Appendixes

Appendix A

The Role of Onshore Federal Land With Respect to Production of Essential Mineral Commodities

A. Introduction

This appendix summarizes the present importance and future potential of onshore Federal land with respect to supplies of some selected essential mineral commodities.

At the outset of this assessment it was recognized that it would be a very large and time-consuming task to try to analyze and report in detail on the contribution onshore Federal land does or could make to an assured and efficiently priced supply of all essential minerals. Rather, it was decided to analyze only enough different minerals to give representative coverage of the various types of essential minerals covered by the principal Federal laws governing mineral activities on onshore Federal land.

The applicable Federal laws are summarized in chapter 3 of this report. Principally, they are the Mining Law of 1872, the Mineral Leasing Acts of 1920 and 1947, and the Geothermal Steam Act of 1970. -' In general, the Mining Law applies to metallic mineral deposits (for example, copper, silver, and uranium) and deposits of most nonmetallic minerals (for example, fluorite). The Mineral Leasing Acts apply to the fuel minerals, except uranium, and to the fertilizer and chemical minerals, The Geothermal Steam Act applies only to geothermal steam and associated resources, Minerals subject to the Mining Law are generally referred to as "locatable" or "hardrock" minerals, while those subject to the Mineral Leasing Acts or the Geothermal Steam Act are referred to as "leasable" minerals.

The criteria used to select representative essential minerals for analysis are described in section B below. The list resulting from these criteria contains five fuel minerals, four fertilizer or industrial minerals, and five (non fuel, nonfertilizer, nonindustrial) metallic minerals. Of these, seven minerals (coal, copper, nickel, phosphate rock, silver, sodium carbonate, and uranium) have a relatively high potential for occurrence on onshore Federal land, six (geothermal steam, fluorspar, lead, natural gas, petroleum, and potash) have a more moderate potential, and one (iron ore) has only limited, but possibly locally important, potential. Even minerals with less Federal land potential may take on added significance when viewed within the context of national needs and the reliability of imports.

[1]Essential in the sense that industry requires an assured supply in order to perform its functions.

[2]Common varieties of sand, stone, gravel, pumice, pumicite, or cinders are governed by the Materials Disposal Act of 1947 and the Surface Resources Act of 1955, 30 U.S.C. §§ 601-604 (1970).

The findings and other information presented in this appendix are supplied only for the general orientation of the reader and are not meant to be definitive or complete. Exhaustive analyses of the variety of available forecasts of supply and demand balances, import dependence, and similar issues are not provided. The data on the occurrence of each mineral with respect to Federal land are also not exhaustive, The data for a comprehensive study simply were not available, and the resources and time allotted for this part of the assessment did not permit the development of such basic data. Furthermore, national conservation goals for minerals do not exist. Therefore, it is not possible to prepare meaningful forecasts of future national requirements for minerals that incorporate conservation in any systematic way. Nevertheless, it is hoped that the data in this appendix facilitate a general understanding, through analysis of representative minerals, of the role of onshore Federal land with respect to production of essential mineral commodities.

B. Criteria for Selection of the Study Minerals

As stated above, time and resource limitations for this assessment made it necessary to select only a few essential minerals for detailed presentation of demand and supply forecasts and the potential on Federal land, It was felt that the minerals chosen should be: 1) representative of the various groups of minerals, other than common-variety minerals, covered by the principal laws governing access to minerals on onshore Federal land; 2) occur, or have a potential for occurrence, on Federal land in sufficient quantities to make a significant contribution to meeting current and projected domestic requirements;[3] and 3) be subject to a continuing high level of demand by domestic industry with a limited potential for recycling or substitution in basic uses.

C. Application of Selection Criteria to Arrive at Study Minerals

The criteria listed in section B above were not applied rigorously or quantitatively to arrive at the study minerals, Rather, they were applied in a somewhat subjective manner by a small group of minerals specialists who believed that it was necessary only to select a representative list of minerals that would illustrate the role Federal land does or could play in meeting domestic U.S. requirements for essential mineral commodities. Once they had been selected, the study minerals were to be subjected to a more rigorous analysis of their potential on Federal land in relation to domestic requirements. Thus, the selections were made on the basis of personal knowledge supplemented by a brief review of the available general literature,

1. Representation of the various groups of minerals covered by the principal Federal minerals laws. The essential noncommon-variety minerals can be divided roughly into four groups: fuel, fertilizer, industrial, and (nonfuel, nonfertilizer, nonin-

[3]The terms "requirements," "demand," "needs," and "consumption" are used more or less interchangeably in this report, not in any strict technical economic sense, but to indicate the degree to which, under the various forecasting assumptions, future requirements for essential minerals might be significantly larger or smaller than future estimated supplies.

dustrial) metallic minerals. Almost all the fuel and fertilizer minerals are “leasable” minerals covered by the Mineral Leasing Acts or the Geothermal Steam Act. Almost all the industrial and metallic minerals are “locatable” or “hardrock” minerals covered by the Mining Law,

The leasable fuel minerals are geothermal steam, coal, natural gas, petroleum, oil shale, natural asphalt, and bitumen. The leasable fertilizer minerals are phosphate and potash. The leasable industrial minerals are sulfur (in Louisiana and New Mexico only) and sodium compounds. There are no leasable metallic minerals other than sodium (except under special leasing acts for acquired land).

As there are at most two leasable minerals in each of the three nonfuel mineral groups (fertilizer, industrial, and metallic), all the nonfuel leasable minerals were retained as candidate study minerals under criterion 1. Geothermal steam was retained as a fuel mineral because it has its own special leasing act, Coal, natural gas, and petroleum were retained as representative fuel minerals under the Mineral Leasing Acts. Oil shale, natural asphalt, and bitumen were eliminated, as they (a) are primarily sources of petroleum substitutes and demand for their products tracks the demand for petroleum, (b) are subject, like geothermal steam, to technological and economic uncertainties, and (c) involve problems in extraction (for example, fragmented ownership, intensive use of large tracts, strip mining, population influx, water consumption, and pollution) similar to those of Federal coal. In sum, geothermal steam, petroleum, natural gas, and coal are adequate representatives of the leasable fuel minerals.

The only locatable fuel mineral is uranium. There are no locatable minerals that are primary fertilizer ingredients. All the industrial and metallic minerals that are not listed above as leasable are locatable.

Uranium was retained as a candidate study mineral under criterion 1, as it is the only locatable fuel mineral. A representative list of locatable industrial and metallic minerals was taken from a report on critical materials, prepared by the U.S. Council on International Economic Policy, that includes “all the major non-fuel raw materials in world trade as well as minor ones known to be important to national security or industrial processes.”[4] The list includes 17 locatable minerals: aluminum, chromium, cobalt, columbium, copper, fluorspar, iron ore, lead, manganese, mercury, nickel, platinum group, tin, titanium, tungsten, vanadium, and zinc. Of these, only one, fluorspar, is a nonmetallic industrial mineral. Silver was added to the candidate study mineral list because it is important to an entire industry—photography—and has been produced in substantial quantities from western land.

2. **Reported known large deposits or significant potential for occurrence on Federal land in relation to domestic requirements.** Data about the occurrence of mineral resources on Federal land were taken from estimates of potential resources published by the U.S. Geological Survey (USGS) in 1973[5] and from information on past or present

[4] U.S. Council on International Economic Policy, *Special Report: Critical Imported Materials* 23 (1974).

[5] U.S. Geological Survey, *United States Mineral Resources*, Prof. Paper 820 (1973).

reserves and production reported by the USGS and the U.S. Bureau of Mines.[9] In the absence of more specific data, it was assumed that a high level of occurrence in the Western States and/or Alaska indicates a significant potential on Federal land.

All the leasable minerals other than sulfur selected under criterion 1 have been reported to have a significant level of occurrence on Federal land. Sulfur was eliminated under criterion 2 as a study mineral because its current and projected onshore domestic supply comes from production on non-Federal land or as a byproduct of processing other minerals.

Both the locatable fuel mineral (uranium) and the locatable nonmetallic industrial mineral (fluorspar) selected under criterion 1 have been reported to have a significant potential for occurrence on Federal land in relation to the Nation's domestic requirements.

Of the locatable (nonfuel, nonfertilizer, nonindustrial) metallic minerals selected under criterion 1, only copper, lead, silver, tungsten, vanadium, and zinc are currently being produced in substantial quantities, in relation to domestic demand, from regions with large amounts of Federal land. For silver and vanadium, however, most of this production from Federal land regions is as byproducts of other mineral production: silver from copper, lead and zinc ores, and vanadium from phosphate and uranium ores. Silver was chosen as representative of these byproduct ores, and vanadium was eliminated from the candidate study mineral list.

There are substantial estimated resources of aluminum (alunite and dawsonite), cobalt, columbium, iron ore, mercury, nickel, the platinum group, and titanium in Federal land regions in relation to domestic requirements. Of these resources, however, only cobalt, columbium, iron ore, nickel, and the platinum group are reported to occur in sufficient quantity and quality in Federal land areas in relation to identified resources elsewhere to serve as significant potential additions to domestic supply. Furthermore, cobalt and platinum would be produced largely as byproducts of copper and nickel production. Therefore, only columbium, iron ore, and nickel were retained in the candidate study mineral list.

Because chromium, manganese, and tin are reported to have minimal potential for occurrence on Federal land in relation to current and projected domestic requirements, they were also eliminated from the candidate study mineral list.

3. Subject to a continuing high level of demand by domestic industry with a limited potential for recycling or substitution in basic uses. All the minerals, except columbium, selected under criteria 1 and 2 also pass this criterion. There are a number of substitutes for columbium, so it was eliminated from the study mineral list.

The fuel minerals are substitutable for one another to a certain extent, but the magnitude of the current and projected demand for energy in the United States is so great that it will be necessary for the fuel minerals to complement rather than compete

[9] U.S. Bureau of Mines, *Commodity Data Summaries, 1976* (1976); U.S. Bureau of Mines, *Minerals Yearbook, 1973, Vol. II, Area Reports: Domestic* (1976); U.S. Geological Survey, Conservation Division, *Federal and Indian Lands Coal, Phosphate, Potash, Sodium, and Other Mineral Production, Royalty Income, and Related Statistics, Fiscal Year 1975* (1976); U.S. Geological Survey, Conservation Division, *Federal and Indian Lands Oil and Gas Production, Royalty Income, and Related Statistics, Calendar Year 1975* (1976).

with one another in the near- and mid-term. Therefore, none of the selected fuel minerals were eliminated under criterion 3,

4. **The Final List.** The purpose of the criteria was to select only a representative number of minerals from the various groups covered by the principal Federal mineral laws. The initial application of the three criteria resulted in the selection of four leasable fuel minerals (coal, natural gas, petroleum, and geothermal steam), both leasable fertilizer minerals (phosphate and potash), and one leasable industrial mineral (natural sodium carbonate, the most significant sodium compound on Federal land in relation to domestic demand). There are no leasable nonindustrial metallic minerals.

The initial application of the selection criteria also resulted in the selection of seven locatable metallic minerals (copper, iron ore, lead, nickel, silver, tungsten, and zinc), the only locatable fuel mineral (uranium, which is also a metallic mineral), and one locatable industrial mineral (fluorspar). There are no locatable minerals that are primary fertilizer ingredients.

The resulting list seemed reasonably short and representative, except for the large number of locatable metallic minerals. It was decided to reduce the number of locatable metallic minerals from seven to five. Tungsten was eliminated because its geographic distribution is approximately parallel to that of copper, which is subject to a higher level of demand. Zinc was eliminated because its geographic distribution is approximately parallel to that of lead, which is the more significant resource on Federal land owing to its occurrence on Federal acquired land in Missouri.

The final list of study minerals broken down into the four basic groups follows:

- Fuel minerals—coal, geothermal steam, natural gas, petroleum, and uranium;
- Fertilizer minerals—phosphate and potash;
- Industrial minerals—fluorspar and natural sodium carbonate; and
- Metallic minerals—copper, iron ore, lead, nickel, and silver.

Other minerals specialists might have selected a different list of representative minerals based on different criteria or on disagreement with the way the criteria were applied. However, the purpose of the exercise was not to produce a definitive list, but to reduce the large number of mineral commodities to a short list through a rough but rational process in order to be able to illustrate, through a subsequent brief analysis of each commodity, the role that Federal land does or could play in meeting domestic requirements for essential mineral commodities. It was felt that the list of minerals compiled through the selection process described in this section would satisfactorily serve that purpose.

D. Methods Used to Analyze the Study Minerals

Each of the mineral commodities selected through the process described in the preceding sections is analyzed in section F. The analysis for all but three[7] of the minerals covers the following specific topics:

- Uses, substitutes, or alternatives,
- Demand/supply outlook,
- Geographic distribution of resources, and
- Potential of Federal land.

The methods used to fill in the details of the topics are described briefly here,

1. Uses, substitutes, or alternatives. Information on these topics was taken from reports of the U.S. Bureau of Mines and condensed for presentation in this report.[8] This information is collected from industry by the Bureau; it is regularly updated and published annually.

The potential for the employment of substitutes for any given mineral is taken into account by the Bureau in the preparation of forecasts of demand/supply balances (see below) for that mineral. Consequently, no independent attempt was made to develop estimates of the future effect of current research or market forces on the possibilities for substitutions,

2. Demand/supply outlook. Although it is an inherent characteristic of forecasting that uncertainty increases over time, comparisons of the projected demand and supply for the study minerals should be useful in providing insight into the likelihood and degree of future problems,

Forecasts of domestic demand[9] and supply for the years 1985 and 2000 are provided for the study minerals, The forecasted demand given is for "primary'" O mineral commodities; the forecasted supply is for domestic mine (or well) production, that is, primary supply. A summary table of historic supplies from all sources (primary, recycled, reconditioned, etc.) is given for 1965, 1970, and 1974. However, forecasts of demand are given only for primary (that is, new) materials in order to indicate the level of need for either increases in mine production or increases in imports when compared with forecasts of primary supply,

All forecasts are the result of evaluations and syntheses of available studies and projections, rather than original research.

