1 Mining Overview

1. Mining: Backbone of the U.S. Economy

Mining is the search for, extraction, and beneficiation and processing of solid minerals from the earth. The kinds of minerals extracted from the earth vary widely. For thousands of years, these and other minerals have provided the raw materials with which human civilizations have been built.

The United States Department of Energy and the National Mining Association are working in partnership to implement the Mining Industry of the Future strategy. Cooperatively, the Department of Energy and National Mining Association selected specific mineral commodities to review in this Mining *Energy and Environmental Profile*. These commodities require significant energy to extract and prepare for first saleable product and have the potential for energy and environmental improvement through research and development.

The U.S. Geological Survey reports on 58 non-fuel mineral commodities in the U.S. The eight groups of mineral commodities selected for analysis in this report include: Coal; Potash, Soda Ash, and Borates; Iron; Copper; Lead and Zinc; Gold and Silver; Phosphate Rock; Limestone and other Crushed Rock. The selected commodities can be grouped into three categories: Coal, Metals, and Industrial Minerals. Iron, Copper, Lead and Zinc, Gold and Silver are metals. Potash, Soda Ash, Borates, Phosphate Rock, Limestone, and other Crushed Rock are grouped into industrial minerals. For the purpose of this overview, we will look at the mining industry as a whole using these groups. The following chapters will look at the commodities individually. This report does not include petroleum or natural gas extraction in its definition of mining.

Coal is defined as a combustible rock containing more than 50 percent by weight and more than 70 percent by value of carbonaceous materials, including inherent moisture. Coal is formed from compaction and induration of various kinds of plant remains.

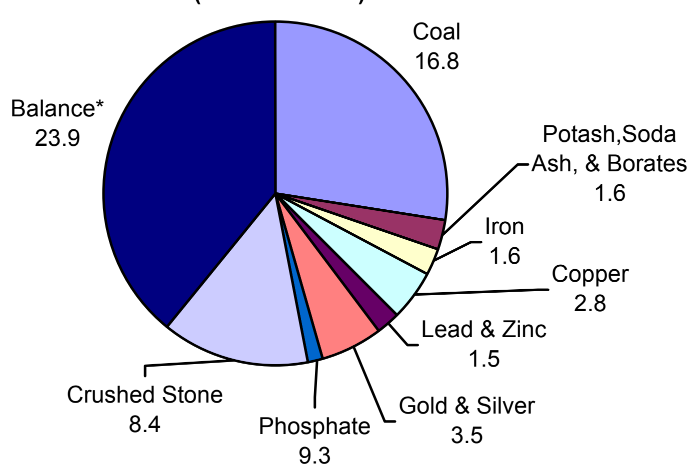
A metal is an opaque lustrous elemental substance that is a good conductor of heat and electricity. It is also malleable and ductile, possesses high melting and boiling points, and tends to form positive ion chemical compounds.

Industrial minerals are rocks and minerals that are not sources of metals or mineral fuels, such as coal.

Table 1-1 lists these mineral commodities and describes some of their end uses. As illustrated in Figure 1-1, these commodities represent 76 percent of all production value in mining in the U.S. Although energy data are withheld for a number of mined commodities, the commodities selected for this report consume an estimated 78 percent of the energy consumed by the U.S. mining industry.[1] Analysis of the energy consumption for these commodities will provide industry with a valuable benchmark for identifying opportunities for improved energy efficiency.

The vitality of the U.S. economy depends on key mineral resources. *In the course of a lifetime, each American will use 3.5 million pounds of minerals, metals, and fuels. Every year, 46,000 pounds of new minerals including 7,500 pounds of coal energy must be provided for every person in the U.S. to maintain our standard of living.* Low-cost coal is used to generate a large portion of the nation's electricity supply, helping to keep U.S. electricity costs among the lowest in the world and thereby enhancing the competitiveness of U.S. industry.[2] The contribution that the mining industry has made to the economic health, well being, and security of the U.S. throughout its history is unquestioned. Mining is critical to the U.S. economy.

Figure 1-1. U.S. Production of Selected Commodities - 2000 (Billion Dollars)



Source: U.S. Department of Interior, U.S. Geological Survey, *Minerals Handbook*, Statistical Summary, 2000

[1] U.S. Department of Commerce, U.S. Bureau of Census, *1997 Industry Series*, Mining

[2] National Mining Association, *The Future Begins with Mining*, *A Vision for the Mining Industry of the Future,* September 1998. http://www.oit.doe.gov/mining/vision.shtml. Estimates developed by National Mining Association based on data from the U.S. Department of the Interior, U.S. Geological Survey, Mineral Commodity Summary (mineral consumption); U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (coal energy consumption); U.S. Department of Commerce, Bureau of Census (population). http://www.nma.org/fastfacts.html#anchor208017.

Table 1-1. Commonly Known Materials and End Uses	
Coal	Generating electricity, making iron and steel, and manufacturing chemicals.
Potash, Soda Ash, and Borates	*Potash* - Used as a fertilizer, in medicine, and in the chemical industry.
	Soda Ash - Glass, chemicals, soap and detergents, pulp and paper, agriculture, brine treatment, corn syrup, drilling mud additives, dyes and pigments, enamels, flue gas desulfurization, food processing, leather tanning, metal refining, perfume, pharmaceuticals, and textiles.
	Borates - Fiberglass insulation, textile ore continuous-filament glass fibers, glass, detergents and bleaches, enamels and frits, fertilizers, and fire retardants.
Iron	Steel products: (kitchen utensils, automobiles, ships, buildings) Powdered iron: used in metallurgy products; magnets; high-frequency cores; auto parts; catalyst. Radioactive iron: in medicine; tracer element in biochemical and metallurgical research. Iron blue: in paints, printing inks, plastics, cosmetics, paper dyeing. Black iron oxide: as pigment; in polishing compounds; metallurgy; medicine.
Copper	Electric motors, generators, communications equipment, electric cables and wire, switches, plumbing, heating, construction, chemical and pharmaceutical machinery, alloys, alloy castings, and protective coatings for other metals.
Lead and Zinc	*Lead* **-** Batteries, solder, military tanks, seals or bearing, electronics; TV tubes and glass, construction, communications, and protective coatings; in ballasts or weights; ceramics or crystal glass; X-ray and gamma radiation shielding; soundproofing material in construction industry; and ammunition.
	Zinc - Die casting, galvanizing brass and bronze, protective coatings on steel, chemical compounds in rubber and paints, used as sheet zinc and for galvanizing iron, electroplating, metal spraying, automotive parts, electrical fuses, anodes, dry cell batteries, nutrition, aluminum products, chemicals, roof gutter, engraver's plates, cable wrappings, organ pipes and pennies. Zinc oxide used in medicine, paints, vulcanizing rubber, sun block. Zinc dust used for primers, paints, precipitation of noble metals, removal of impurities from solution in zinc electrowinning.
Gold and Silver	*Gold* - Jewelry, satellites, electronic circuits, dentistry, medicine, arts, coins, ingots as a store of value, scientific and electronic instruments, electrolyte in electroplating industry.
	Silver - Electronic circuitry, coins, jewelry, photo film, chemistry, in lining vats and other equipment for chemical reaction vessels, water distillation, catalyst in manufacture of ethylene, mirrors, silver plating, table cutlery, dental, medical and scientific equipment, bearing metal, magnet windings, brazing alloys, solder.
Phosphate	Plant fertilizers, feed additives for livestock, elemental phosphorus, variety of phosphate chemicals for industrial and home consumers.
Crushed Rock	Highways, paint, plastics, medicines, glass, concrete sidewalks, bridges, wallboard, vinyl, brick and stone buildings and homes, concrete block, roofing tile, asphalt shingles, minerals for agriculture.

