 1/1/83	10	21,400	3,490	16.3
Totals	24	55,050	25,000	45.4

Source: U.S. DOE (1983), Table VII-3, p. 45.

Production Lifetime

A "typical lifetime" statement about a uranium mine, is difficult to make. This is so because uranium ore deposits are so varied as to size, grade, depth, and difficulty of mining. A uranium mine life is also impacted by price, mining technology improvements and by-product production. However, some general comments can be made.

The San Juan Basin Regional Uranium Study (1980) lists uranium mine assumptions that were used in their study as a basis on which to gauge future uranium mine development in the San Juan Basin region (Table 4.14). These assumptions, based on industry and government sources, were made concerning the average new uranium mine going into production in the basin from 1980 on. The average life expectancy is given as 20 years.

TABLE 4.14. Average New Mine

Capacity	375 tons U_3O_8 in ore/year 1,030 tons ore/day Grade: 0.14% U_3O_8
Life Expectancy	20 yr
Area of Disturbance:	
Development drilling	258 holes/mine
Drill holes	1/3 acre/hole
Roads to site	1/2 acre/hole
Subtotal	215 acres
Mine Site	45 acres
Roads to site (12 miles)	60 acres
Subtotal	105 acres
Total Area Disturbed	320 acres
Vents	3
Exhaust Air	Varies to 400,000 or more cu ft/min
Mine Water Discharge ^(a)	500 to 3,000 gal/min (720,000 to 4.3 million gal/day 800 to 4,800 acre-ft/yr)

(a) Academic use only. U.S. Geological Survey model uses other methods.

Source: San Juan Basin Regional Uranium Study (1980) p. II-30.

Other examples of mine lives as taken from company annual reports and other sources are given for comparison:

Kerr-McGee Corp.:

- Section 19 Mine has been operating for 7 years
- Section 30E Mine has been operating for 24 years
- Section 30W Mine has been operating for 14 years
- Section 35 Mine has been operating for 12 years
- Section 36 Mine has been operating for 23 years

Homestake Mining Co.:

- Section 23 Mine has been operating for 24 years
- Section 25 Mine has been operating for 24 years

Gulf Mineral Resources:

- Mt. Taylor Mine has 20-year expected life
- Mariano Lake Mine has had a 5-year total life (now depleted)

Phillips Petroleum Co.:

- Nose Rock has 20-year expected life

4.2.5 Productivity and Employment Trends

Productivity

Mining technology and methods have had few major changes since the early 1950s. The industry though has seen improvements in the productivity of existing procedures plus has benefited from general improvements in mining equipment and methods--especially blasting and hauling (Charles River Associates, Inc. 1977).

The impact of technological change can be manifested in increased labor productivity over time. However, due to other contributing factors, it is cautioned that such labor productivity may not be the best measure of technological change. Table 4.15 gives data on output per man-shift. The table shows that labor productivity increased substantially after the 1950s. This was a period of mechanization and increasing uranium mining experience (Charles River Associates, Inc. 1977).

TABLE 4.15. Estimates of Labor Productivity in Uranium Mining

Date	Output Per Unit Labor Input	Source
1954-56 (Colorado Plateau)	1.0 - 3.1 tons ore/man-shift	Bureau of Mines ^(a)
Pre-1960 (Colorado Plateau)	2.1 - 13.3 tons ore/man-shift	Bureau of Mines ^(b)
1969	Open-pit: 16 tons ore/man-shift	Facer ^(c)
Late 1960s, early 1970s	Underground: approximately 8 tons ore/man shift (as much as 20 tons ore/man-shift in larger mines)	Facer
1974	Open-pit: 30 tons ore/man-shift	Facer
1974	Underground: approximately 7 tons ore/man-shift (10 tons ore/man-shift in larger mines)	Facer
1978	Underground: averages 6 tons ore/man-shift	(Facer 1978)
1979	Underground: nearing 8 tons ore/man-shift	(Facer 1979)
1980	Underground: averaging 8 tons/man-shift	(Anderson 1980)

(a) W. L. Dare, Uranium Mining Methods and Costs at Several Mines on the Colorado Plateau, BOM, Information Circular 8015, 1961.

(b) BOM, Mineral Factor and Problems, 1960, p. 928.

(c) J. Fred Facer, Jr., "Production Statistics," in ERDA, Uranium Industry Seminar, Grand Junction, Colorado, 1975; p. 152.