For the demand side of the demand/supply balance, the forecasts of the U.S. Bureau of Mines have been used[11] because they are based on the contingency forecast-

[7] There has been a departure from the full format in three cases, where instead a brief summary of supply and demand and Federal land potential has been given. Iron was summarized because it was found upon more detailed analysis to have very limited potential for occurrence on Federal land in relation to its potential on non-Federal land. Similarly, lead has a limited relative potential on the 93 percent of Federal onshore land found in the 11 contiguous Western States and Alaska; only the Federal acquired land in Missouri is known to have a substantial lead resource. Finally, geothermal steam is such a newly exploited resource domestically that detailed supply and demand projections would not be very meaningful.

[8] U.S. Bureau of Mines, *Mineral Facts and Problems, 1975 Edition*, Bull. 667 (1976); U.S. Bureau of Mines, *Commodity Data Summaries, 1976* (1976).

[9] See note 3.

[10] As used here, primary mineral commodities are new materials, not recycled, reconditioned, or reused, which have been produced from deposits of naturally occurring materials in the Earth's crust.

[11] U.S. Bureau of Mines, *Mineral Facts and Problems, 1975 Edition*, Bull. 667 (1976).

ing approach, are generally comprehensive and consistent, and have a continuing historic basis lacking in other forecasts. In the contingency forecasting approach, values are assigned by the Bureau on the basis of constructed scenarios that describe, in all relevant ways, the nature of the future operating environment. The demand forecasts are presented by the Bureau, in most cases, as ranges; high, low, and most likely future levels are given for the year 2000, while for 1985 only a forecast of the most likely level is given.

For the supply side, the forecasts of primary minerals were also taken mainly from reports of the Bureau of Mines. " These forecasts are based on probable trends in demand, pricing, and the availability of domestic and imported mineral supplies. Such factors as technological change, substitution or interchangeability, and the impact of foreign demand are taken into account. In some cases, estimates of future supply were modified on advice from individual mineral commodity specialists of USGS.

3. **Geographic distribution of resources.** Data for this topic were obtained from a variety of sources, generally from publications of USGS. The general source was USGS Professional Paper 820, unless otherwise indicated in the discussion of a particular mineral (see section F).

4. **Potential of Federal land.** The goal of this task was to provide an estimate of the role that Federal land may be expected to play in the domestic supply of essential minerals to the end of this century. Toward this end available geologic information on the occurrences of mineral resources was combined with Federal land ownership patterns. The complicated structure of land ownership and mineral rights, plus the limitations and gaps in existing geologic data, however, permitted at most only a broad, order-of-magnitude view of mineral and Federal land relationships. ' Consequently, the findings of this section should be viewed with caution, as representing only very rough estimates, and not as definitive statements with a measurable range of probability.

Generally, the assessment of mineral potential on Federal land was restricted to the 11 contiguous Western States" and Alaska. On occasion, significant mineral resources within Federal land in other States were also described (for example, the copper and nickel resources of Minnesota and the lead resources of Missouri).

Qualitative estimates of mineral resources on Federal land were made by overlaying geological and mineral resource maps on maps of Federal land distribution.[15]

Ibid. It should be noted that certain inconsistencies appear in the historic data on supply and demand reported by different Bureau publications. The data reported in the *Mineral Facts and Problems* and *Minerals in the U.S. Economy* series have been cross-checked, analyzed, and reconciled by the Bureau, whereas the data in the *Commodity Data Summaries* series reflect quick straight reporting. Consequently, special care should be taken in attempting to correlate the data presented in this appendix with data in the *Commodity Data Summaries* series. Especially in the case of imports and secondary supplies for some minerals, the latter source seems to significantly understate historic data.

[13]A quantitative, statistical approach to estimating the mineral potential of onshore Federal land was investigated, but was found to be unsuitable. Such an approach (called "geostatistics") uses statistical techniques to correlate occurrences of minerals within large, continuous, well-explored areas to occurrences within other large, continuous, but mostly unexplored areas. See, e.g., M. Allais, "Method of Appraising Economic Prospects of Mining Exploration Over Large Territories: Algerian Sahara Case Study," 3 *Management Science* 285 (1957); D. P. Harris, "Operations Research and Regional Mineral Exploration," 238 *AIME Transactions* 450 (1967). However, the onshore Federal lands are distributed irregularly and are interspersed with State and private lands according to no consistent pattern. Furthermore, surface and mineral ownership is often split and fragmented. Under such circumstances, the geostatistical approach is inappropriate.

[14]Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

[15]Maps used were from the U.S. Bureau of Land Management, the U.S. Geological Survey, the U.S. Forest Service and other government agencies such as State planning commissions.

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Metallogenic provinces and mineral belts recognized by J. A. Noble[16] were also compared with land distribution patterns. In making an estimate of resources on Federal land, account was taken of the fact that many of the known hard-rock mineral deposits in the Western States are on patented land, that is, land once in the Federal public domain but now privately owned according to the provisions of the Mining Law of 1872. These deposits were counted as Federal resources since they were discovered on Federal land. Undiscovered resources were assumed to exist in the vicinity of the known deposits and on that basis were estimated to have the same degree of Federal ownership as the known resources. Some undiscovered resources undoubtedly exist in unexplored areas, but estimates of probable ownership of these are, of course, very difficult.

The map overlay approach produced results that necessarily were highly qualitative. The available information, with but a few exceptions, was insufficient for a quantitative assessment of mineral potential on Federal land. Land and mineral ownership is highly fragmented, and ownership of the surface is often split from ownership of the subsurface. Mineral deposits are three-dimensional, while mapped data is usually presented in only two dimensions. Land status changes daily, while maps are updated infrequently. Maps occur in varying detail, scale, and quality. Many areas are not adequately mapped in terms of either land status or mineral potential. In light of all these problems, any quick assessment of Federal land mineral potential must be both very approximate and quite subjective.

E. Mineral Resources Classification System

In discussing the potential for mineral resources on Federal land, various terms are used to indicate the state of knowledge about the resources. The terms used were taken from the joint U.S. Bureau of Mines/U.S. Geological Survey system of classification of mineral resources. ” The terms and the relationships between them are illustrated in figure A-1 and briefly described below.

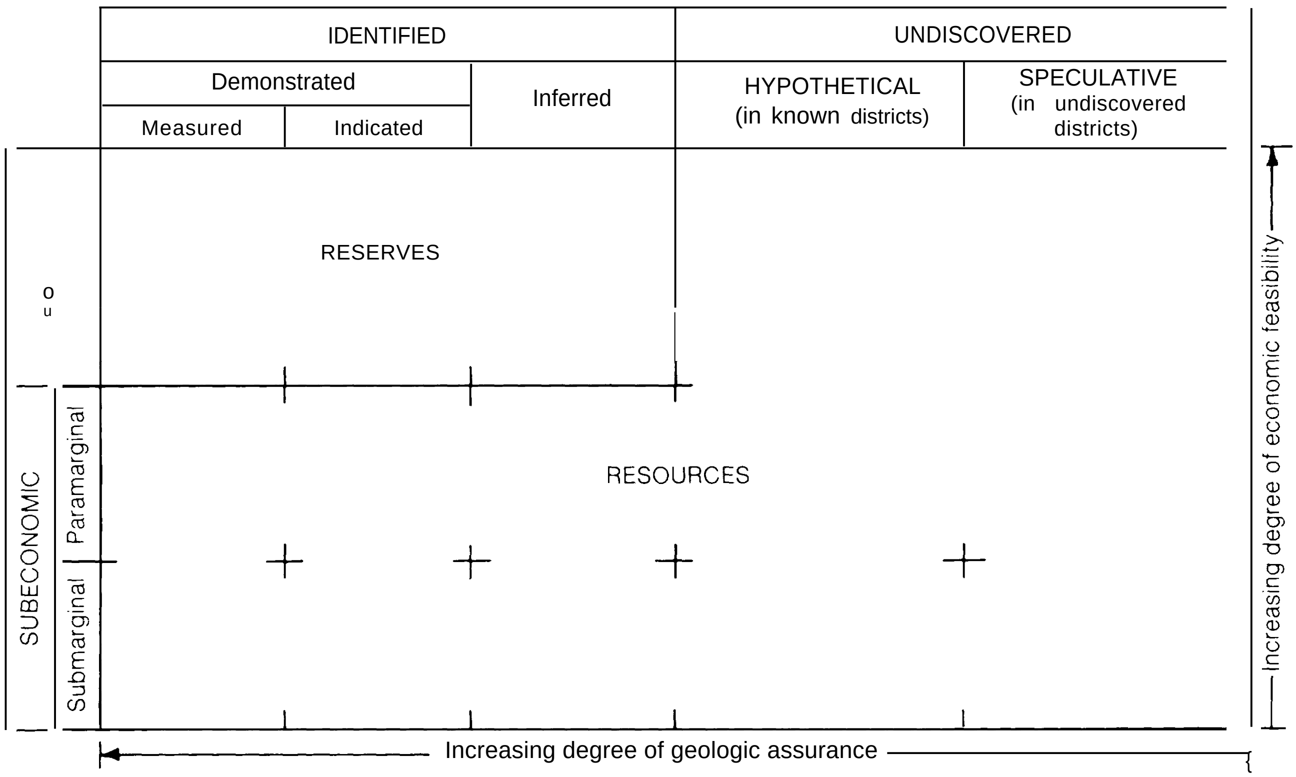
- **Identified Resources:** Specific bodies of mineral-bearing material, the location, quality, and quantity of which are known from geologic evidence and, if they are in the demonstrated category, are supported by engineering measurements,
  - —Reserve: That portion of the identified resource from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination. The term ore is used for reserves of some minerals.
  - —ldentified Subeconornic: Identified resources that may become reserves as a result of changes in economic, technologic, and legal conditions.

[16] J. A. Noble, "Metal Provinces in the Western United States," 81 *Geological Society of America Bulletin* 1607 (1970).

[17] U.S. Bureau of Mines and U.S. Geological Survey, *Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey*, USGS Bull. 1450-A (1976).

These terms were used for all of the study minerals except uranium. Estimates of resources of uranium are prepared by the Energy Research and Development Administration (now the Department of Energy), which uses its own classification system.

Figure A-1 .—Classification of Mineral Reaources



- **Undiscovered Resources:** Bodies of mineral-bearing material surmised to exist on the basis of broad geologic knowledge and theory. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as reserves or as identified subeconomic resources.

  —Hypothetical Resources: Undiscovered resources that may reasonably be expected to exist in a known mining district under known geologic conditions.

  —Speculative Resources: Undiscovered resources that may exist either as familiar types of deposits in a favorable geologic setting where no discoveries have been made or as unfamiliar types of deposits that remain to be recognized.

Measured, indicated, and inferred resources include both reserves and identified subeconomic resources. They are defined as follows:

- **Measured:** Identified resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits, which are stated, and no such limit is judged to be different from the computed tonnage or grade by more than 20 percent.

- **Indicated:** Identified resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on the basis of geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade to be established throughout.
- **Inferred:** Identified resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. Continuity or repetition is assumed on the basis of geologic evidence, which may include comparison with deposits of similar type, Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

F. Individual Mineral Commodity Summaries

In this section, summaries of data available in 1975 for each of the 14 selected study minerals are presented according to the methods and format described in section E. Data available in 1975 were used because this part of the assessment was conducted in 1975 and early 1976. ” The data have not been updated in this appendix, as the purpose of the summaries has never been to provide a definitive analysis of the individual mineral commodities, but rather an idea of the role Federal land does or could play in supplying those commodities,

1. Coal

U.S. resources, ” which are of growing importance in the national energy supply picture, are widespread and abundant, with about 70 percent of total remaining resources within the 11 Western States and Alaska. An estimated 40 percent of the Western and Alaskan resources are on Federal land; an estimated 35 percent of total U.S. coal resources are on Federal land.

a. **Uses, Substitutes, or Alternatives.** Coal is a major component of the Nation's total energy supply. Other significant fuel sources for power generation include

Unless otherwise indicated, data on total resources of a mineral commodity and the geographic distribution of those resources are from U.S. Geological Survey, *United States Mineral Resources*, Prof. Paper 820 (1973) (hereinafter cited as USGS Prof. Paper 820); supply and demand historical data and projections are from U.S. Bureau of Mines, *Mineral Facts and Problems, 1975 Edition* (1976), supplemented for the energy minerals by U.S. Bureau of Mines, *United States Energy Through the Year 2000 (Revised)* (1975],

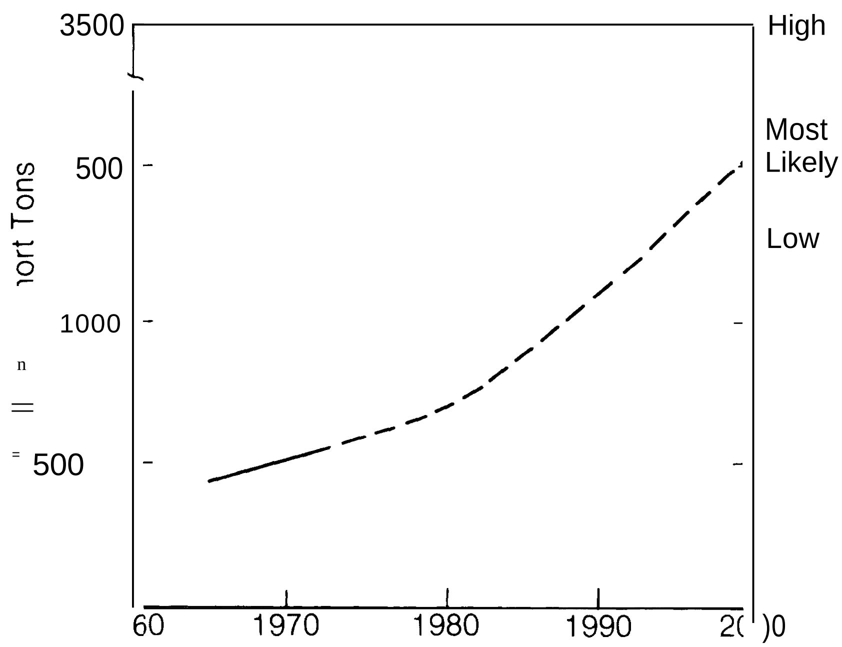
"As used herein, "coal resources" refers to total remaining identified and hypothetical resources of lignite and bituminous (including sub-bituminous) coal. Bituminous coal is widespread in the lower 48 States and Alaska; lignite is important only in the Western States. Anthracite has been excluded because it is important only in Pennsylvania, which contains a minimal amount of Federal land.

uranium, oil, and natural gas. However, the extent to which uranium will substitute for coal is highly uncertain because of constraints of capital costs, licensing, and public acceptance. Oil cannot be considered as a substitute for coal in the future; rather liquids derived from coal are viewed as future substitutes for oil. A similar situation exists with gas as a substitute for coal, complicated by a more variable supply situation.