Sources: U.S. Bureau of Mines, *This is Mining*.
Mineral Education, National Mining Association, 2000.
National Stone Association, *Crushed Stone: Our National Resource*, <www.aggregates.org>
Industrial Minerals and Rocks, Boron and Borates, 1994, p. 171
U.S. Department of Interior, Bureau of Mines, *Mineral Facts and Problems*, 1985.

Though minerals are essential to practically every aspect of our lives and our economy, they are scarcely noticeable to most of us. In the U.S., minerals have for decades been so readily available that most of us never give a thought to what our lives would be like without them. We may never actually see minerals as they emerge from underground and surface mines, as they pour molten-hot from furnaces, or as they come off the line at processing plants. Yet, without minerals, civilization as we know it could not exist. A myriad of items that we use in our homes and offices and for transportation, communications, and national defense all require minerals. Minerals are the source of all the metals in buildings, cars, airplanes, and household products. Minerals are a major source of the raw materials for the building and chemical industries. Even in the information age, minerals are used to produce telephones, computers, and televisions. In fact, 30 different minerals are needed to make a television or a computer and a telephone is made from as many as 42 different minerals including aluminum, beryllium, coal, copper, gold, iron, limestone, silica, silver, talc, and wollastonite.

America's mining industries work together in providing billions of dollars per year to the nation's economy. A study conducted by the Western Economic Analysis Center found that coal mining had a direct impact of $15.5 billion on the domestic economy in 1995.[3] Combining the direct impact with the calculated indirect impact of wages and other business transactions stemming from mining, the total economic contribution of coal mining in 1995 was $167.5 billion. If the mining of coal is considered not just as a source of money income, but as a source of vital fuel used in the generation of more than half the nation's electricity, then the total combined direct and indirect impact on the national economy as a result of coal mining in 1995 was in the trillions of dollars, not billions.[4]

Modern Mining is a Highly Sophisticated Industry

The use of advanced technologies, including automation, satellite communications, smart sensors, and robotics has become common in mining. Computers and microprocessors are responsible for making machinery efficient and reliable, and for assisting exploration, mineral processing, and mine operations adapt to new competitive environments in a safe and environmentally sound manner.

Through technology and process improvements, labor productivity in the U.S. industrial sector is making important strides. The same trend is seen in the U.S. mining industry. For example, Figure 1-2 shows that mining productivity for a single company as measured by ton per person-year has increased due to technology improvements. The largest jump in production was the result of in-situ remote production. An even larger jump is anticipated by the introduction of automated technologies.

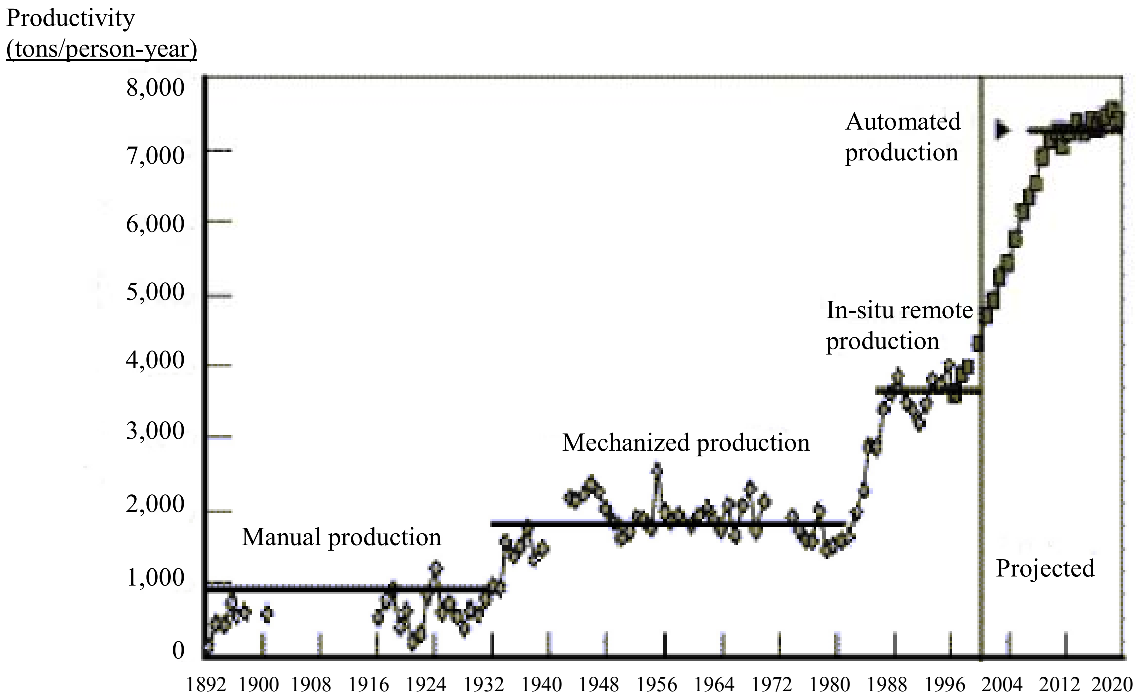
Advances in mine exploration, extraction, and processing technologies are helping to create opportunities for new markets for coal, metals, and industrial minerals. For example, the consumption of zinc used as an alloy is now increasing, after years of decline, because of higher demand for lightweight metals. Also, its use as an anti-corrosive coating for metals has grown. Copper, with its high degree of conductivity and relatively low cost, has an opportunity to

[3] Western Economic Analysis Center, *Mining and the American Economy*, 1997
[4] Ibid.

expand its markets in, for example, high efficiency motors. Also, copper is becoming the metal of choice for high performance integrated circuits. Gold's corrosion resistance and high conductivity make it an essential component in the growing market for sensitive electronics and other advanced products. There will be an increase in the demand for lead as battery-driven vehicles penetrate the transportation market.

As demand for such commodities increase, so will the need to mine and process them at competitive costs. This means continually finding better methods, technologies, and processes to maintain and improve safety and environmentally sound conditions while permitting the production of lower-cost mineral commodities.