Source: As found in Charles River Associates, Inc. (1977).
Added--Facer (1978, p. 189; 1979, p. 195) and Anderson (1980, p. 125).

Other data from the U.S. Department of Energy on output per employee is given in Table 4.16. It is noted that these figures do not reveal changes in the average duration of employment and thus may not accurately reflect labor productivity trends (Charles River Associates, Inc. 1977). However, the figures show that output per man was stable between 1968 and 1974 for underground mining. A sharp drop occurred in 1975, but productivity has since risen to 1.3 tons/man for 1982.

TABLE 4.16. Changes in Output Per Man in Open-Pit and Underground Mines

	Open Pit			Underground		
	Employment (a) (number)	Total Ore Production (short tons)	Output/ Man	Employment (a) (number)	Total Ore Production (short tons)	Output/ Man
1968	675	2366	3.5	2890	4082	1.4
1969	956	2173	2.3	2865	3731	1.3
1970	1033	2801	2.7	2521	3523	1.4
1971	1122	3284	2.9	2236	2995	1.3
1972	1221	3887	3.2	1766	2531	1.4
1973	1167	4544	4.0	1552	1993	1.3
1974	1071	4216	3.9	2020	2811	1.4
1975	1274	4247	3.3	2927	2810	1.0
1982	1365	5504	4.0	2150	2809	1.3

(a) Number employed at end of year: includes miners, and service and support personnel; excludes supervisors, and technical and clerical employees. For 1975 and 1982, figures reflect average employment levels for the year.

Source: Employment: ERDA/AEC, Statistical Data of the Uranium Industry, 1969-1976; Output: Appendix Table A.4 as found in Charles River Associates, Inc. (1977).
 Added--U.S. Dept. of Energy (1983), Tables I-6 and XI-1.

Employment Trends

Historical data on employment in the uranium industry has been kept by the U.S. Department of Energy and its predecessors. Table 4.17 gives such data for years 1973 through 1982, divided by type of activity. Total employment peaked in 1979 at 22,191 and has been falling ever since.

TABLE 4.17. Employment in the Uranium Industry

Type of Activity	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Exploration	1,557	1,697	2,049	2,793	4,140	4,449	4,066	3,370	2,300 ^(a)	N.A. ^(c)
Mining ^(b)	3,516	3,928	5,386	7,603	11,453	13,338	14,649	13,298	8,984	6,242 ^(d)
Milling	<u>1,522</u>	<u>1,668</u>	<u>2,237</u>	<u>2,727</u>	<u>3,175</u>	<u>3,615</u>	<u>3,476</u>	<u>3,251</u>	<u>2,367</u>	1,956 ^(d)
Totals	6,595	7,293	9,672	13,123	18,768	21,402	22,191	19,919	13,651	

(a) Estimated.

(b) Includes solution mining and by-product operations.

(c) N.A. = Not available.

(d) Not included are an estimated 140 contract truckers.

Source: DeVergie (1982) p. 23. 1982 data from U.S. Dept. of Energy (1983). Table XI-1, p. 63.

DeVergie (1982) notes that the greatest relative change is seen in the exploration sector. From 1979 through 1982, employment here has plummeted by 2800 workers. Also, with the general slowdown in development work, fewer people were employed in the fields of shaft-sinking and other development functions in 1981 and 1980. Other mineral and mineral fuel industries have had substantial layoffs as well during 1981 and 1982, which makes it very difficult for the displaced uranium worker to find new jobs in their field of expertise.

4.2.6 Imports/Exports

Imports

As mentioned earlier, import levels have an effect on the domestic uranium industry. Import levels effect demand for uranium in the sense that if a utility can secure its reactor fuel requirements through lower-cost imported foreign supplies, then their demand for domestic higher cost uranium would be less.

U.S. Government policy has affected import levels in this country. The U.S. Department of Energy is the only domestic processor allowed to enrich uranium concentrate for nuclear applications. Between 1964 and 1976, imports were banned. All foreign uranium enriched in the U.S. had to be returned to the country of origin. The ban was lifted by 10% beginning in 1977, i.e., 10% of any U.S. utility's enriched uranium requirements could be of foreign origin. This amount increased by an additional 10% each year through 1981. In 1982, the ceiling was 60%, rising to 80% in 1983 and then vanishing altogether in 1984 (Nuclear Fuel 1981c).