Coal is also essential to the primary metal industries, where it is used in the production of metallurgical-grade coke. In addition, coal has the potential to become a major source of supply of some organic chemicals and of gaseous and liquid fuels.

b. **Demand Outlook.** Domestic demand for coal is expected to increase significantly through the year 2000 (see figure A-2).

Figure A-2.— Bituminous Coal and Lignite Demand Outlook



Forecast Assumptions

High: Most likely demand plus an additional 1.8 billion tons for extensive synfuel production.

Low: No commercial synfuel production.

Most Likely: Continued GNP growth averaging 3.5 percent per year; continued slow growth in population averaging less than 1 percent per year; strip mining permitted under regulations requiring environmental protection; more efficient use of energy by industry; some commercial synfuel production before the year 2000.

c. Supply Outlook. As illustrated in table A-1, historically the United States has been self-sufficient in the supply of coal.

To meet the projected most likely demand in the year 2000, coal production will have to be tripled (see figure A-3).

Production at this projected rate, however, will consume only about 10 percent of the identified coal resources of the United States currently deemed available for mining (see table A-2).

Figure A-3. —Bituminous Coal and Lignite Supply Outlook

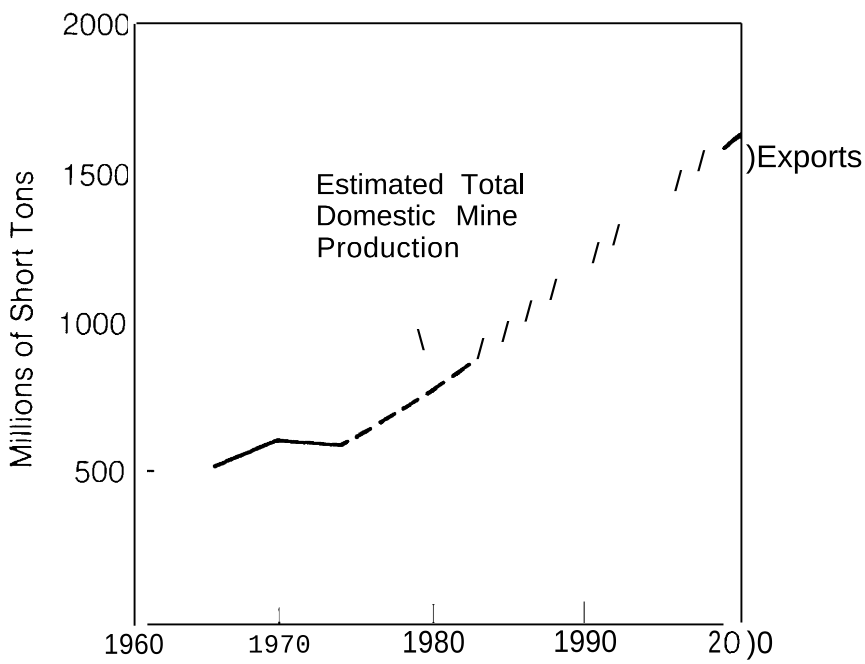


Table A-1 .—Bituminous Coal and Lignite Supply (Millions of Short Tons)

	1965	1970	1974
Domestic U.S. Mine Production	512	603	603
Minus Exports	(50)	(71)	(60)
Plus Imports	—	—	2
Industry Stocks, January 1	78	82	103
TOTAL Coal Supply	540	614	648

Table A-2.—Resources of Coal (Including Anthracite)

Identified:	1,730 billion tons, of which only about 424 billion tons are currently estimated to be economically and legally available for mining; average recovery rate is approximately 50 percent. Of the 1,730 billion tons, an estimated 130 billion are in Alaska.
Hypothetical:	1,849 billion tons, of which an estimated 1,130 billion are hypothetical coal resources in Alaska.

Source: P Averitt, Coal Resources of the United States, January 1, 1974, U S Geological Survey Bull 1412 (1975)

d. Geographic Distribution of Resources. U.S. coal resources are widespread and abundant. About 46 percent of the total remaining identified coal resources (and about 88 percent of total hypothetical coal resources) are in Alaska and the Western States. The approximate distribution of remaining identified coal resources, including anthracite, is as follows:[20]

North Dakota	20.3%
Montana	16.800
Illinois	8,4%
Wyoming	7.90/0
Alaska	7.5%
Colorado	7.4%
West Virginia	5.8°A
Pennsylvania	4.8%
Kentucky	3.7%
New Mexico.	3.5%
Ohio	2.4%
Indiana	2.0%
Missouri.	1.8%
Utah.	1.3%
Arizona	1.2%
Kansas.	1.l%
Others	4.1%

e, Potential of Federal Land. It is estimated that about 43 percent of Alaska's total coal resources (identified and hypothetical) are on Federal land. A significant portion of these resources lies within Naval Petroleum Reserve No. 4,[21] Approximately55 to 60 percent of the combined total coal resources in Colorado, Montana, NewMexico, Utah, North Dakota, South Dakota, Wyoming, and Arizona are on Federal land.[22] This land is principally crop and open rangeland. Much of the Federal coal resource, particularly in Colorado, Montana, North Dakota, and Wyoming, underlies privately owned surface.[23]

2.Copper

Copper is basic to industrial production. Abundant resources of this mineral have been identified, mainly in States with extensive Federal landholdings.

a. **Uses, Substitutes, or Alternatives.** Copper has high electrical and heat conductility, is relatively resistant to corrosion, and has high strength and malleability. Although aluminum can be substituted for copper in power transmission, and steel and plastic can be substituted in construction, copper remains uniquely suited for use in generators and motors and in electronic and general wiring applications.

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[20] P. Averitt, *Coal Resources of the United States, Jan. 1, 1974,* U.S. Geological Survey Bull. 1412 (1975).

[21] Derived from Alaska Division of Geological and Geophysical Surveys, *Coal,* Open File Report 51 (1975).

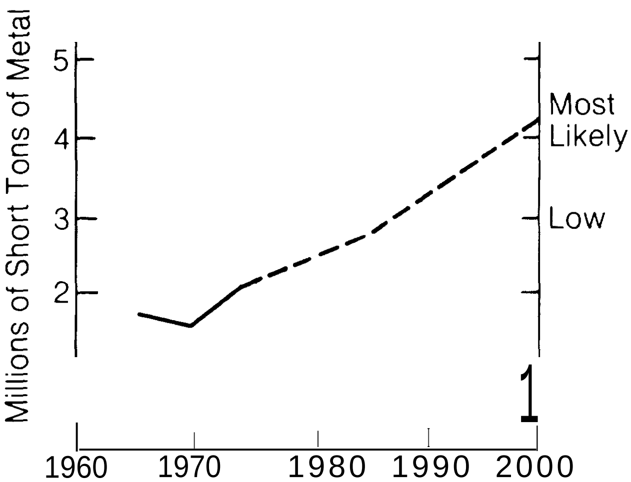
[22] P. Averitt, note 20, at 72.

[23] Cf. U.S. Bureau of Land Management, *Public Land Statistics,* 1975, table 17 (1976).

b. **Demand Outlook.** Historically, U.S. copper consumption has grown at a gradual but steady rate, correlating closely with increases in gross national product and population. Between 1975 and 2000, demand for primary copper is expected to continue to expand as illustrated in figure A-4.

c. **Supply Outlook.** In the past, levels of copper consumption in the United States have been met largely by domestic production, supplemented by supplies from secondary sources (recycled scrap) and imports (see table A-3).

Figure A-4. —Primary Copper Demand Outlook



Forecast Assumptions

High: Heavy reliance on coal and uranium for power generation; increased solar heating; underground power distribution systems.

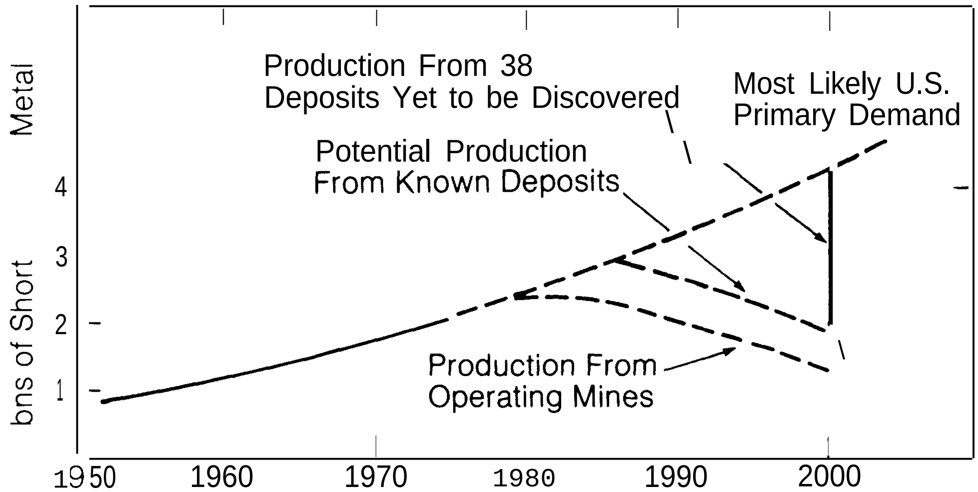
Low: Replacement of copper with aluminum; introduction of advanced power generation systems not requiring use of generators; use of cryogenic techniques in power transmission.

Table A-3.—Copper Supply
(Thousands of Short Tons)

	1965	1970	1974
Domestic U.S. Mine Production	1,336	1,521	1,421
Copper from Secondary Sources (Recycled Scrap)	513	504	483
Government Stockpile Releases	120	—	252
Minus Exports (Refined)	(325)	(221)	(127)
Plus Imports (Mainly Peru, Chile, South Africa)	513	376	548
Industry Stocks, January 1	467	541	456
TOTAL Copper Supply	2,624	2,721	3,033

Taking into account the depletion rate of reserves, the following will be required in order to reach most likely future demand levels if reliance is placed solely on production from known domestic reserves: (i) development of the equivalent of 14 new deposits (each producing 50,000 tons of copper per year) by 1985, and (ii) development of 44 such deposits by 2000 (see figure A-5 and table A-4). Within the latter group, 38 deposits have yet to be identified. Some of these 38 may be developed from currently known but subeconomic resources. Discovery of the remainder depends on the success of mineral exploration efforts within the next 10 to 15 years.

Figure A-5. —Primary Copper Supply Outlook



Source D P Cox, U S Geological Survey, Written communication, 1975

Table A-4.— Resources of Primary Copper

Identified:	90 million tons of reserves in 37 operating mines, plus 30 million tons in 20 known deposits.
Hypothetical and Speculative:	220 million tons in undiscovered deposits.

Sources D P Cox, U S. Geological Survey, written communication, 1975; USGS Prof. Paper 820,

d. **Geographic Distribution of Resources.** Copper reserves are located mainly in Arizona and New Mexico. The present distribution by groups of States is as follows:[24]

Arizona New Mexico	80%
Utah Nevada	9%
Montana Michigan Other	11%

Future discoveries will probably be concentrated in those five Western States shown above, with Arizona offering the greatest potential. New discoveries of important deposits in Alaska, Washington, Idaho, and Wyoming suggest that these States may contain large resources as well.

[24]D. P. Cox, U.S. Geological Survey, written communication, 1975.

e. Potential of Federal Land. Analysis of Federal land distribution and known areas of mineral potential was inconclusive because of insufficient resource data. Most known deposits lie in States with large Federal landownership. The deposits tend to be in enclaves of former Federal land, which passed into private ownership on the discovery of valuable mineral deposits under the Mining Law of 1872. Furthermore, they tend to be clustered in old established mining districts. The areas having the greatest potential for new discoveries lie in unpopulated regions in the West. Much of this land is federally owned.

3. Fluorspar (Fluorine)

This industrial mineral is important to the aluminum, iron and steel, chemical, and glass industries. Fluorspar resources are found largely in Kentucky, Illinois, Tennessee, the Western States, and Alaska. Fluorspar resources in the Western States are mostly on Federal land.

a. **Uses, Substitutes, or Alternatives.** Fluorspar is the main source of fluorine, which is used in the electrolytic process for making aluminum. Fluorine is used as a flux in making iron and steel and is also a basic element in the production of certain chemicals (fluorocarbon compounds), ceramics, and glass. There is no substitute, practically speaking, for fluorspar in its most important uses.

b. **Demand Outlook.** U.S. demand for fluorine has approximately doubled between 1963 and 1973. It is expected to continue to increase, although at a much lower rate of growth. The precise rate of growth will be related to technological change in the chemical industry and the use of direct reduction methods in steelmaking. Figure A-6 illustrates the projected demand for fluorine.

c. **Supply Outlook.** Over the past 10 years, annual domestic mine production of fluorspar has remained relatively constant. Consequently, growth in fluorine consumption has been largely met by increased imports (see table A-5).