Figure 1-2. Past Productivity and Anticipated Productivity from Technology Change from One Company



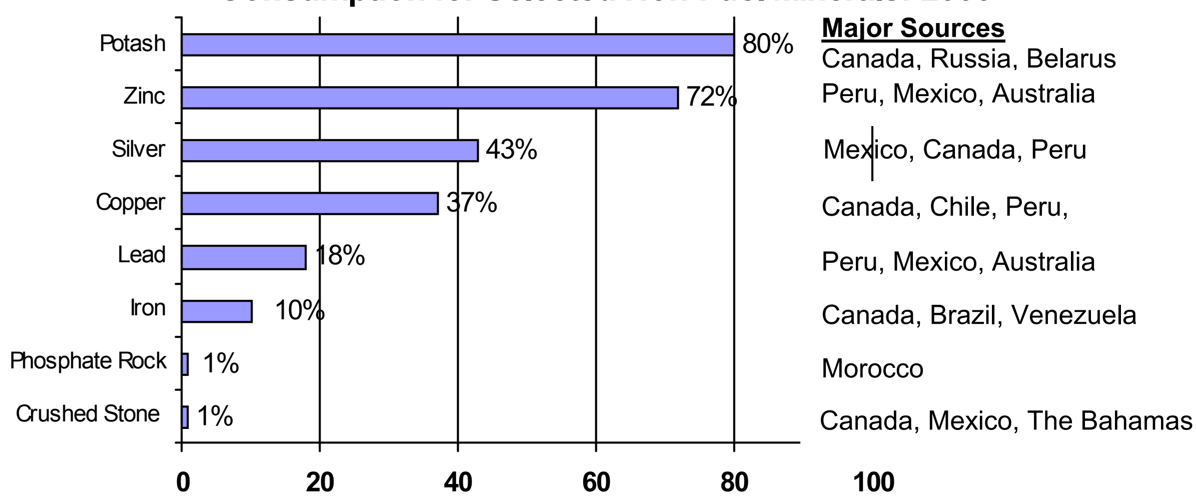
Source: RAND, *New Forces at Work In Mining: Industry Views of Critical Technologies*, 2001

1.1 Mining Market Overview

Mineral production has always been a cyclical business, with production levels for any given period showing peaks and valleys for almost every mineral. The U.S. leads the world in developing and employing highly efficient and advanced environmental technologies to supply the world with coal, metals, and industrial minerals. Table 1-2 provides market and industry data for the minerals selected for this report.

Although, the U.S. is one of the top world producers of coal, soda ash, borates, copper, lead, gold, silver, and phosphate, it relies heavily on imports to meet many of its mineral needs. In 2000, the U.S. imported 48.1 million tons of minerals valued at $3.5 billion in 2000. For example, the selected minerals shown in Table 1-2, for example the U.S. imported 17.3 million tons of iron ore. The U.S. also relies on imports for a significant portion of copper demand. In all, the U.S. is a significant importer of over 40 minerals. U.S. exports of coal in 1998 were valued at $2.3 billion. The U.S. is a major exporter of coal, soda ash and other minerals. Other leading countries in mineral production include China, Russia, and Australia among others. Figure 1-3 illustrates net import reliance of the selected commodities for those that apply.

Figure 1-3. Net Import Reliance as a Percentage of Consumption for Selected Non-Fuel Minerals: 2000



Source: U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2002

U.S. Mineral Production

The abundance of mineral resources has served the U.S. well. U.S. mineral production (for the selected commodities) in 2000 was over 3.2 billion tons, which was valued at $41.7 billion. As shown in Table 1-2 shows coal had the largest value. The U.S. is the world's leading producer of coal producing about 1.1 billion tons in 2000 valued at $18 billion. This was nearly 21 percent of world production. The U.S. also is the world's leading producer of lead, soda ash, and

Table 1-2. Market and Industry Data for Selected Commodities (2000)

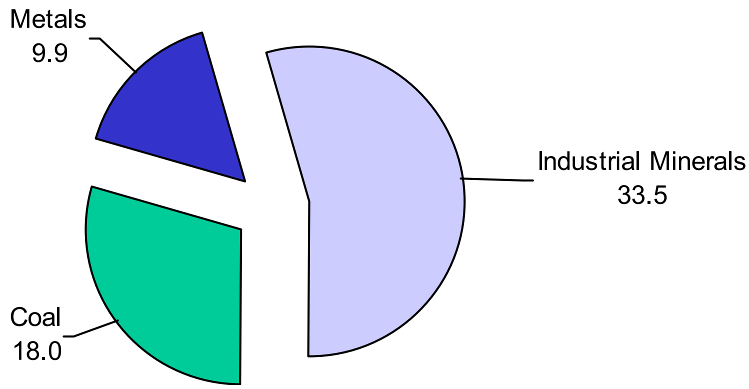
Commodity	Number of Mines	Number of Employees[a] (mine & mill and/or processing)	Average Annual Wage[b] ($)	Materials Handled in U.S. crude ore and waste (000 tons)	U.S. Production (000 tons)	U.S. Production Value (millions $)	World Production (000 tons)	U.S. Percent World Production	U.S. Imports (000 tons)	U.S. Value of Imports (millions $)	U.S. Exports (000 tons)	U.S. Value of Exports (millions $)
Coal[c, l]	1,453	71,522	46,388[d]	1,413,419	1,073,612.0	18,015[e]	4,736,000.0	21	12,512.6	402.6[f]	58,489.0	2,274.6[g]
Underground	707	42,352	-	644,240[t]	373,659.0	9,240[h]	-	-	-	-	-	-
Surface	746	29,170	-	769,179[t]	699,953.0	8,721[i]	-	-	-	-	-	-
Potash, Soda, & Borates[l]	16	5,175	49,405	15,689	13,856.1	1,595	70,415.5	19.8	82.7	8.6	4,299.0	477.0
Borates	4	1,300	-	2,359[t]	1,179.5	557	4,828.1[p]	24.4	0	0	0	0
Soda Ash	6	2,600	-	0	11,243.6	748	37,699.0[x]	30.0	82.7	8.6	4,299.0	477.0
Potash	6	1,275	-	13,330[t]	1,433.0	290	27,888.5[r]	5.1	0	0	0	0
Iron	11	6,000	49,737	364,865	69,556.0[u]	1,560	1,168,450.0[w]	6.0	17,306.3	420.0	6,779.2	246.0
Copper	30	10,200	40,081[j]	986,437	1,587.3[v]	2,810	14,550.5[m]	10.9	1,377.9[k]	2,400.0[k]	281.1[k]	389.0[k]
Lead & Zinc[l]	20	5,000	41,607	17,836	1,429.7	1,459	13,040.4	12.3	92.6	34.7	705.5	331.6
Zinc	10	3,600	-	7,220	913.8[v]	1,020	9,623.2[m]	9.5	58.2[m]	26.9[m]	576.5[m]	289[m]
Lead	10	1,400	-	10,616[t]	515.9[v]	439	3,417.2[m]	15.1	34.4[m]	7.8[m]	129.0[m]	42.6[m]
Gold & Silver[l]	48	11,900	43,262	222,877	2.5	3,480	23.0	12.1	0.0011[m]	.865[m]	0.0079[m]	18.7[m]
Silver	0	1,500	42,106	210[t]	2.1[v]	300	20.2[m]	10.2	0.001[m]	0.229[m]	0.0718[m]	9.1[m]
Gold	48	10,400	44,418	222,667	0.4[v]	3,180	2.8[m]	13.9	0.0001[m]	0.636	0.0008[m]	9.6[m]
Phosphate	16	6,300	43,929	Withheld	42,549.2	932	146,607.4	29.0	2,367.0	144.0	329.6	12.1
Stone (crushed)	3,453	78,800	34,770	1,807,790	1,675,513.0	8,390	-	-	14,330.0	105.0	4,508.5	29.7
Subtotals Selected Commodity	**5,047**	**194,897**	**43,647**	**4,828,913**	**2,878,105.8**	**38,241**	**6,149,086.8[w]**	-	**48,069.1**	**3,515.8**	**75,392**	**3,778.7**
Balance of U.S. Mining Industry	8,857	40,451	-	2,123,479	1,192,802.2	15,694	-	-	-	-	-	-
U.S. Totals	**13,904**	**235,348**	**45,312**	**6,952,392**	**4,070,908**	**53,935**	-	-	-	-	-	-