Table 4.18 shows actual and allowable percentages of foreign uranium that toll enrichment customers (utilities) could have delivered for domestic end use each year. Note that domestic utilities are currently buying less foreign uranium than the percentage allowed by law.

TABLE 4.18. Deliveries of Uranium to DOE Enrichment Plants by Domestic Customers

Year	Origin (Short tons U ₃ O ₈)			Percent Foreign	
	U.S.	Foreign	Total	Actual	Allowable
1977	14,240	703	14,943	4.7	10
1978	11,957	728	12,685	5.7	15
1979	15,436	1,591	17,027	9.3	20
1980	11,135	1,241	12,376	10.0	30
1981	10,067	1,132	11,199	10.1	40
1977-1981	62,835	5,395	68,230	7.9	22

Source: U.S. Department of Energy (1982). Table XII, p. 16.

Recent action taken by the U.S. Congress, beginning in 1981, has been aimed at protecting the U.S. uranium producing industry. On March 31, 1982, the Senate approved an amendment originally proposed by Senator Domenici of New Mexico to the 1982/1983 NRC Authorization Bill (S1207). This amendment proposed an import limit of foreign uranium to 20% of required fuel for U.S. Nuclear reactors. A Senate/House conference Committee resulted when such a provision was not included in the Houses' version of the bill (H.R. 2330) (Connor 1983). The conference committee settled on a 37.5% foreign import limit which was passed by the Senate on October 1, 1982.

The bill called for an annual report by the DOE containing a calculation of the ratio of imports to requirements for the next 10 years. When the 37.5% limit was exceeded in any two consecutive years, a two-year freeze on new foreign contracting would be triggered. Also a study would be triggered of the viability of the U.S. uranium industry by the U.S. International Trade Commission and an assessment by the Department of Commerce of the national security impact of uranium imports. In addition, the DOE would be required to revise its enrichment criteria so as to enhance the use of domestic uranium (Nuclear Fuels 1982a).

Reaction to the proposed import ban was mixed among utility, industry, and professional people. The issue was the prime topic at the Uranium Colloquium V held in Grand Junction, Colorado, in October 1982.

Paul Gilman of the Senate Subcommittee on Energy Research and Development, opened the conference by showing full support for the import restriction. He said that weakening demand resulting from reactor cancellations and deferrals were the prime cause of the current depressed state of the U.S. uranium industry, but that the threat of increased foreign imports is also affecting the U.S. industry. He gave data from the DOE's Energy Information Administration that import commitments increased by 20,200 tons U_3O_8 in 1981 and an additional 19,800 tons U_3O_8 during the first half of 1982 - an 85% share of all new commitments made by domestic buyers for the 18-month period through July 1982 (Gilman 1982).

Two utility representatives gave opposing views. Russell Hulse, of the Arizona Public Service company preferred legislatively-imposed import restrictions over self-imposed limits by utilities. However, he still thought that it would not be wise to restrict all foreign uranium so as to keep some competition between U.S. and foreign producers (Hulse 1982). Louis Martin of Carolina Power and Light on the other hand, was opposed to restrictions. He said that such restrictions were overrated as being the solution to the problems of the U.S. industry but admitted that import limits may have some place in an overall program to support its existence (Martin 1982).

James Bedore of the Uranium Institute in London opposed the restrictions while Eugene Lang of Rocky Mountain Energy was in support of import limits

(Bedore 1982 and Lang 1982). A view was also expressed by James Munro, a representative of the Australian Western Mining Corporation, Ltd. He opposed restrictions (Munro 1982).

After discussing all arguments, the House of Representatives defeated the import restriction legislation on December 2, 1982 (Nuclear Fuel 1982b). Thus, the present import ban phase-out will continue as scheduled, ending totally in 1984.

The NRC FY-82/83 Authorization Act (of which the import issue was a part) was passed, however. This Act requires various studies of the U.S. uranium industry. The Department of Energy must determine annually between 1983 and 1992 the viability of the domestic industry using criteria adopted by September 1983 following a public rulemaking (Nuclear Fuel 1983a). As reported in the American Mining Congress Journal (1983), the AMC Uranium Policy Council has formed a working group to gather information to submit to the Department of Energy on this subject of domestic uranium industry viability. This information will be part of the DOE's report.