Even with a significant increase in the supply of fluorine obtained as a byproduct of phosphate production,[25] there does not appear to be sufficient domestic fluorspar resources to satisfy forecasted demand (see figure A-7 and table A-6). A similar supply problem may also develop worldwide before the year 2000.

d. **Geographic Distribution of Resources.** Identified significant fluorspar resources are in Illinois, Kentucky, Texas, Tennessee, New Mexico, Nevada, Utah, Colorado, Idaho, Montana, and Alaska. Approximately 20 percent of the U.S. total resources is in the Western States.[26]

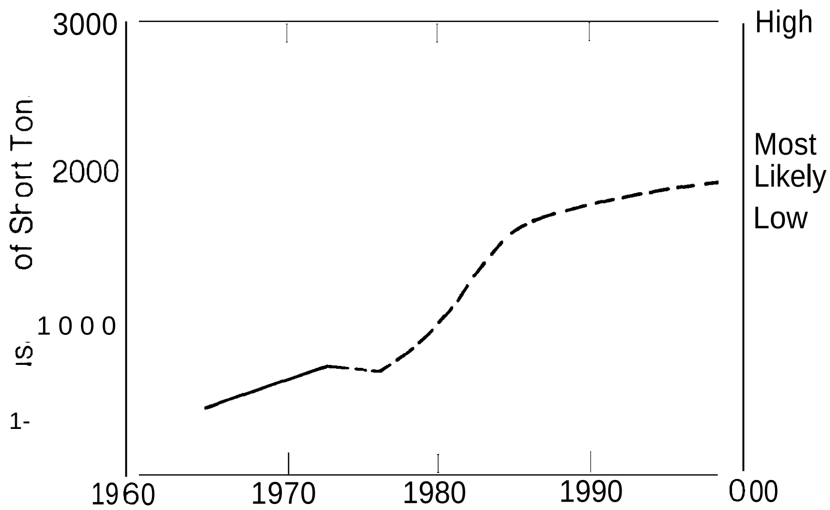
e. **Potential of Federal Land.** It was not possible to estimate fluorspar resources on Federal land because of insufficient resource data.

Although the largest U.S. fluorspar resources occur in Illinois, Kentucky, and Tennessee, significant potential for new discoveries exists in the Federal land of the Western States and Alaska. Map studies indicate that identified resources are located

[25] High-grade phosphate rock contains as much as 4 percent fluorine (see "Fluorine" in the USGS Prof. Paper 820).

[26] Ralph Van Alstine, U.S. Geological Survey, written communication, 1975.

Figure A-6.— Fluorine Demand Outlook



Forecast Assumptions

High: Present chemical uses continue to grow and new fluorocarbon products are developed; high growth in use of basic oxygen furnace as reduction method in steelmaking.

Low: Increased replacement of fluorocarbon compounds by other chemicals; high growth in use of direct reduction methods in steelmaking; salvage of some fluorine used in aluminum production.

Table A-5.— Flourine Supply
(Thousands of Short Tons of Fluorine)

	1965	1970	1974
Domestic U.S. Mine Production of Fluorspar	109	121	91
By-Product of Phosphate	—	—	46
Government Stockpile Releases	—	48	—
Minus Exports	(4)	(7)	(3)
Plus Imports (Primarily from Mexico)	310	501	601
Industry Stocks, January 1	174	131	148
TOTAL Fluorine Supply	589	794	883

Figure A-7.—Fluorine Supply Outlook

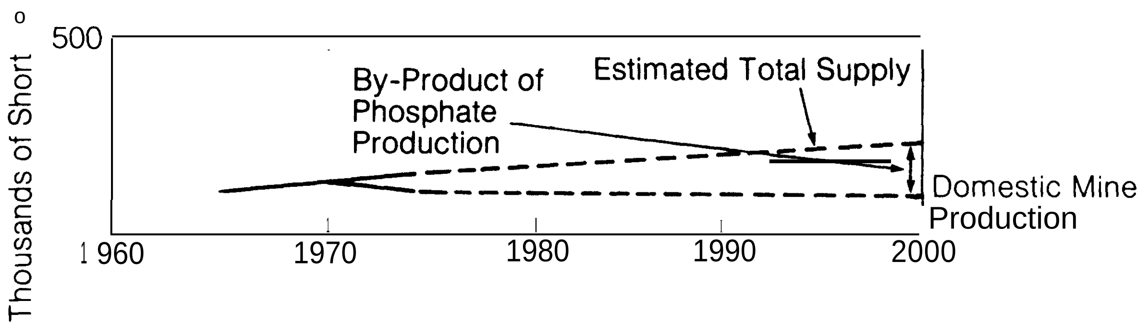


Table A-6.—Resources of Fluorspar

Identified:	25 million tons of fluorspar ore (approximately 8.3 million tons of processed fluorspar recoverable with an average fluorine content of approximately 45 percent).
Hypothetical and Speculative:	45 million tons of hypothetical fluorspar resources (approximately 15 million tons of processed fluorspar recoverable with an average fluorine content of approximately 45 percent).

mainly in national forest land along the Continental Divide, as well as in Texas, New Mexico, Colorado, Idaho, and Montana. In addition, all of the resources in California and Nevada are on Federal land, with one district in each State being within a national forest, Deposits in Alaska, Arizona, Utah, and Washington occur mainly on Federal land, and about one-third of these deposits lies within national forests.

4. Geothermal Energy

As stated in the Geothermal Steam Act "geothermal steam and associated geothermal resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water, and hot brines; (ii) steam and other gases, hot water, and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any byproduct derived from them. This section, however, will deal only with the heat, or heat transfer, aspects of resources of geothermal energy.

Geothermal energy contributes only a very small part of domestic energy supply; however, estimates of resources on Federal land indicate that it could provide an important source of energy in the future.

a. **Uses, Substitutes, or Alternatives.** The principal use of geothermal energy in the United States is in the generation of electricity. At present, only one commercial generating project uses geothermal energy. Located at the Geysers, Calif., it provided approximately one-tenth of one percent of the Nation's total electricity in 1974. [27] Geothermal energy is also used directly in the heating and cooling of buildings, in the heating of hothouses and soil for agricultural purposes, and in product processing. Production of freshwater by self-desalination of geothermal fluids has been proposed for the Imperial Valley of southern California, If this proves to be feasible the geothermal waters of the Imperial Valley may prove to be a significant source of additional freshwater supply for the Southwest United States.

Substitutes for geothermal energy are the fossil fuels and uranium, as well as solar and other nonmineral energy sources.

b. **Demand Outlook.** The potential importance of geothermal energy depends both on the extent of the resource and the development of technologies for harnessing it.

Except for localized heating applications, the primary use for geothermal energy is generating electricity. Because of rapid heat losses during transportation, geothermal fluids must ordinarily be utilized within about a mile of their extraction point. Since most areas with geothermal potential are located far from industrial centers, geothermal generating plants would probably be sited at some distance from such centers, It has been estimated that in order to justify the expense of building transmission lines, a geothermal reservoir must have the ability to support a geothermal complex of at least 200 megawatts (MW). Future demand, therefore, will depend somewhat on the size of discoveries. However, there has been very little experience in geothermal exploration and evaluation, so that any estimation of future demand must be based on the tenuous grounds of overall forecasts of future energy requirements and the potential promise of geothermal energy. The U.S. Bureau of Mines has estimated that installed geothermal electrical-generating capacity might reach 3,000 MW by 1985 and 10,000 MW by the year 2000. The installed capacity in 1976 amounted to only 500 MW, all at the Geysers in California.

c. **Supply Outlook.** Serious environmental and operating problems could limit the potential of geothermal energy. Some of the problems are land sinking because of withdrawal of large amounts of hot water, destruction of equipment by highly corrosive and harmful compounds, plugging up of equipment by heavily mineral laden brines, and large quantities of waste fluids that must be disposed of without polluting water supplies for normal uses.

Research is being carried out to find ways to cope with the problems and to increase geothermal capacity. The Geysers area is estimated to have an ultimate capacity of about 2,500 MW, five times its present capacity. The Bureau of Mines reports that there are 38 geothermal areas, in seven Western States, which are under lease or exploration. There are near- or medium-term plans to install only about 2,100 MW of additional generating capacity, almost all of which would be at the Geysers.[28] This

[27] U.S. Federal Trade Commission, Bureaus of Competition and Economics, *Report to the Federal Trade Commission on Federal Energy Land Policy: Efficiency, Revenue, and Competition*, Ser. No. 94-28 (92-118), Senate Comm. on Int. & Ins. Affairs, 94th Cong., 2d sess. 687 (Comm. Print 1976).

[28] U.S. Bureau of Mines, *Projects to Expand Fuel Sources in Western States*, Info. Circ. 8719 (1976).

amount added to current capacity falls short of the estimate of 3,000 MW of total installed capacity by 1985 cited above.

The useful heat recoverable from identified geothermal systems with present or near-current technology and with prices at or double present prices exists almost entirely in the hydrothermal convection systems of the Western States and Alaska and in the geopressured zones of the gulf coast. Estimated recoverable electric power from these resources, assuming present and near-current technology, but without regard to cost, is shown in table A-7 (sizable resources in Mt. Lassen and Yellowstone National Parks are not included).

Table A.7—Recoverable Geothermal Resources (Annual Megawatts (MW) for 30 Year Production Plan)

Hydrothermal Convection Systems	
Identified:	11,700 reserves, plus over 15,000 in paramarginal and submarginal resources.
Hypothetical and Speculative:	126,700
Geopressured Zones	
Identified:	19,000 from thermal energy, plus 11,900 in mechanical energy; all onshore.
Hypothetical and Speculative:	Over 250,000 in unassessed parts of the gulf coast (onshore and offshore) and other geopressured environments.

Source U S Geological Survey, Assessment of Geothermal Resources of the United States—19 75, Circle 726, Tables 27 and 28 (Plan 3) (1 975)

d. **Geographic Distribution of Resources.** In general, the average heat content of rocks is considerably higher in the Western United States than in the East. The hydrothermal convection systems in the Western States and Alaska, not including the sizable systems in Mt. Lassen and Yellowstone National Parks, account for 46 percent of the Nation’s recoverable onshore geothermal resources in terms of electric power potential; the geopressured zones of the gulf coast account for the remainder (see table A-7).

The most attractive identified convection systems are those with predicted reservoir temperatures above 1500 C. The approximate distribution of such systems according to heat content is as follows:[29]

California . . . . ., ..., ..., ... 47.6%
Wyoming , ... , ..., ... 33.7%
Nevada 5.4%

[29]U.S. Geological Survey, Assessment of Geothermal Resources of the United States--1975, Circ. 726 (1975).

New Mexico	4.6°/0
Oregon	3.7%
Idaho	3.3%
Utah	0.9%
Alaska	0.4%
Washington	0.3%
Arizona	O.1%

This percentage breakdown includes the geothermal systems in Mt, Lassenand Yellowstone National Parks. The Mt. Lassen system constitutes 3 percent of the California resource above 150°Canal 25 percent of the resource above 200°C(the remaining 75 percent being in the Geysers area). The Yellowstone systems constitute 100 percent of the Wyoming resource above 150°C.

e. Potential of Federal Land. The U.S. Geological Survey has identified more than 100 known geothermal resource areas, encompassing over 3 million acres, on Federal land. Another 98 million acres have been identified as prospectively valuable. At the end of 1975, there were 548 Federal geothermal leases encompassing close to 1 million acres.[30]

The hydrothermal convection geothermal systems, which occur in the western public land States, account for 46 percent of the recoverable geothermal resources of the United States in terms of electric power potential, even excluding the 35 percent (by heat content) of the Nation's hydrothermal convection resources in Mt. Lassen and Yellowstone National Parks (which are closed to mineral development).

One study has reported that approximately 56 percent of the Nation's known geethermal resources is estimated to be on Federal land.[31]

5. Iron Ore[32]

The 'United States is potentially self-sufficient in iron ore. Our iron ore resources, primarily concentrated in the Lake Superior region, appear adequate to meet projected demand. Domestic production capacity is being used to supply only about 70 percent of domestic demand owing to the commercial advantages of using foreign high-grade ores to supplement domestic production. Imports in excess of exports during the past 5 years have averaged 29 percent of total domestic iron ore consumption.

The iron and steel industry is extremely "transportation oriented" with regard both to sources of raw materials and to existing markets for iron and steel products. Locations having adequate water supplies, proximity to markets, and low transportation costs for the three bulk raw materials required for steelmaking—coking coal, iron ore, and limestone—have the greatest economic advantageas sites for ironmaking and steelmaking facilities. These factors have favored the growth of the industry in the eastern and central regions of the Nation, and it is there that the bulk of future growth in demand is expected to occur. The iron and steel industry of the Western States,

[30] U.S. Geological Survey, Conservation Division, *Federal and Indian Lands Oil and Gas Production, Royalty Income, and Related Statistics, Calendar Year 1975*, at 33 (1976).

[31] Federal Trade Commission Report, note 27, at 687.

[32] USGS Prof. Paper 820, supplemented by H. Klemic, U.S. Geological Survey, written communication, 1976.

based principally on domestic ores and scrap metal from the Western States, also has potential for continued growth as demands in that region increase and as additional raw material sources there are developed.

The Western States and Alaska contain about 10 billion tons of identified iron ore resources, but less than 1 billion tons of this amount is considered to be reserves. About 70 percent of the resources are on Federal land. Additional iron ore resources are likely to be discovered in the Western States, but an estimate of their magnitude is not available.