Sources: Department of Energy, Energy Information Administration, Coal Industry Annual 1998, June 2000
Department of the Interior, U.S. Geological Survey, Minerals Yearbook, Mining and Quarrying Trends, 1998 (Number of Mines, Materials Handled)
Department of the Interior, U.S. Geological Survey, Minerals Yearbook, Statistical Summary, 1998 (U.S. Production, U.S. Production Value, World Production, U.S. Imports and Import Values, U.S. Export and Export Values)
Department of the Interior, U.S. Geological Survey, Mineral Commodity Surveys (Number of Employees)
Department of Commerce, U.S. Census Bureau, Mineral Industry Reports, 1997 (Average Wage)
World Coal Institute, Coal Fact 1999 (World Coal Production)

[a] Estimated for 1998, except for coal data which is actual
[b] Calculated by dividing the annual payroll by all employees for all establishments (Census, 1997)
[c] Source Department of Energy, Energy Information Administration, Coal Industry Annual 1998, June 2000
[d] Calculated from NMA data of $892.07 average weekly earnings
[e] Production Value calculated by dividing production by $16.78 (U.S. average nominal price per short ton in 2000)
[f] Calculated based on $32.18 nominal dollars per ton
[g] Calculated based on $38.89 nominal dollars per ton
[h] Production value calculated by dividing production by $24.73 (U.S. average underground mining nominal price per short ton in 2000)
[i] Production Value calculated by dividing production by $12.46 (U.S. average surface mining price nominal per short ton in 1998)
[j] Based on copper nickel data
[k] Unmanufactured
[l] Summation of Individual Commodities
[m] Ore and concentrates
[n] Estimate based on number of mines and companies
[o] Number of companies
[p] Quantity sold ore used by producers
[q] Estimate based on number of mines and companies
[r] K_2 equivalent
[s] Number of firms
[t] Estimated based on recovery ratios (underground coal = 58%; surface coal = 91%; silver = 1%; lead = 5%; boron = 50%; potash = 21.5%)
[u] Gross Weight
[v] Recoverable content of ores
[w] Gross weight
[x] U.S. production is natural only

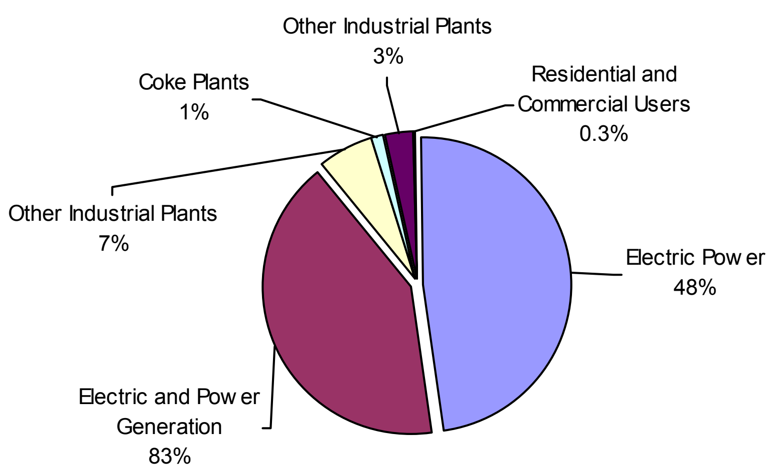
phosphate rock and is the second-largest producer of gold and copper.[5] Figure 1-4 illustrates the value of U.S. production for the coal, metals, and industrial minerals. Industrial Minerals represents about 55 percent of the value of production, followed by coal (29%) and then metals (16%). Figure 1-5, 1-6, and 1-7 show major markets for coal, industrial minerals, and metals in the U.S.

Figure1-4. Value of Mining in the U.S. - 2000 (Billion Dollars)



Source: Mining Engineering, *2000 Annual Review*, May 2001
U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual 2000*

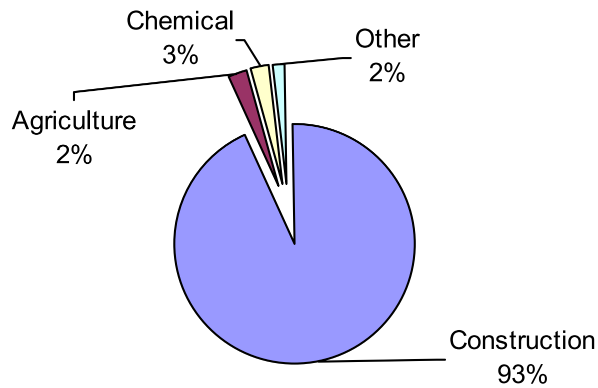
Figure 1-5. Coal Consumption by Sector - 2000



Source: U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual 2000*
Note: Other Power Producers include utility coal-fired power plants sold to nonutilities during 1998, 1999 and 2000. Coal consumption by cogenerators is included in the end-use sector.

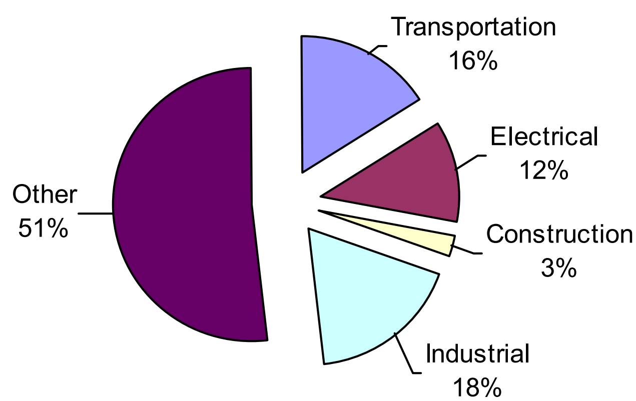
[5] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, Various Commodities, 1998, 1999

Figure 1-6. Industrial Minerals Consumption by Sector - 1998



Source: U.S. Department of the Interior, U.S. Geological Survey, Various *Mineral Commodity Summaries,* 1999

Figure 1-7. Metals Consumption By Sector - 1998



Source: U.S. Department of the Interior, U.S. Geological Survey, Various *Mineral Commodity Summaries*, 1999

Important Role in State and Local Economies

The mining industry plays an important role in all 50 states. As a supplier of coal, metals, and industrial minerals to businesses, manufacturers, utilities, and others, the mining industry is vital to the well-being of communities across the country.