Exports

Export levels also have an effect on the domestic uranium industry. Export levels reflect the world market demand for domestically produced uranium. U.S. producers are and will be faced with competition from lower cost foreign suppliers. Table 4.19 gives historical data on U.S. imports and exports. Through 1975, the U.S. was a net exporter as imports were governed by law. From 1975 to 1977, imports exceeded exports but from 1978 through 1980, the reverse prevailed with the U.S. becoming a net exporter of uranium. In 1981, the U.S. again reversed and became a net importer.

4.3 FINANCIAL CHARACTERISTICS

4.3.1 Capital Requirements

This section will provide an overview of the current financial situation of the uranium/minerals industry. An introduction to types of analyses used in making mineral investment decisions will provide background for further financial discussion. Data will be given on uranium industry expenditures and a closing comment will be made on project financing from a banking perspective.

TABLE 4.19. U.S. Imports and Exports of Uranium for Commercial Uses
(tons U₃O₈)

<u>Year</u>	<u>Annual Imports</u>	<u>Annual Exports</u>
1966	0	400
1967	0	700
1968	0	800
1969	0	500
1970	0	2,100
1971	0	200
1972	0	100
1973	0	600
1974	0	1,500
1975	700	500
1976	1,800	600
1977	2,800	2,000
1978	2,600	3,400
1979	1,500	3,100
1980	1,800	2,900
1981	3,300	2,200

Source: U.S. Department of Energy. 1982.
Table X, p. 14.

Investment Decisions/Expenditures

Stermole, (1983) simply states that "the current financial state of the mineral industry, in general, is bad...and that economic prospects for improvements in the near future are uncertain." He emphasizes that mineral commodity prices must rise so that mineral investment economics can improve and so that industry can return to a more normal level of production. Prices must rise so as to make reopening of closed mines and expansion or development of new mines economically justifiable. Product prices are seen in investment analysis as being one of the key parameters in assessing the economic potential of existing or new investments. Stermole (1983) states that "it will take significant improvement in nonprecious metal mineral commodity prices in 1983 to develop significant new mine investment interest except in very high grade ore body special situations."

As for uranium specifically, White (1983) summarizes the 1982 uranium situation by citing the trend in U.S. exploration and development activity and the participation levels of companies. The trend in activity for uranium continued downward throughout 1982. Many programs were curtailed or completely terminated. Drilling activity was reduced dramatically. Participation by companies in the uranium business dropped considerably as well. White (1983) notes that of 15 major oil companies active early in 1982, 8 have since announced an intent to terminate all uranium activities. The other 7 have reduced activities sharply. For small mining companies and independent operators, the exodus rate is even higher.

Mineral investment decision making generally involves three types of analysis according to Stermole (1983):

- Economic analysis
- Financial analysis
- Intangible analysis.

An economic analysis considers "the relative economic merits of investment situations from a profitability viewpoint based on discounted cash flow analysis of projected investment revenues and costs." Financial analysis, however, "refers to where and how the funds for proposed investments will be obtained." And finally, intangible analysis "considers factors affecting investments but which cannot be quantified easily in economic terms." A careful distinction must be made between economic and financial analyses.

Expenditure or capital investment data is summarized by the Department of Energy. Table 4.20 shows uranium industry capital investment for the years 1977-1984. Capital investment for exploration and mining/milling facilities increased throughout the latter 1970s. In 1981-1982 total capital investment decreased substantially while planned expenditures will be even lower.

Financing/Capital Acquisition

Borrowing money to finance new mining ventures is an important consideration in a company's overall project analysis. If project financing cannot be secured, the project will not get off the ground regardless of its

TABLE 4.20. Capital Investment for the Domestic Uranium Industry

Investment Category	Expenditures in Million Dollars							
	Actual						Planned	
	1977	1978	1979	1980	1981	1982	1983	1984
Exploration								
Companies Reporting Expenditures	146	174	164	147	107	71	63	48
	258	314	316	267	145	71	40	23
Mine (a)								
Companies Reporting Expenditures	31	25	26	34	29	23	15	16
	325	271	282	273	212	81	26	23
Mill (a)								
Companies Reporting Expenditures	26	19	26	27	22	15	13	8
	167	156	203	242	59	11	10	9
Total Expenditures	750	741	801	782	416	163	76	55

(a) Data through 1981 are based on editions of Survey of United States Uranium Marketing Activity. Data for 1982 are preliminary figures provided by the Energy Information Administration based on the January 1, 1983, uranium marketing survey.