6. Lead

Demand for lead in the United States from 1974 to 2000 is forecast to grow at an average annual rate of 1.6 percent. This anticipated growth rate is based essentially on continued growth in demand for automotive batteries, and on expected growth in demand for batteries for electric-powered vehicles and standby power. Consumption of lead in gasoline additives is expected to decline about 60 percent from the 1973 level. Domestic mine production is expected to increase steadily to maintain the level of self-sufficiency achieved in recent years. Ore reserves are more than adequate to meet cumulative lead requirements to the year 2000.

About 86 percent of total identified domestic lead resources are located in the Central and Eastern States; specifically, the larger resources are in southeast Missouri, located on and adjacent to the Mark Twain National Forest. Several areas in the forest, not covering the identified resources, are believed to have good potential. Approximately 14 percent of the U.S. lead resources are in the Rocky Mountain, Northwestern, and Western States. The largest western lead resources are in the Coeur d'Alene district of the Rocky Mountains and the Great Basin.

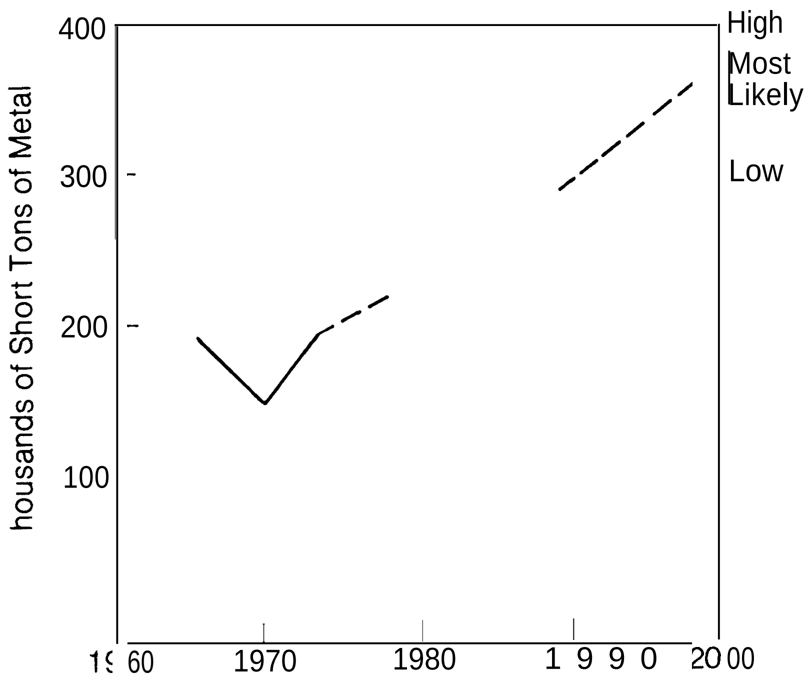
7. Nickel

Nickel is an industrial metal important to many industries. Almost all new potential nickel sites are on Federal land.

a. **Uses, Substitutes, or Alternatives.** Nickel's importance rests in its ability to impart resistance to corrosion and to improve mechanical and high-temperature properties of other metals, The primary use of nickel is as an alloy in materials used to contain or transport corrosive chemicals. Although substitute and alternative materials are available for nickel in almost all of its uses, the products derived from these other materials are either more costly or of lower quality in terms of chemical and physical resistance to corrosion than the equivalent nickel-based products. Moreover, most of the best metallic substitutes—namely, chromium, manganese, cobalt, and platinum-are not produced in any appreciable quantity in the United States.

b. **Demand Outlook.** Although primary consumption of nickel has fluctuated, a steady rate of growth is forecasted (see figure A-8).

Figure A-8. Primary Nickel Demand Outlook



Forecast Assumptions

High: Expansion of developing technologies requiring nickel, such as oil shale processing: coal gasification, and desalinization industries; increased mechanization in industries and increased demand for metals of superior quality.

Low: Increased substitution of plastic and titanium for coatings in the chemical, petroleum and superalloy manufacturing industries.

c. Supply Outlook. In the past, levels of nickel consumption in the United States have been met largely by imports, supplemented significantly by secondary (recycled) nickel, and to a lesser extent by domestic production (see table A-8).

It is anticipated that imports will assume a much more significant role in the future. In the United States there is only one operating mine—at Riddle, Ore. This deposit is expected to be depleted in 15 years. With the closing of the Riddle operation, one of three supply scenarios may develop over the next 25 years, as illustrated in

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figure A-9. In scenario I, the most likely future supply situation assumes the development of one new mine in Minnesota, with an average annual production of 25,000 tons of nickel. Scenario II, the low range of the forecast, assumes that no new mines would open and the United States would become 100-percent dependent on imports for primary nickel supplies. Scenario III, the high side of the supply forecast, assumes development of six new mines in Minnesota (within the next 10 to 15 years) each with a capacity of 25,000 tons of nickel per year. The implication of this third scenario is that imports could be reduced to approximately one-half the scenario II level.

Estimated domestic resources of primary nickel are shown in table A-9.

Table A-8.—Nickel Supply
(Thousands of Short Tons)

	1965	1970	1974
Domestic U.S. Mine Production	14	16	14
Nickel from Secondary Sources (Recycled Scrap)	51	49	64
Government Stockpile Releases	16	2	5
Minus Export	(6)	(6)	(4)
Plus Imports (Mainly from Canada)	163	156	221
Industry Stocks, January 1	17	32	71
TOTAL Nickel Supply	255	249	371

Table A-9.—Resources of Primary Nickel

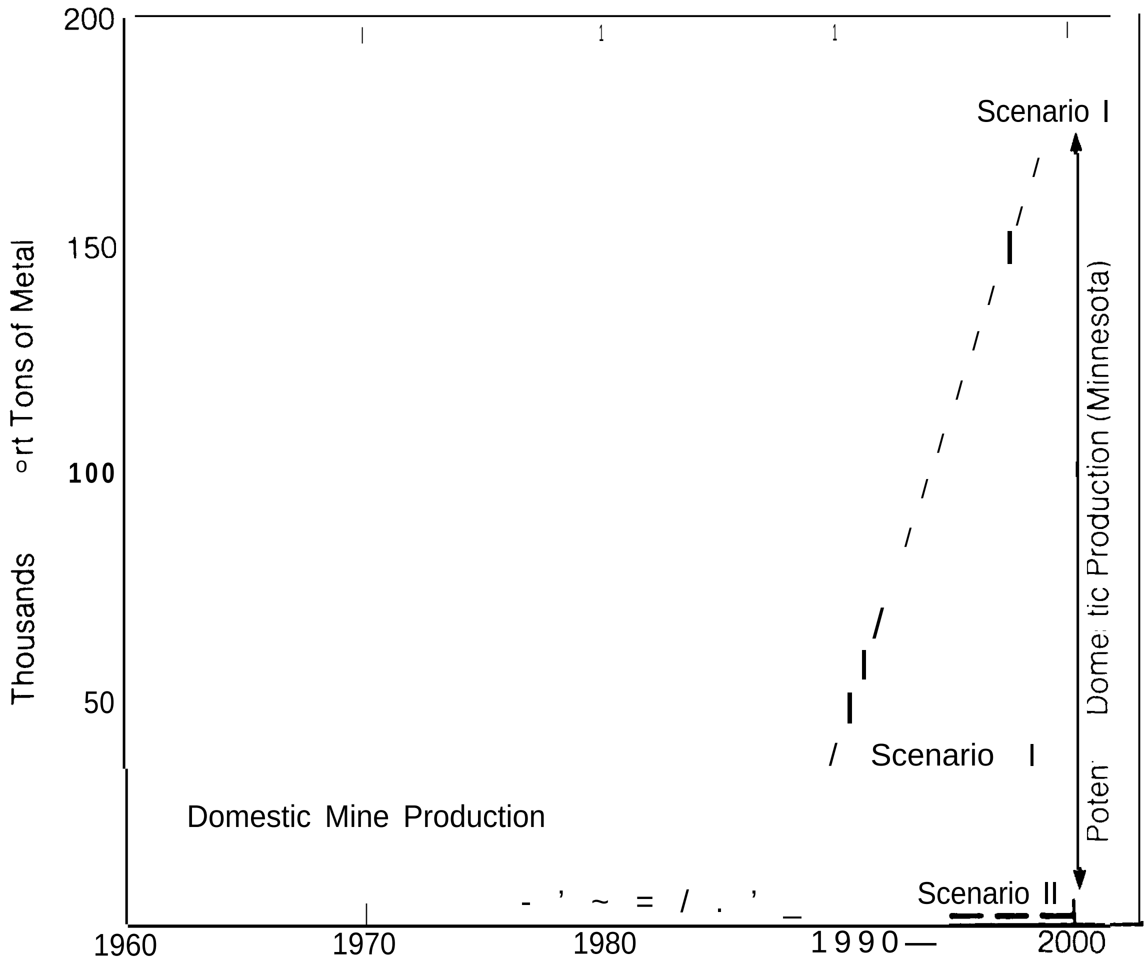
Identified:	2.6 to 14.7 billion tons of nickel-sulfide ore (5 to 20 million tons of contained nickel), plus 100 million tons of nickel-laterite ore (0.76 million tons of contained nickel). The estimated nickel-sulfide resources are tentative modifications of the data in USGS Prof. Paper 820 based on the Bonnichsen data cited in Figure A.9.
Hypothetical and Speculative:	Not given in sources used.

d. **Geographic Distribution of Resources.** Identified nickel resources in the United States (nickel sulfide and nickel laterite deposits] in terms of contained nickel are distributed as follows:

Minnesota	88.0%
Alaska	3.6%
California and part of Oregon	2.7%
Montana	2.4%
Oregon (Nickel Mountain)	1.0%
Washington	1.0%
Maine	0.6%
Other	0.7%

Minnesota is the most promising area for exploration. The estimated size of this State's nickel resources is enormous. Alaska, Oregon, California, and Washington also have potentially significant nickel resources.

Figure A-9 .—Primary Nickel Supply Outlook



Scenario I (Most Likely): One new domestic mine with 25,000 tons of annual production.

Scenario 11: No new domestic mines.

Scenario Ill: Six new domestic mines, each with 25,000 tons of annual production.

Source: Scenarios independently developed, based on data in U.S. Bureau of Mines, *Mineral Facts and Problems, 1975 Edition* (1976), and B. Bonnichsen, *Copper and Nickel Resources in the Duluth Complex, Northern Minessota*, Minnesota Geological Survey Info. Circ. 10 (1974).

e. **Potential of Federal Land.** All of the identified resources in Minnesota are in the Superior National Forest. As similar geologic structure extends northward, additional resources of perhaps a comparable magnitude may fall within the Boundary Waters Canoe Area. All of Alaska's identified resources are on Federal land. The largest deposit is in the Glacier Bay National Monument. The other two major deposits are in the Tongass National Forest. About 85 percent of the identified deposits of nickel in California and Oregon (other than Nickel Mountain) are located mostly in national forest areas, including the Trinity, Cleveland, and Siskiyou National Forests.

8. Petroleum and Natural Gas

Alaska, the Pacific Coastal States, the western and northern Rocky Mountains, west Texas, and eastern New Mexico contain almost two-thirds of identified U.S. onshore crude oil resources and approximately two-fifths of identified U.S. natural gas resources. Alaska alone contains about 29 percent of identified U.S. onshore crude oil resources and about 14 percent of identified natural gas. About half of Alaska's undiscovered potential crude oil and natural gas resources are estimated to be on Federal land. Approximately 28 and 31 percent of the identified crude oil and natural gas resources, respectively, in the 11 Western States are on Federal land.

a. **Uses, Substitutes, or Alternatives.** Petroleum and natural gas are essential to the Nation's energy supply. Historically, natural gas has been a cheaper fuel than oil. Petroleum is vital to the transportation sector and petrochemical industry.

Synthetic liquid hydrocarbons (syncrude) and synthetic natural gas (substitute natural gas or SNG) may one day be substituted for petroleum and natural gas. Several complex pilot processes have been developed to produce syncrude and SNG from coal. Syncrude and syngas may also be developed from oil shale. However, the costs for all these processes at present and the time required to develop a commercial-sized industry seem to prohibit any major contribution of synthetic substitutes over the next 25 years.

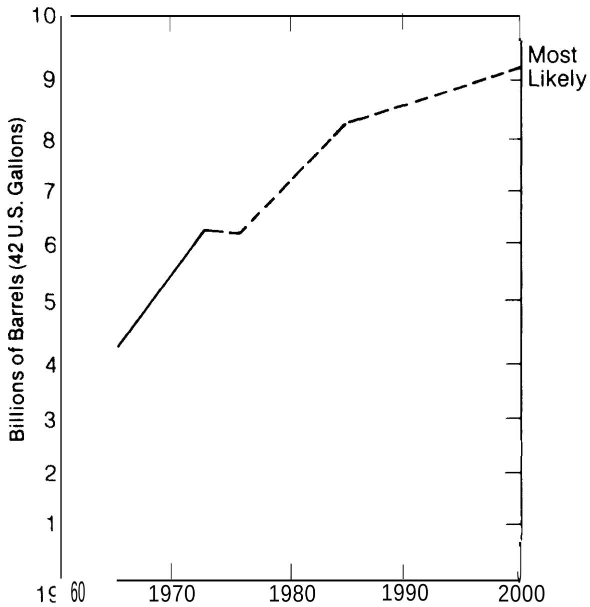
Coal can substitute for both petroleum and natural gas in the production of steam for generation of electricity and heating, Nuclear and solar energy are also alternative sources of power generation. However, there is still considerable use of natural gas and oil to generate electricity and to heat large building complexes. Coal chemicals can also serve as substitutes for a variety of petrochemicals.

b. **Demand Outlook.** Historically, the demand for petroleum and natural gas has steadily increased, with the demand for natural gas increasing less rapidly than it had in the past. In the years since 1973, consumption has been a function of supply availability as well as the rate of substitution of coal and uranium as sources of energy. This relationship is expected to continue in the future (see figures A-10 and A-1 1).