Mining operations are often the leading employers in the communities where they operate. Direct employment in the mineral areas selected for this report is 210,530 people or 60 percent of total industry employment. Across all categories of minerals, the mining industry directly employs over 355,000 people. The mining industry indirectly supports an additional five million jobs in manufacturing, engineering, and environmental and geological consulting. Employment is led largely by the coal and crushed stone industries. The number of employees in coal mining and processing is 81,257 people. Employment in crushed stone is 78,500 people. Overall, industrial minerals and coal mining operations account for an estimated 80 percent of mining employment. Metal mining accounts for the remaining 20 percent. Mining employees earn the highest wages of all U.S. industries; nearly $49,995 per year compared with $30,053, the average for all industries (See Table 1-2 for employment and wage data).

Mining occurs in all 50 states based on economic viability of the identified mineral. Minerals occur based on varying geologic conditions, thus the same minerals are not found everywhere, but in very limited areas. The following lists major mined commodities in the U.S. and their primary producing states.[6]

Coal

Coal deposits are a major fuel mineral in the U.S. and have been found in 38 states. Nearly one-eighth of the U.S. landmass lies over coalbeds. Although coal is found in the majority of U.S. states, it is not economic to mine in all cases. The most important coal deposits in the Eastern U.S. are in the Appalachian Region, which includes portions of nine states. The West contains the Wyodak coalbed, the nation's leading source of coal, which is part of the Powder River Basin of Wyoming and Montana. In the interior states, coal occurs in several separate basins located from Michigan to Texas. The seven largest producing states, in order, are Wyoming, West Virginia, Kentucky, Pennsylvania, and Texas.

Potash, Soda Ash, and Borates

Potash - U.S. potash production in 2000 is from Michigan, New Mexico, and Utah. The majority of production is from southeastern New Mexico.[7]

Soda Ash - In 2000, companies in Wyoming, California, and Colorado comprised the U.S. soda ash (sodium carbonate) industry, which was the largest in the world.[8]

Boron - Large domestic reserves of boron materials occur in California, chiefly in sediments and in their contained brines. In 2000, domestic production of boron minerals, primarily as sodium borates, was by companies centered in southern California.

Iron

Iron is commercially recoverable in large deposits or ranges. Magnetite, a type of iron ore, is found in the Mesabi Range of the Lake Superior district and in the northeastern U.S. The five largest producing states in order are Minnesota, Michigan, Missouri, South

[6] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, various commodities, 2001. Except coal.
[7] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2001.
[8] Mining Engineer, *Industrial Minerals Review*, p. 61, June 2000.

Dakota, and New Mexico. Other types of iron ore are found in Alabama and the southwestern U.S.

Copper

In 2000, the principal copper mining States, in descending order, are Arizona, Utah, New Mexico, and Montana. They account for more than 99 percent of domestic production.[9]

Lead and Zinc

Lead - The U.S. is one of the major producers of lead in the world. In 2000, lead mines in Missouri plus lead-producing mines in Alaska, Idaho, and Montana yielded most of the total. Primary lead was processed at smelter-refineries in Missouri and in Montana.

Zinc - Alaska, Missouri, New York, and Tennessee accounted for 98% of domestic mine output; Alaska alone accounted for about three-fourths of production.

Gold and Silver

Gold - Nevada produces about two-thirds of domestic gold production. Other major gold mining states include Utah, California, Alaska, and Montana.

Silver - Nevada is one of the largest producers of silver followed by Alaska, Idaho, Arizona and Utah. Precious metal ores accounted for approximately one-half of domestic silver production while the other half is recovered as a byproduct from processing copper, lead, and zinc ores.[10]

Phosphate Rock

U.S. production of phosphate rock is mainly in Florida. In 2000, Florida and North Carolina accounted for 85% of total domestic output, with the remainder produced in Idaho and Utah. Phosphate rock is also mined in Idaho and Utah.[11]

Crushed Stone

About three-quarters of the crushed stone production in the U.S. is limestone and dolomite, followed by granite, traprock, sandstone and quartzite, miscellaneous stone, marble, slate, calcareous marl, shell, and volcanic cinder and scoria. In 2000, leading states, in order of production, were Texas, Florida, Pennsylvania, Illinois, Georgia, Missouri, Ohio, North Carolina, Virginia, and Tennessee, together accounting for 51% of the total output.[12]

[9] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2001.
[10] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2001.
[11] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2001.
[12] U.S. Department of the Interior, U.S. Geological Survey, *Mineral Commodity Summaries*, 2001.

Mining Methods

Surface mining and underground mining are the prevailing mining methods. The method selected depends on a variety of factors including the nature and location of the deposit as well as the size, depth, and grade of the minerals. Both surface and underground mining are widely used in the extraction of coal. In 2000, the total amount of coal produced was 1.07 billion tons. Of this, 373 million tons or 35 percent came from underground mines and the remaining 699 million tons or 65 percent came from surface mines.[13] Of the 1.3 billion crude metal ore produced in the U.S. in 2000, 1.2 billion tons or 92 percent came from surface mining.[14] Most of the industrial minerals in the U.S. are extracted by surface mining. In 2000, the total amount of crude industrial ore mined in the U.S. was 3.2 billion tons. Of this, 3.1 billion or 96 percent came from surface mines.[15]

Bingham Canyon near Salt Lake City, Utah, is probably the best-known example of a surface mine in the U.S. It is also the largest surface mine in the U.S., measuring approximately 2 miles in diameter and a little more than a half mile deep. Conical in shape and used for near-surface ore bodies, these mines feature a series of benches winding down into the pit. The benches are used as working areas and haul roads. The rock is drilled, blasted and loaded into large haul trucks that take it to a processing facility.

Underground mining is used when mineralization is deep beneath the surface and/or when ore grade or quality is sufficient to justify more targeted mining. In order to get to the ore body, a vertical shaft, horizontal adit, or inclined passageway must be drilled remove ore and waste and provide ventilation. Once the ore body is exposed, several levels of horizontal tunnels called drifts and crosscuts are created to provide access to mining areas called stopes. The area actually being mined at any given time is called the face. Broken rock is hauled from the face by trains, loaders, or trucks that go directly to the surface, or to the shaft where it is hoisted to the surface and sent to a processing facility.