Source: U.S. DOE. (1983). Table Xi-2, p. 64.

economic potential. G. E. Kurt Pralle of Citibank Corporation in New York has outlined three reasons why companies looking to finance new projects will turn to financial institutions (banks) (Nuclear Fuel, 1981a):

- they may have better forms of investments open to them,
- at a particular point in time the company may wish to put more money into dividend payments rather than the project
- the company may feel that with so large an expenditure it is not wise to put retained earnings and share holders funds into a venture.

Pralle discusses that very few innovative methods of financing have been done for uranium mining projects due mainly to uncertainty about ore reserves, operating economics and so forth. The types of financing include:

- balance sheet financing
- project financing
- leverage base method

- take-or-pay contracts,
- production payment method.

Of these, balance sheet financing will form the basis of the majority of loans in the 1980s. Here, money is lent against the balance sheet of the company versus lending to a project with no recourse to any third parties as per the project financing method.

In making loans, the banks look for cost competitiveness of the company rather than relying solely on a sales contract or spot price to ensure them of the project's viability. Banks also look at a company's good credit, sufficient cash flow, project reserves, adequate mining and mill techniques and strong management (Nuclear Fuel, 1981a and 1981b).

4.3.2 Financial Data

The uranium market in 1982 saw a decline in U.S. production, reduced exploration activity and little overall change in the depressed spot market. There has been little to indicate any improvements in the medium-term uranium situation. Under conditions of low market price and steadily rising production costs, many marginally operating mines and operations are being terminated or put on standby. As an example, the number of uranium production sources has fallen steadily since 1979 from a total of 432 to a low of 196 in 1982. The number of underground mine sources has declined from 300 to 139 over the same period (U.S. DOE, 1979, 1980, 1981, 1982, 1983).

Updated financial data is provided for three companies: Homestake Mining Company, Kerr-McGee Corporation and UNC Resources, Inc. (Table 4.21). These were chosen because they are representative mine owners/operators in the mine study group as discussed under Section 3.8. Also, these companies breakout the uranium segment in reporting their financial data.

Of the three, only Homestake had an increase in revenues, up 6% in 1982. Operating earnings were up as well, contributing 40% of consolidated earnings in 1982 compared to 11% in 1981. Homestake's capital expenditures dropped dramatically along with a decrease in uranium assets which is indicative of the company's present degree of activity in exploration and development of property.

TABLE 4.21. Financial Information for Three Uranium-Mining Companies

		<u>Revenues</u>	<u>Operating Earnings</u>	<u>Depreciation and Amortization</u>	<u>Capital Expenditures</u>	<u>Assets</u>
Homestake (Uranium Division)	1976	22,441	10,389	192	2,036	14,144
	1977	59,141	24,622	80	2,628	45,023
	1978	44,928	20,454	0	7,961	42,990
	1979	42,388	14,097	17	8,553	47,790
	1980	45,363	(601)(a)(b)	6,980	12,521	54,798
	1981	59,983	5,703	5,339	12,036(c)	83,135
	1982	63,702	15,592	19,953	1,025	80,831
Kerr-McGee (Nuclear Division)	1976	96,800	32,700	7,500	NA(d)	215,300
	1977	123,300	22,300	9,300	NA	236,500
	1978	115,200	20,100	13,800	NA	272,000
	1979	163,400	(200)	15,600	28,800	288,400
	1980	238,900	30,000	21,300	17,900	304,800
	1981	201,500	26,300	16,600	14,200	304,500
	1982	153,100	20,000	16,300	7,300	312,400
UNC (Uranium Division)	1976	29,339	7,103	1,070	27,856	87,222
	1977	80,816	28,539	1,952	54,499	145,376
	1978	133,193	42,320	5,414	49,518	203,041
	1979	181,626	61,339	9,677	39,156	279,436
	1980	167,811	12,243	11,952	46,662	239,888
	1981	102,102	20,537	6,993	14,386	210,471
	1982	84,038	2,409	3,249	8,606	209,791

(a) includes an \$8,075,000.00 loss on settlement of uranium litigation.

(b) Value in parenthesis equals loss.

(c) Excludes acquisition of partnership interest.

(d) NA - not available.

Source: Company Annual and Form 10-k reports.

Kerr-McGee and UNC Resources revenues, operating earnings and capital expenditures were down in 1982 for their nuclear segment. UNC notes that revenues from the sale of uranium concentrate decreased 9% for 1982 while costs and operating expenses increased 48%. The company spent \$11.3 million alone just to place and maintain their uranium mining and milling facilities in a standby condition.