The relative share of petroleum and natural gas in the total energy picture is expected to decline. Petroleum supplied 45.9 percent of total U.S. energy in 1972. This share is forecasted to decrease to about 43 percent by 1985 and about 32 percent by the year 2000. Similarly, natural gas, which supplied 32 percent of total U.S. energy in 1972, is expected to supply approximately 20 and 17 percent of the total energy in 1985 and 2000, respectively,

c. Supply Outlook (Onshore and Offshore). Cumulative petroleum demand for the period 1974 to 2000 could well be approximately 200 billion barrels, if stringent energy conservation is not followed. Total onshore and offshore domestic reserves plus

Figure A-1 O. —Petroleum Demand Outlook

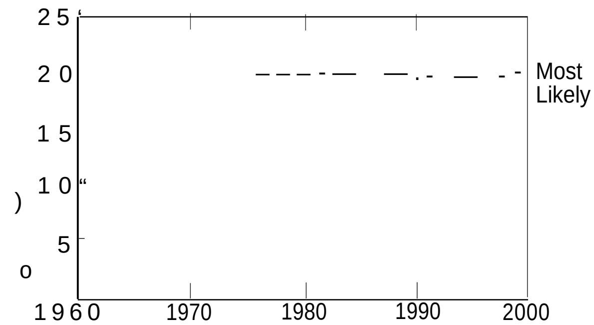


Forecast Assumptions

Most Likely: Continued growth in GNP averaging approximately 3.5 percent per year; continued slow growth in population averaging less than one percent per year; supply limitations explicitly taken into consideration; 1974 prices; more efficient use of energy by industry.

NOTE: According to information provided to OTA in March 1979 by the Department of Energy (DOE), the DOE Base Case Projections show approximately 7 billion barrels of petroleum consumption in the year 2000.

Figure A-1 1. —Natural Gas Demand Outlook



Forecast Assumptions

Most Likely: Same as in Figure A-10.

NOTE: According to information provided to OTA in March 1979 by the Department of Energy (DOE), the DOE Base Case Projections show 20 trillion and 21 trillion standard cubic feet of natural gas consumption in the years 1985 and 2000 respectively.

undiscovered recoverable resources are estimated to be on the order of 135 billion to 223 billion barrels of petroleum (see table A-10).

It is unlikely that domestic petroleum demand can be met from domestic supplies during the forecast period, even if strong energy conservation measures are implemented and the rate of finding and developing reserves is increased. The rate of exploration and development has not been sufficient in recent years to maintain domestic production even at the level achieved in 1970 when about 23 percent of consumption was filled by imports (see table A-11).

Annual production of natural gas is forecasted to approximately meet the projected annual demand, if the rate of finding and developing reserves can be sustained at pre-1970 levels. The demand forecast, which reflects the expected supply of natural gas, estimates cumulative demand for the period 1974 to 2000 to be approximately 575

Table A-1 O.—Recoverable Resources of Petroleum

Identified:	74 billion barrels of reserves (56 onshore crude oil, 6 offshore crude oil and 12 onshore and offshore natural gas liquids).
Hypothetical and Speculative:	61-149 billion barrels of undiscovered recoverable resources (37-81 onshore crude oil, 10-49 offshore crude oil and 11-22 onshore and offshore natural gas liquids).

Source U S Geological Survey, Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States, Circ 725 (1975) The estimated ranges for undiscovered resources were derived by Monte Carlo simulation techniques and are not additive The low end of each range is estimated to be 95 percent certain, the high end is estimated to be only 5 percent certain Ibid at 26-27

Table All .—Petroleum Supply
(Billions of Barrels (42 U.S. Gallon))
(Onshore and Offshore)

	1965	1970	1974
Domestic Production of Crude Oil	2.8	3.5	3.2
Domestic Production of Natural Gas Liquids	0.4	0.6	0.6
Processing Gain	0.1	0.1	0.2
Minus Exports	(0.1)	(0.1)	(0.1)
Plus Imports	0.9	1.2	2.2
Industry Stocks, January 1	0.8	1.0	1.0
TOTAL Petroleum Supply	4.9	6.3	7.1

trillion cubic feet. Such a demand would require not only all of the identified U.S. recoverable resources, but also a large amount of the estimated undiscovered natural gas resources (see tables A-I2 and A-13).

Table A-1 2. —Recoverable Resources of Natural Gas

Identified:	439 trillion cubic feet of reserves (335 onshore and 104 offshore).
Hypothetical and Speculative:	322-655 trillion cubic feet of undiscovered recoverable resources (264-506 onshore and 42-181 offshore).

Source Same as table A-1O

Table A-l3 .—Natural Gas Supply
(Trillions of Standard Cubic Feet)
(Onshore and Offshore)

	1965	1970	1974
U.S. Domestic Production (Dry)	16.0	21.9	21.6
Transfer Out, Extraction Loss	(0.8)	(0.9)	(0.9)
Minus Exports	—	(0.1)	(0.1)
Plus Imports	0.5	0.8	1.0
Industry Stocks, January 1	2.3	2.9	3.9
TOTAL Natural Gas Supply	18.0	24.6	25.5

d. **Geographic Distribution of Resources.**[33]

(1) Petroleum. About 63 percent of the identified onshore crude oil resources in the United States are in four western regions and Alaska; the distribution of these resources is as follows:

Alaska . . . . , ... 28.8%
West Texas and eastern New Mexico ... , ... 19.1%
Pacific Coastal States . . . . , ... , . , ... , ... , ., . 7.3%
Northern Rocky Mountains. . . . . , ., . . . 5.2%
Western Rocky Mountains ... , , ... 2.2%
Other . . . . , ... 37.4%

[33]U.S. Geological Survey, *Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the United States*, Circ. 725 (1975).

Alaska and these four western regions also have potential for additional onshore discoveries of crude oil reserves; these areas contain an estimated 44 percent of total U.S. undiscovered recoverable crude oil resources.

(2) Natural Gas. Alaska and the Western States are estimated to contain about 38 percent of total identified U.S. onshore natural gas resources. The distribution is as follows:

West Texas and eastern New Mexico	14.3 %
Alaska	13.8%
Western Rocky Mountains	36%
Northern Rocky Mountains	3.6%
Pacific Coastal States	2.6%
Other	62.1 %

The "Other" category for both petroleum and natural gas includes the western Gulf Basin, midcontinent Michigan Basin, eastern Interior, Appalachians, eastern Gulf, and Atlantic Coastal Plain.

e. Potential of Federal Land. Only rough estimates of resources of petroleum and natural gas on Federal land were possible because of the quality of resource information available.

Less than 1 percent of identified Alaskan onshore crude oil and natural gas resources are on Federal land, principally Naval Petroleum Reserve No. 4. An estimated 55 percent of the undiscovered onshore resources of crude oil in Alaska might be present on all categories of Federal land including Petroleum Reserve No. 4, which has the highest potential of the Federal land in Alaska. An estimated 50 percent of Alaska's undiscovered onshore gas resources are on Federal land, including Naval Petroleum Reserve No. 4.

Of the onshore petroleum and natural gas resources in the 11 Western States, an estimated 28 percent of the identified petroleum, 31 percent of the identified natural gas, 42 percent of the undiscovered petroleum, and 39 percent of the undiscovered natural gas are or might be on Federal land, primarily rangeland and national forest land.

In addition to the Nation's domestic onshore resources of liquid petroleum, there is a very large oil shale deposit located in the Green River Basin of the Rocky Mountains, a relatively concentrated area of approximately 25,000 square miles (about 16 million acres) extending over parts of Colorado, Utah, and Wyoming. Of this 25,000 square miles, 17,000 square miles are believed to contain about 600 billion barrels of synthetic crude oil in high-grade oil shale and perhaps 1,200 billion barrels of oil in lower grade oil shale. It is estimated that 72 percent of the oil shale land is under Federal control. Eighty percent of this federally controlled land contains high-grade oil shale deposits. The likelihood of oil shale production depends on the price of substitutes (imported and domestically produced crude oil), developments in oil shale technology, the availability of water, and the solution of environmental problems (especially air quality and disposition of the spent oil shale).[34]

[34] Federal Trade Commission Report, note 27, at 469-471.

9. Phosphate Rock

As a source of phosphorus, phosphate rock is essential to the fertilizer industry. There are sufficient domestic resources to meet U.S. demand at least for the next 25 years. About half of the phosphate resources are in the Western States and in Alaska, in areas having a relatively high proportion of Federal land.

a. **Uses, Substitutes, or Alternatives.** The principal use of phosphate rock is in the manufacture of fertilizers. There is no substitute for phosphorus as a plant nutrient. Phosphates are also used in the manufacture of detergents, animal feed supplement, and insecticides and in the electroplating and polishing of metals. There may be some substitutions for these nonfertilizer end uses. The rate and amount of substitution, however, will vary as a function of price, stability of supplies, and environmental considerations.

b. **Demand Outlook.** The consumption of phosphate rock has grown at a relatively strong rate in the past, closely correlated with increases in population and living standards (per capita food consumption). In the future, demand will depend on the same economic factors, as well as on the adequacy of technology for the control of detergent phosphates in waste water.

The domestic demand outlook for phosphate rock is shown in figure A-12. In addition, it is estimated that the United States will continue to export phosphate fertilizer in a proportion similar to that prevailing today (see table A-14).

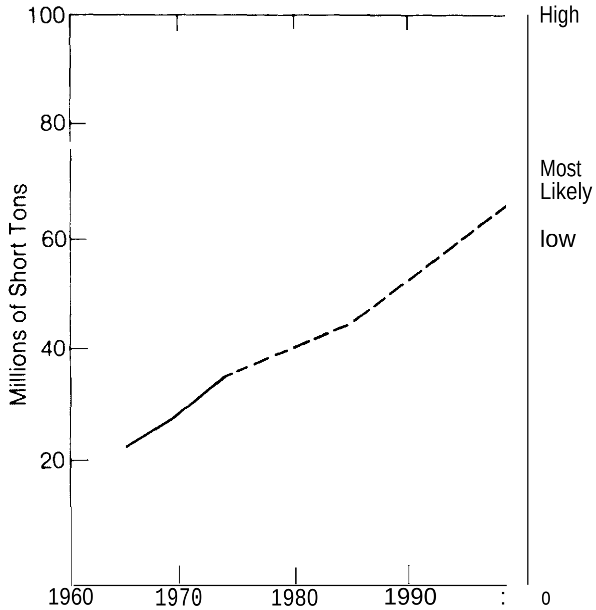
c. Supply Outlook, Over the past decade, domestic supplies of phosphate rock have steadily increased to meet growing demand (see table A-14). The small volume of imports consists principally of low fluorine phosphate, used as an animal feed supplement, from Aruba and Curacao.

Over the next 25 years, U.S. phosphate rock resources (see table A-15) will probably be sufficient to meet the U.S. demand. However, whether U.S. mines will produce a sufficient supply is a question of price sensitivity and environmental restrictions on mining.

Morocco currently contains the bulk of the world's resources of high-grade, easily minable phosphate rock and has expanded its control to include some of the resources of the Spanish Sahara. Consequently, Morocco has the potential ability to exert influence on world prices, particularly after 1990. Therefore, whether or not the United States will produce all of its own phosphate needs will depend somewhat on the competitiveness of Moroccan phosphate prices.

The "most likely" forecast for domestic phosphate rock production (see figure A-13) indicates a steady growth in domestic mine output over the next 10 years, with a gradual leveling off during the remainder of the decade, as domestic supply is replaced by increased imports. However, issues relating to potential damage to the environment from phosphate mining may restrict phosphate production, particularly in the Southern Atlantic Coast States.

Figure A-1 2 .–Phosphate Rock Demand Outlook



Forecast Assumptions

High: High growth rate in population and food requirements.

Low: Slower rate of growth in population and food requirements.

Table A.14.– Phosphate Rock Supply (Thousands of Short Tons)

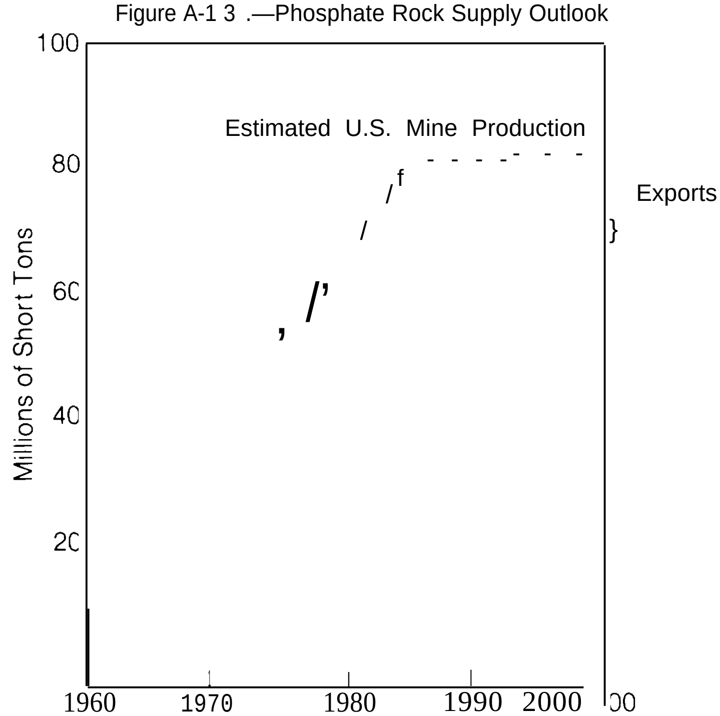
	1965	1970	1974
Domestic U.S. Mine Production	29,482	38,739	45,686
Minus Exports	(7,323)	(11,738)	(13,897)
Plus Imports	148	136	182
Industry Stocks, January 1	6,123	13,697	7,595
TOTAL Phosphate Supply	28,430	40,834	39,566

Table A-1 5 .—Resources of Phosphate Rock

Identified	2.9 billion metric tons of reserves, plus 10.5 billion metric tons of additional identified resources.
Hypothetical and Speculative:	25.1 billion metric tons of hypothetical resources.