1.2 Materials and Equipment

There are seven general phases of the mining process. These are: 1) mine exploration; 2) design; 3) construction, which includes mine site preparation; 4) extraction operations in either underground or surface mines; 5) beneficiation operations consisting of crushing and grinding, separations, solvent extraction/electrowinning; 6) processing, which consists of smelting and/or refining depending on the mineral and the final product; and 7) reclamation (closure and post-closure). In each of these stages, there are a variety of equipment and materials used. This section describes major materials and equipment used in each of these phases.

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[13] U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual 2000*
[14] U.S. Department of the Interior, U.S Geological Survey, *Mining and Quarrying Trends*, 2000
[15] U.S. Department of the Interior, U.S Geological Survey, *Mining and Quarrying Trends*, 2000

Equipment

Equipment used in mining depends on the type of mine and which mineral is being excavated. The processes, and therefore the equipment required to process minerals vary significantly from commodity to commodity. Major equipment needed is listed in the commodity chapters.

Water

Water is used to extract materials from the ground and often to wash the ore after it has been extracted. Water needed per ton of material handled decreased by 56 percent from 1990 to 1995. In 1995, the non-fuel mining industry consumed less than one percent, about 3.8 billion gallons per day of the total U.S. water consumption (402 billion gallons per day). In 1995, the total U.S. materials handled in non-fuel mining was 6.0 billion tons. Therefore, in 1995 the non-fuel mining industry used 1.4 billion gallons of water or 231 gallons per ton of material handled. In 1990, the non-fuel mining industry used nearly 5 billion gallons per day with a total amount of non-fuel materials handled of 3.5 billion tons.[16] As a result, in 1990 the non-fuel mining industry used a total of 1.8 trillion ($x10^{12}$) gallons or 521 gallons per ton of material handled.

Explosives

As shown in Table 1-3, most of the explosives and blasting agents sold in the U.S. are used in mining. There are two classifications of explosives and blasting agents:

- High explosives - High explosives include permissibles and other high explosives. Permissibles are explosives that the Mine Safety and Health Administration approved.

- Blasting Agents and Oxidizers - These include ammonium nitrate-fuel oil (ANFO) mixtures, regardless of density; slurries, water gels, or emulsions; ANFO blends containing slurries, water gels, or emulsions; and ammonium nitrate in prilled, grained, or liquor form. Bulk and packaged forms of these materials are contained in this category. In 1998, about 95% of the total blasting agents and oxidizer were in bulk form. [17]

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[16] U.S. Department of the Interior, U.S. Geological Survey, *Mining and Quarrying Trends*, 1994, 1996
U.S. Department of the Interior, U.S. Geological Survey, Water Science for Schools, Mining Water, 1990, 1995,
http://ga.water.usgs.gov/edu/wumi.html

[17] U.S. Department of the Interior, U.S. Geological Survey, Mineral Commodities, Explosives, 1999, http://minerals.usgs.gov/minerals/pubs/commodity/explosives/

Table 1-3. Estimated Industrial Explosives and Blasting Agents Sold for Consumption in the United States, by Class and Use (Thousands of Metric Tons)								
Classes	**Permissibles**		**Other High Explosives**		**Blasting Agents and Oxidizers**		**Total**	
Year	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
Coal Mining	2	2	4	4	1,400	1,720	1,410	1,720
Quarrying and Nonmetal Mining	<0.5	<0.5	14	15	277	332	291	347
Metal Mining	<0.5	<0.5	1	1	202	235	203	236
Construction Work	<0.5	<0.5	11	12	147	182	157	194
All Other Purposes	0	0	a	1	58	70	59	10
Total	**2**	**2**	**31**	**34**	**2,090**	**2,530**	**2,120**	**2,570**

Note: Data are rounded to three significant figures: may not add to totals shown.
Source: U.S Department of the Interior, U.S. Geological Survey, Mineral Commodities, Explosives, 2000, http://minerals.usgs.gov/minerals/pubs/commodity/explosives/

The principle distinction between high explosives and blasting agents is their sensitivity to initiation. High explosives are cap sensitive, whereas blasting agents are not.

Many coal mines use explosives to loosen the rock and coal. In surface mining, holes are drilled through the overburden, loaded with explosives, and discharged, shattering the rock in the overburden. In one underground mining method, the coal is blasted off the bed without any undercutting to help break it down. The drawback to this method is that a dangerously large explosive charge is needed, and much dust and fine coal are produced. In another underground mining method using explosives to break down the coal, shot holes are drilled at intervals along the face of the coal bed. The explosives are inserted in these holes or shots. When the explosion occurs, the coal wall cracks into pieces. Coal mines use cylinders of compressed air, liquid carbon dioxide, or chemical explosives. Approximately 1.72 million metric tons (Mt) of explosives used for coal mining in 2000. This accounted for 67 percent of total U.S. explosives consumption. The largest coal producing states, Wyoming, West Virginia, and Kentucky were also the largest explosives-consuming states, accounting for 41 percent of total U.S. explosive sales.[18]

[18] U.S. Department of the Interior, U.S. Geological Survey, Mineral Commodities, Explosives, 1999, http://minerals.usgs.gov/minerals/pubs/commodity/explosives/

Quarrying and nonmetal mining, the second-largest explosives-consuming industries, accounted for 14 percent of total explosives sales and metal mining accounted for 9 percent. Kentucky, Wyoming, West Virginia, Virginia, and Indiana, in descending order, were the largest consuming states, with a combined total of 51 percent of total U.S. sales of explosives.[19]

Table 1-4 shows the estimated energy released by explosives used in mining. These estimates are based on 3.49 million Btu per metric ton of explosives. The explosive type, blasting agents, and oxidizers, accounts for most of the explosive energy used in mining.

Table 1-4. Estimated Energy Released by Explosives used in Mining

Year	Coal Mining Trillion Btu	Quarrying and Nonmetal Mining Trillion Btu	Metal Mining Trillion Btu	Total Trillion Btu
1999	4.9	1.0	0.7	7.3
2000	6.0	1.2	0.8	9.0

Note: Based on 3.49 million Btu per metric ton of explosives
Sources: Institute of Makers of Explosives (IME), Blasters Handbook, 17th edition.

1.3 Energy Consumption

1.3.1 Materials Handled

The quantity of material that must be extracted, transported, processed, and disposed is the key factor impacting energy consumption per unit of production for each commodity. As the data in Table 1-2 show, significantly more material must be handled to produce a ton of metal (i.e., iron, gold, silver) than coal or industrial minerals. Material handled versus production for metals and industrial minerals and coal is illustrated in Figures 1-14. In the case of metals, saleable product is four percent of the material that is required to be handled and processed to produce those metals. In other words, for every ton of saleable product, 24 tons of material must be handled. The ratio is much lower for industrial minerals and coal. For every ton of saleable coal produced, 1.38 tons of material must be handled and for every ton of saleable industrial minerals produced, 0.96 tons of materials must be handled. Energy consumption in the industry is dictated by the quantity of materials that must be handled. Figure 1-8 also shows the ore recovery ratios of the selected commodities. Improvements in technology or techniques that reduce the quantity of waste material handled can improve energy efficiency in the industry.