Sources. USGS Prof. Paper 820, supplemented by U S. Geological Survey, Phosphate Resources in Southeastern Idaho (1975), and J B Cathcart, U S Geological Survey, written and oral communications, 1975

Figure A-1 3 .—Phosphate Rock Supply Outlook



d. **Geographic Distribution of Resources.** Identified phosphate rock resources are divided almost equally between the Southeastern and Western States. Southeastern Idaho contains about 35 percent of U.S. reserves.

The distribution of identified U.S. phosphate rock resources by area is as follows:

Idaho Montana Utah Wyoming }	57.1 0/0
Florida Georgia North Carolina South Carolina I	41 .9%
Tennessee Kentucky Alabama 1	1.0%

e. Potential of Federal Land. Quantitative estimates of phosphate resources located on Federal land are not available. However, map studies indicate that all of the existing mines and 25 percent of the outcrop areas in Utah are on Federal land. About 50 percent of the outcrop areas in Montana, Wyoming, and Idaho are also on Federal land, Portions of these areas are in the Caribou National Forest and possibly other national forests with sites under study for proposed wilderness areas. Large phosphate resources (perhaps as much as 1 billion tons) are estimated to be present in the Osceola National Forest in Florida, but due to environmental concerns there is considerable resistance to the development of these resources.

A large resource of phosphate rock, estimated to be about 1 billion metric tons [hypothetical resources category), is believed to be present in Alaska. Of the phosphate-bearing areas in Alaska, it is estimated that 35 percent are on national forest land, 30 percent are within the Arctic National Wildlife Refuge, and 15 percent are within proposed additions to the national park, wildlife refuge, and forest systems.

10. Potash

Potash is the common term used to describe potassium compounds. It is frequently used to mean the equivalent potassium oxide content of those compounds. Potash is an essential source of potassium for the fertilizer industry. An estimated 47 percent of total potash resources are located on Federal land.

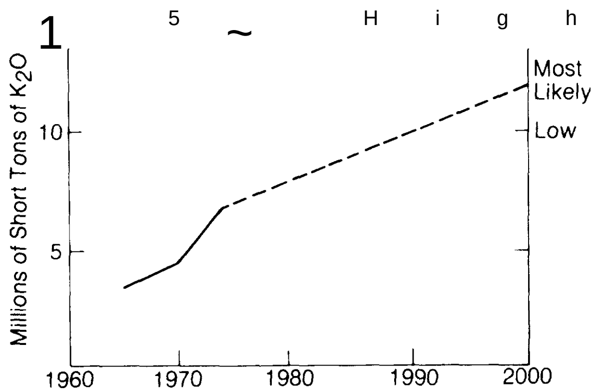
a. **Uses, Substitutes, or Alternatives.** Potassium is one of the three major nutrients essential to plant growth, and there is no alternative to the use of potash as a fertilizer. It is possible to substitute some sodium compounds for potassium compounds in certain chemical applications. Such substitutions, however, are rarely necessary because the supply of potassium is more than adequate. No increased substitution of other materials for potassium is expected.

b. **Demand Outlook.** Demand for potash has increased steadily over the past 10 years as domestic fertilizer use (expressed in pounds of potash per capita] has increased. This trend is expected to continue, with the variation in the forecast range depending upon growth in gross national product, conversion of poorer quality soils to agricultural use, and substitution and technologic change within the chemical industries (see figure A-14).

c. Supply Outlook. There are enough recoverable domestic potash resources to enable the United States to be self-sufficient over the forecast period (see table A-16).

Canada (specifically, the Province of Saskatchewan, which is the source of all Canadian potash) supplies a very large part of the total potash consumed in the United States because of the price competitiveness of that country's producers (see table A-17), Recent actions by the Provincial Government of Saskatchewan suggest that the province intends to seek control of its potash industry through the purchase of some or all of the potash mines there. Legislation was introduced in November 1975 to allow the provincial government to expropriate the property of any company with which it could not negotiate a purchase agreement.[35] However, it is too early to assess the impact of this development.

Figure A-14. —Potash Demand Outlook



Forecast Assumptions

High: Increased fertilization of pasture land; increased use of potash in various forms for cooling uranium fuel elements, driving turbines and abating air pollution.

Low: Farm use and GNP do not grow as expected; sodium chemicals substituted for potassium chemicals.

Table A-1 6 .—Resources of Potash

Identified:	450 million tons in "known reserves, " plus 569 million tons in "inferred reserves. "
Hypothetical and Speculative:	Not given in source used.

Source U S Bureau of Mines, the United States Position and Outlook in Potash, info Circ. 8487 (1970)

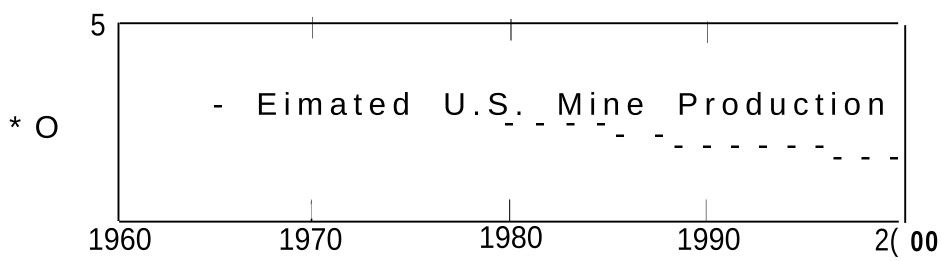
Table A-1 7.—Potash Supply (Thousands of Short Tons of K_2O)

	1965	1970	1974
Domestic U.S. Mine Production	3,140	2,729	2,552
Minus Exports	(648)	(544)	(787)
Plus Imports (Mainly from Canada)	1,108	2,605	4,326
Industry Stocks, January 1	295	392	206
TOTAL Potash Supply	3,895	5,182	6,297

[35] *Wall Street Journal*, Dec. 4, 1975, at 27.

The supply outlook for domestic potash is shown in figure A-15.

Figure A-1 5 .—Potash Supply Outlook



SOURCES Mineral Facts and Problems 1975. supplemented by W F Keyes U S Bureau of Mines written and oral communications 1976

d. **Geographic Distribution of Resources.**[36] Most identified potash resources are in the Western States, principally in New Mexico, Utah, and Colorado, The distribution of "known reserves" is as follows:

Utah, Colorado	76.7%
New Mexico	18.9%
California	4.4%

The distribution of "inferred reserves" is as follows:

New Mexico	70.3%
Utah, Colorado	29.7%

e. Potential of Federal Land. Approximately 47 percent of the "known" potash reserves are on Federal land, some of which are located partially in the Manti-La Sal National Forest.

Of the "inferred" potash reserves, approximately 40 percent are on unreserved Federal land, principally grazing land, 15 percent on military land, and a small percent in national parks,

11. Silver

Silver is an industrial metal that is important to a wide range of industries. Almost all of the silver resources in the United States are in eight Western States and Alaska, all of which have a high degree of Federal landownership.

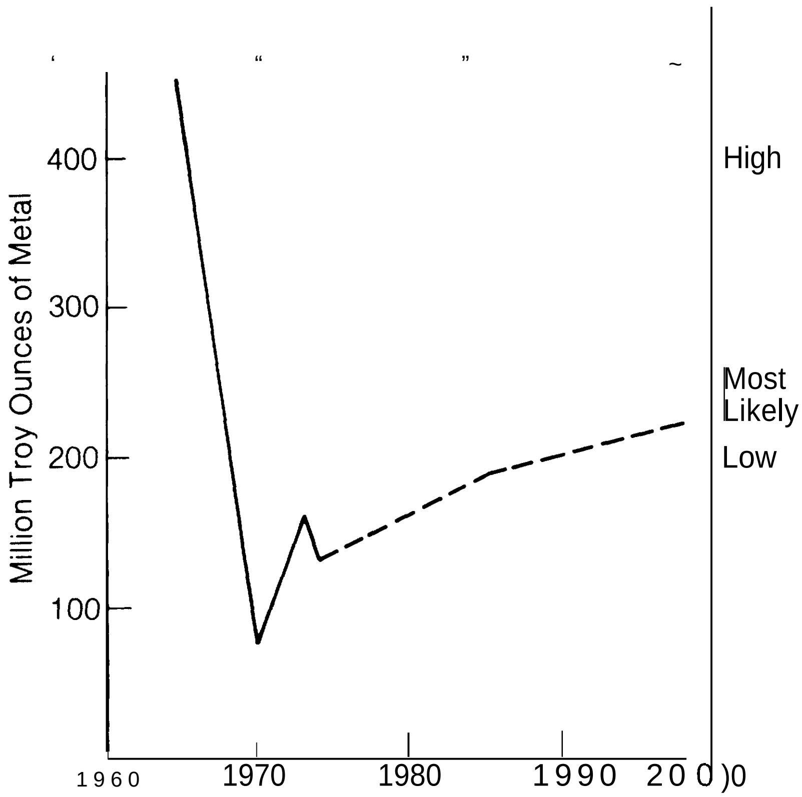
a. Uses, **Substitutes, or Alternatives.** Silver is very malleable, can be highly polished, and has the highest thermal and electric conductivity of any metal. The major silver-consuming sectors are silverware, jewelry, and arts; photography; refrigeration appliances and equipment; batteries; electrical and electronic equipment; and coinage. Stainless steel is a lower cost substitute for silver in cutlery and dental work. Semiconductors may substitute for silver in transistor switching devices.

[36] U.S. Bureau of Mines. *The United States Position and Outlook in Potash.* Info. Circ. 8487 (1970).

b. **Demand Outlook.** Over the past 10 years, primary silver demand has fluctuated widely (see figure A-16), This is due in large part to the substantial decrease in silver used for coins (from 320 million troy ounces in 1965 to 1 million troy ounces in 1974). On the other hand, the use of silver in the production of jewelry, photographic and electrical equipment, appliances, and other manufactured goods has been steadily growing. This growth is expected to continue over the next 25 years.

Because in the United States this metal is generally produced as a byproduct or coproduct of copper, lead, and zinc, the demand for these other minerals becomes a

Figure A-16 .—Primary Silver Demand Outlook



Forecast Assumptions

High: Strong growth in automation, communication, electrical equipment and other end-use demand.

Low: Increased use of substitutes (e.g., stainless steel) and reduced per unit consumption through technological change (e.g., photography and energy-intensive appliances).

factor in the future domestic supply of silver. (Copper and lead are discussed individually in other parts of this section.)

c. Supply Outlook. U.S. mineral deposits wherein silver is the main constituent have in general been mined out and are no longer productive except in a few major districts. Major prospecting programs for these kinds of deposits, such as have occurred in northern Idaho in recent years, could expand this source.

Over the next 25 years, most silver will most likely be developed as a byproduct from the following sources, assuming no radical jump in price that might make several other types of deposits attractive: copper porphyry deposits, copper-zinc-lead replacement deposits and vein clusters, massive sulfide deposits, lead-zinc replacement deposits, copper deposits in sandstones and shales, and nickel and magnetite deposits.

If the highest demand for silver were realized, the United States would be required to draw approximately 5.4 billion ounces of silver from world reserves because there would not be sufficient domestic reserves to meet this projected demand (see tables A-I8 and A-19). A large free world deficit of silver production in recent years, however, makes reliance on domestic resources and on better recovery from scrap and used film of increasing importance.

As shown in figure A-17, the domestic supply of primary silver is forecast to remain relatively stable between 1975 and the year 2000.

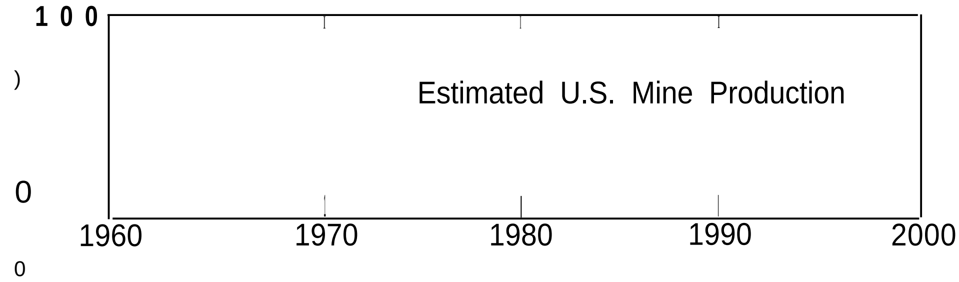
Table A-18.—Silver Supply
(Millions of Troy Ounces)

	1965	1970	1974
Domestic U.S. Mine Production	40	45	34
Secondary (Refined Scrap)	34	56	54
Minus Exports	(40)	(28)	(18)
Plus Imports, Ore and Concentrates	47	36	30
Plus Imports, Refined	7	33	92
Industry Stocks, January 1	Available	86	56
Commodity Exchange Stocks, January 1	3	113	92
Net U.S. Treasury Release	401	31	1
TOTAL Silver Supply	492	372	341

Table A-1 9.—Resources of Primary Silver

Identified:	1.4 billion troy ounces as by-product, plus 765 million troy ounces as main product.
Hypothetical and Speculative:	3.4 billion troy ounces of hypothetical resources, including deposits in which silver would be a by-product.

Figure A-17 .—Primary Silver Supply Outlook



d. **Geographic Distribution of Resources.** Most of the U.S. silver resources are in eight Western States and Alaska. The approximate distribution of identified and estimated hypothetical silver resources is as follows.

Nevada ... , ... , ... , ... , ... , ...	21.19i0
Idaho . . . . , ...	19.40/o
Montana ., ., ...	17.7%
Utah. , ., ...	15.9%
California ... , ..., ...	11.50%
Colorado	6.2%
Arizona	3.5%
New Mexico.	2.8%
Other	Less thanl%

In 1974, 90 percent of domestic silver production came from these eight Western States and Alaska.

e. Potential of Federal Land. Analysis of the distribution of public land with respect to known areas of silver potential was inconclusive because of insufficient resource data. However, most of our identified silver resources are on Federal land or patented claims. In Alaska, although current silver production is from patented claims, most potential silver provinces are on Federal land, mainly in the Chugach and Tongass National Forests. Generally, more than half of the potential silver provinces in Arizona, California, Colorado, Idaho, Missouri, Nevada, New Mexico, and Washington are on Federal land, including national forest land and rangeland. In Montana and Utah there are much smaller percentages of potentialsilver provinces on Federal land.

Mineral Facts and Problems, 1975, supplemented by A. V. Heyl, U.S. Geological Survey, written communication, 1976. The Arizona estimate does not include silver in copper porphyries; the "Other" category includes Alaska, but does not include silver in southeast Missouri lead and zinc, Michigan copper, or Minnesota nickel.

12. Sodium Carbonate (or Soda Ash)

Sodium carbonate is used principally by the glass, chemical, paper and pulp, and detergent manufacturing industries. Domestic resources of natural sodium carbonate are abundant. They are all located in Western States, mostly on Federal land.

a. **Uses, Substitutes, or Alternatives.** Trona is the principal source of natural sodium carbonate or “soda ash, ” which in turn is a major industrial chemical used in the manufacture of glass, chemicals, paper and pulp, soap, detergents, water softeners, and other products. Caustic soda is used extensively as a soda ash substitute, particularly in the aluminum industry.

b. **Demand Outlook.** For the past 10 years, domestic consumption of soda ash has grown slowly but steadily. It is forecast that total demand will continue to climb at a rate that will depend on various technologies and growth factors for the primary end-use industries (see figure A-18).

c. Supply Outlook. It is estimated that the trona deposits now being mined in southwestern Wyoming could supply national needs for more than several thousand years at the present rate of consumption (see tables A-20 and A-21). Synthetic soda ash, derived from limestone and salt, is expected to eventually disappear because of rising fuel and labor costs as well as pollution problems (see figure A-19).

d. **Geographic Distribution of Resources.** The distribution of United States natural sodium carbonate resources is as follows:

Southwestern Wyoming trona resources .,. . . . . ., ...	72.5%
Northwestern Colorado nahcolite resources , ...	26.2%
California (Searles and Owens Lakes)	1.0%
Western playa lakes ., ...	0.3%

e. Potential of Federal Land. About 60 percent of the trona resource in southwestern Wyoming is on Federal land that is principally used for grazing. About 90 percent of the nahcolite resource in the Piceance Creek basin in northwestern Colorado is on Federal land largely used for grazing. Searles and Owens Lakes in California are on private land.

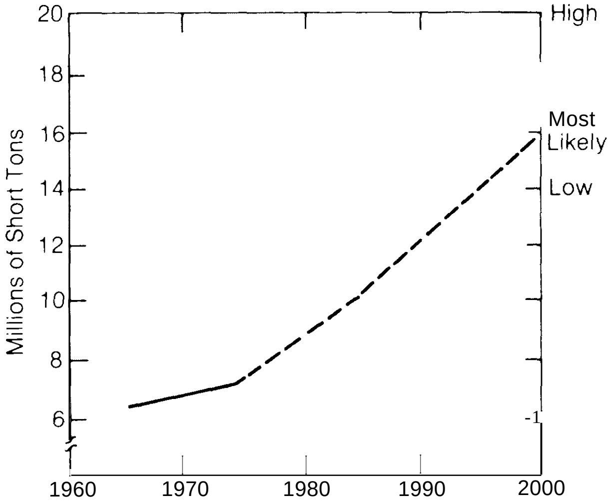
13. Uranium

Uranium probably will be essential to future energy supplies. Almost all U.S. uranium reserves at a price of $30 per pound, * and 70 percent of potential uranium resources of this same price category, are in Western States. About one-half of these resources are on Federal land.

a. **Uses, Substitutes, or Alternatives.** Uranium, a radioactive metal and nuclear fuel, is an important source of energy for generating electricity. Plutonium also maybe used as fuel in reactors. A non-naturally occurring isotope of uranium, bred from thorium, could also be used as reactor fuel. Advanced reactors may eventually reduce the demand for uranium.

*See note added in proof, table A-23

Figure A-18. —Sodium Carbonate Demand Outlook (Both Natural and Synthetic)



Forecast Assumptions

Range in high-low variances due to variances in projected sodium carbonate demand by glass manufacturers and sodium carbonate, chemical and paper Industries.

Figure A.19.— Sodium Carbonate Supply Outlook (Both Natural and Synthetic)

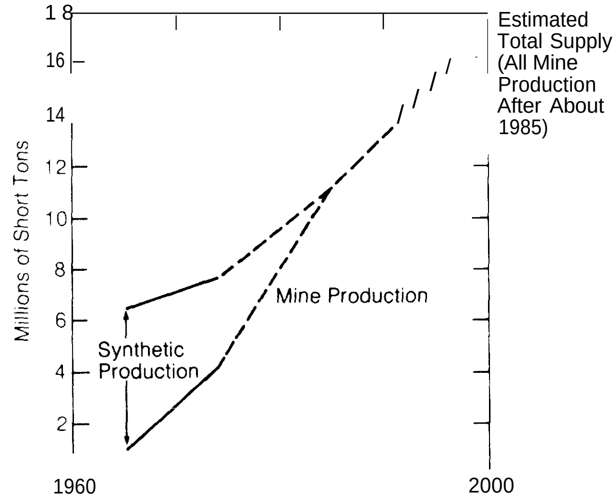


Table A-20.–Sodium Carbonate Supply (Thousands of Short Tons)

	1965	1970	1974
U.S. Natural Production	1,494	2,678	4,059
U.S. Synthetic Production	4,926	4,393	3,502
Minus Exports	(277)	(336)	(564)
Plus Imports	—	—	35
Industry Stocks, January 1	644	178	105
TOTAL Sodium Carbonate Supply	6,787	6,913	7,137

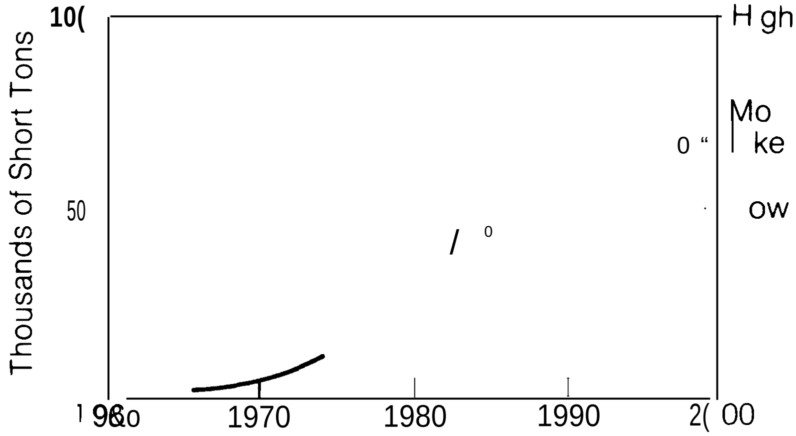
Table A-21 .—Resources of Natural Sodium Carbonate

Identified:	53.1 billion tons of sodium carbonate in trona in beds more than 3 feet thick (this trona, which is in southwestern Wyoming, contains impurities and is about 62.5 percent sodium carbonate), plus
	19.2 billion tons of sodium carbonate in nahcolite (nahcolite is about 60 percent sodium carbonate), plus
	0.7 billion tons of sodium carbonate in Searles and Owens Lakes, California.
Hypothetical and Speculative:	0.2 billion tons of potential sodium carbonate in small playa lakes in the western states,

44-526 O - 7 - 22

b. **Demand Outlook.** U.S. consumption of uranium has been gradually increasing over the past few years and the growth rate is expected to continue to climb as more nuclear reactors are constructed (see figure A-20). The rate at which new reactors are built, however, has been affected by delays and siting difficulties arising from licensing procedures, community opposition, and capital constraints.

Figure A-20.— Uranium Demand Outlook



High, Low and Most Likely forecasts are based on variations in degree of public acceptance of nuclear power, degree of energy conservation, extent of lead times for reactor licensing and construction, and success of exploration.

NOTE, According to information provided to OTA in March 1979 by the Department of Energy, 67.7 thousand short tons of natural U_3O_8 will be required to meet domestic enrichment demand in the year 2000, based on a planning case of 325 GW (e) of nuclear power. The calculated demand assumes no recycling, 0.200/0 tailings assays, and a plant factor of 750/0.

c. **Supply Outlook.** As shown in table A-22 domestic mine production of uranium has grown over the last 9 years, keeping pace with U.S. demand.

Although reserves of uranium may not be adequate for much beyond the year 2000, large undiscovered resources are believed to exist (see table A-23), and recent

Table A-22 .—Uranium Supply
(Thousands of Short Tons)

	1965	1970	1974
Domestic Mine Production	8.8	10.9	9.8
Industry Stocks, January 1	4.4	9.2	21.7
Government Stockpile Releases	0.2	0.6	1.0
TOTAL Uranium Supply	13.4	20.7	32.5

Table A-23.—Resources of Uranium
(Thousands of Short Tons of U_3O_8 at $30 Per Pound)

Reserves:	640 not including by-product uranium from phosphate and copper production.
Undiscovered Resources:	2,920 consisting of 1,060 probable, 1,270 possible and 590 speculative.

Source: U.S. Energy Research and Development Administration, Grand Junction Office, *National Uranium Resource Evaluation, Preliminary Report* (1976). (ERDA's uranium resource classification terminology, which is followed in this table, varies from the USGS/USBM terminology used elsewhere in this appendix). For another perspective on uranium resource estimates, which are controversial, see National Academy of Sciences, *Mineral Resources and the Environment, Supplementary Report: Reserves and Resources of Uranium in the United States* (1975).

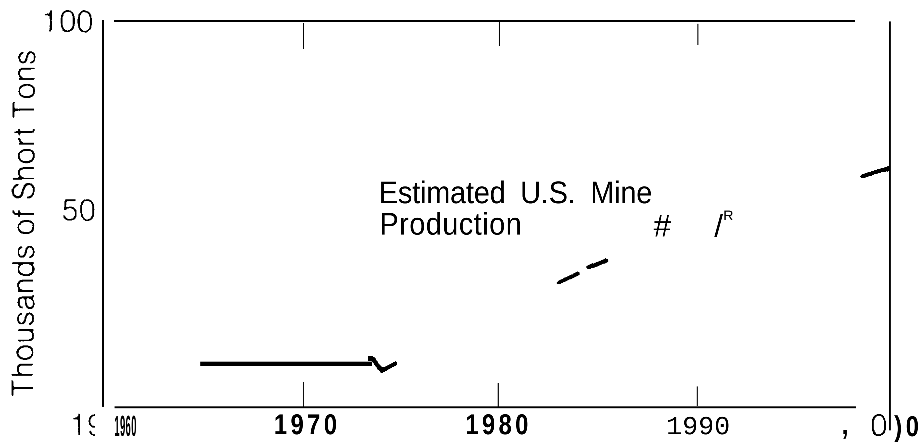
NOTE According to Information provided to OTA In March 1979 by the Department of Energy, estimated uranium resources at $50 per pound of U_3O_8 on January 1, 1978, were 890 thousand short tons of reserves, 1,395 thousand short tons of probable resources, and 565 thousand short tons of speculative resources.

price trends indicate there will be sufficent incentives to explore for and develop these resources.

A secondary supply of uranium and plutonium could come from reprocessed fuel. However, there are presently no plans to begin reprocessing,

The uranium supply outlook is shown in figure A-21.

Figure A-21 .— Uranium Supply Outlook



d. **Geographic Distribution of Resources.**[38] The regional distribution of reserves estimated to be available at a price of $30 per pound is as follows;

Colorado Plateau.	50.90/0
Wyoming Basins	36.49%
Gulf Coastal Plains	6.9°A
Northern Rockies,	3.1 %
Colorado and Southern Rockies	1.4%
Great Plains.	1.0%
Basin and Range and other regions	0.3%

The Colorado Plateau and Wyoming Basins are estimated to account for approximately 70 percent of the probable resources (40 and 30 percent, respectively). The Colorado Plateau and Wyoming Basins also account for 56 percent of the possible uranium resources and 23 percent of the speculative uranium resources at the $30 price level. The share these two regions represent of total potential resources (probable, possible, and speculative) is about 55 percent.

e. **Potential of Federal Land.** Based on the State-by-State uranium reserve data released by the Atomic Energy Commission in 1974, it has been estimated that at least one-half of the Nation's uranium reserves of the $8 category is within Federal land in

[38] U.S. Energy Research and Development Administration, Grand Junction Office, *National Uranium Resource Evaluation, Preliminary Report* (1976).

Colorado, New Mexico, Utah, and Wyoming. A detailed study of the distribution of the estimated uranium reserves at $30 per pound of U_30_8 and their relationship to Federal land has not been made. Therefore, it is not known whether the proportion of reserves on Federal land remains the same at the $30 price level as at the $8 price level. The Federal land on which uranium resources are found includes several national forests—Uncompahgre, Cibola, Manti-La Sal, and Shoshone National Forests. The Shoshone National Forest has sites under study for possible wilderness areas. Small amounts of uranium are also found in the Dinosaur National Monument and on military land.