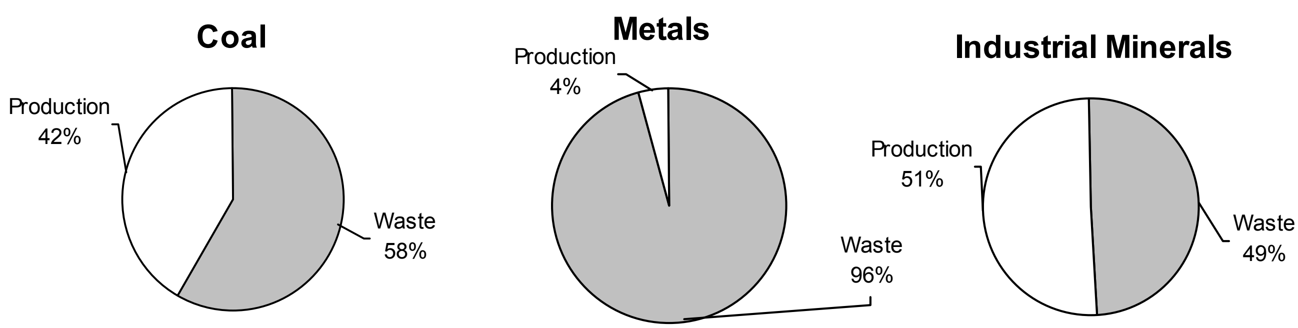
1.3.2 Energy Requirements

Energy used in mining operations accounted for approximately 3.3 percent of total industrial energy use in the U.S. in 2000 or approximately 1.125 quadrillion Btu.[20] In

[19] U.S. Department of the Interior, U.S. Geological Survey, Mineral Commodities, Explosives, 1999, http://minerals.usgs.gov/minerals/pubs/commodity/explosives/
[20] Estimated by U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Industrial Technologies.

1997, the mining industry spent \$3.7 billion on energy[21], representing about 17 percent of the total cost of supplies. This is an increase from 1992 when the mining industry spent \$3.5 billion on energy[22], representing about 16 percent of the total cost of supplies. Major energy sources used in mining include electricity (purchased and produced on-site) as well as fuel oil, coal, and natural gas. About 35 percent of energy needs are met by electricity followed by fuel oil at 32 percent. Coal, gas, and gasoline supply the rest of the energy. Major energy requirements include electricity for ventilation systems, water pumping, and crushing and grinding operations. Diesel fuel is used for hauling and other transportation needs. Although the mining industry is a significant energy user, it continues to make strides in improving productivity and energy efficiency.

Figure 1-8. Material Handled vs. Production for Coal, Metals, and Industrial Minerals



Ore Recovery Ratios for Selected Commodities

Coal	Potash, Soda Ash, & Borates	Iron	Copper	Lead & Zinc	Gold & Silver	Phosphate	Crushed Rock
82%	36%	54%	52%	41%	21%	33%	93%

Source: U.S. Department of the Interior, U.S. Geological Survey, *Minerals Yearbook*, Mining and Quarrying Trends, 1998
U.S. Department of Energy, Energy Information Administration, *Coal Industry Annual 1998*

Energy requirements vary considerably for each commodity and depend upon the type of ore being mined, whether it is underground or surface, whether it must be beneficiated or processed, and the extent to which is must be beneficiated or processed. For example, energy requirements in underground gold mining are significantly higher on a per-ton

[21] U.S. Department of Commerce, Bureau of Census, *Mining Industry Series*, 1992, 1997 (Supplies include minerals received, purchased machinery installed, resales, purchased fuels consumed, purchased electric energy and contract work.)
[22] U.S. Department of Commerce, Bureau of Census, *Mining Industry Series*, 1992, 1997 (Supplies include minerals received, purchased machinery installed, resales, purchased fuels consumed, purchased electric energy and contract work.)

basis than underground coal mining where the resource can be obtained in larger quantities. Moreover, due to the significant increase in hauling requirements, ventilation, water pumping, and other operations, underground mining operations require significantly greater amounts of energy than surface mining operations. The majority of the energy used in surface mining is diesel fuel for haulage. However, electricity is a major source of energy for underground mining, where the ore must be hoisted to the surface and the mine ventilated. A substantial amount of energy, particularly electricity, is also used in beneficiation and processing operations. More efficient methods of transporting material are needed in the mine. Innovative methods to locate and mine small, deep, highly complex ores are needed, along with new beneficiation methods that are environmentally friendly or benign.

Within the beneficiation stage, comminution, or crushing and grinding, accounts for an estimated two-thirds of energy requirements. The individual chapters of this report provide estimates of energy consumption for mining, beneficiation, and processing of selected commodities. Due to the lack of current information on energy requirements in specific mining, beneficiation, and processing operations, the *SHERPA Mine Cost Estimating Model* along with the *Mine and Mill Equipment Cost, An Estimators Guide* from Western Mine Engineering, Inc. were used to estimate the energy requirements for mining, beneficiation, and processing the commodities selected for this profile. The appendix to this report describes the methodology for developing these estimates as well as discusses extrapolating estimates for the selected commodities to estimates for all commodities.

Energy Requirements for Mine Exploration and Site Preparation

Energy requirements in exploration and site preparation largely involve transportation energy and drilling, which both typically require fuel oil. Electric power can be produced on-site or purchased from local utilities where available. At smaller properties, or those in very remote locations far from low-cost sources of electricity, diesel generator sets are installed within the mine-mill plant for on-site power. The generators can be pre-engineered by manufacturers to company specifications. The principal considerations are identifying a resource site suitable for unloading and storage of bulk fuel, distance of transmission and distribution lines, and position of the plant away from residential areas because of noise.

Large mining developments usually involve contracts with power companies and public utilities for new transmission lines and substations necessary to provide electric power. Where electric utility power is available, the mine owner usually finds it cheaper and more reliable than using generators, and will share in the cost of constructing the connecting line from the closest existing utility line. Up to a connected load of about 1,000 horsepower, it is cheaper to let the utility provide a primary substation; above this horsepower, a more favorable rate may be obtained by constructing a private primary substation to transform incoming power to usage voltages.

Energy Requirements for Mine Extraction, Conveying, and Hauling

Table 1-5 shows the type and quantity of fuels consumed by selected mined commodities as reported by the 1997 U.S. Department of Commerce, Bureau of Economic Census. The term "mining," as defined by the Census, is used in a broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and floatation), and other preparations customarily performed at the mine site or as part of the mining activity. Therefore, the data in Table 1-5 represents mine extraction, conveying, hauling and some mineral preparations customarily performed at the mine site.

The U.S. Department of Commerce reports total energy consumption in mining to be 491 trillion Btu, however, this does not include data withheld. The total energy consumed (all fuels and electricity) in mining operations for the commodities selected for this report is 382.0 trillion ($x10^{12}$) Btu as reported by the U.S. Department of Commerce. Coal mining operations consume the most energy at 103.1 trillion ($x10^{12}$) Btu. The Department of Energy, Office of Industrial Technologies has estimated total industry energy consumption including data withheld to be 753 trillion Btu. This estimate is based on analysis of both Department of Commerce, Bureau of Census data and Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey data.

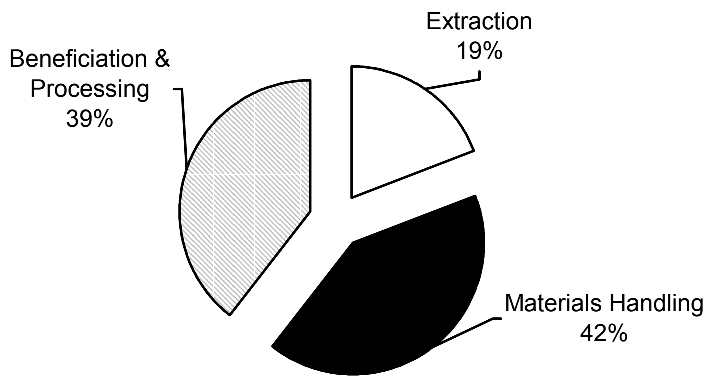
Table 1-5.
Type and Quantity of Fuels Consumed for Selected Commodities (1997)

Commodity	Coal 1,000 st	Fuel Oil 1,000 bbl	Gas Bcf	Gasoline Mil gal	Electricity Mil kWh	Total Tbtu***
Coal	252.9+	9075.3	1.2	33.7	11,355	103.1
Potash, Soda Ash, & Borate	1,712.2	Withheld	25.2	0.3	1,317	68.6
Iron	Withheld	910.7*	34.3	1.4	6,234	62.1
Copper & Nickel	0	3,057.9*	1.8	3.1	7,779	46.6
Lead and Zinc	Withheld	Withheld	Withheld	0.1	462	1.6
Gold	Withheld	3654.9*	Withheld	13.1	4,480	38.2
Silver	0	Withheld	Withheld	0.1	168	0.6
Phosphate Rock	Withheld	423.7	0.7	1.4	2,933	13.4
Crushed Rock	43.0*	4,011.3	5.4*	14.7	4,628	47.8
Total	2,008.1	21,133.8	68.6	67.9	39,356	
Subtotal Selected Commodities (Trillion Btu)	44.7	123.8	70.7	8.5	134.3	382.0
Total All Commodities (Trillion Btu)	50.0	163.0	108.6	10.5	158.6	491.0

Sources: U.S. Department of Commerce, Census of Mineral Industries, Various Commodities, 1997.
+Produced on site
*supporting data withheld
**Does not include withheld data
***Trillion ($ex10^{12}$)

Equipment-level and process-level energy consumption estimates are needed because improvements in energy efficiency will be driven by improvements in mining processes and technologies. The SHERPA "Mine Cost Estimating Model" and the "Mine and Mill Equipment Cost, An Estimators Guide" were used to estimate energy consumption by type of equipment for major areas of activity in mining.[23] As shown in Figure 1-9, materials handling accounts for 42 percent of the energy consumed. Diesel equipment accounts for 87 percent of energy used in materials handling. Beneficiation and processing consume 39 percent of the energy in mining. Crushing and grinding activities account for 75 percent of the energy used in beneficiation and processing. The remaining 19 percent of energy in mining is consumed by extraction activities. Pumps account for 41 percent of the energy in extraction.

Figure 1-9. Estimated Energy Consumpiton by Stage
(Percent of Total Energy Requirements)



Note: Data in figure represent estimated energy consumption in the mining stage (extraction, blasting, conveying and hauling) for the eight commodities selected for this report. (see Appendix for complete explanation)

[23] Estimates developed by BCS, Incorporated. The methodology is explained in the Appendix of this report.

1.4 Environmental Overview

The mining industry strives to conduct its business in an environmentally responsible manner. Mining, essential to our way of life, has touched less than one quarter of one percent of our nation's land. Yet mining by its very nature requires that land, air and water systems be disturbed. While the economic benefits of the industry are as important today as they ever were, the public has become increasingly concerned about the impact of mining on the natural environment.

The metals and industrial minerals that mining produces can find their way into the environment and become pollutants. Table 1-6 lists typical emissions, effluents, and solid wastes from mining operations by selected commodity. The fuels and chemicals the industry uses to do its job are also potential pollutants. Mining creates and employs hazardous substances that must be handled with care. Other pollutants produced by the mining industry, such as dust and noise, are more of a concern to the workers in the industry than to the public at large.

The challenge for mining companies is to find, extract and process mineral resources with the least possible disruption to the environment. To meet this challenge, they adopt a broad range of protective measures, including sensitive treatment of the land during exploration; environmental and aesthetic management of land under development; environmentally sustainable production procedures during the mining process; and reclamation practices aimed at meeting future land use designations.

Many different mine and mill materials are generated during extraction and beneficiation. These can be categorized as emissions, effluents, solid wastes and by-products, or hazardous waste. Another environmental issues is subsidence from underground mining.

Environmental Aspects of Mineral Exploration and Mine Site Preparation

Environmental protection begins at the earliest stages of mine exploration, long before the first mineral is extracted. During this stage, companies make every effort to minimize the impact of prospecting, drilling, trenching, road building, and other related activities. Exploration activities usually affect the environment only temporarily and, with proper planning, work can be carried out with minimal disturbance to land, vegetation, and wildlife habitats. Even so, companies have learned that it is important to keep local communities informed about their activities. This consultation process sets the stage for good community relations once mine planning begins.

Table 1-6.
Typical Emissions, Effluents, Byproducts, and Solid Wastes

Coal	***Potash, Soda Ash, Borate***	***Iron***	***Copper***
Methane Carbon dioxide Carbon monoxide Coal dust Radon gas Acid alkaline Sulfuric acid Trace metals Rock waste	Airborne particulates Calcination particulates Residual particulates Calciner offgases Particulate emissions from dryers Crushing ore particulates Ore insolubles Filter aid and carbon absorbent Scrubber water Spent carbon and filter wastes Suspended particulate matter Spent brine	Carbon dioxide Sulfur compounds Chlorides Fluorides Waste rock Tailings/silicate rock	APC dust/sludge Waste contact cooling water WWTP liquid effluent Process wastewaters Surface impoundment waste liquids Slime/muds Crud/gunk Tankhouse/anode slimes Acid plant blowdown Waste rock Tailings Raffinate or barren leachate Spent bleed electrolyte Discarded furnace and converter brick Chamber solids and scrubber sludges WWTP sludge
Lead & Zinc	***Gold & Silver***	***Phosphate***	***Crushed Rock***
Sulfur dioxide Particulates Lead oxides Iron pyrites Iron-limestone silicate slag Arsenic Acid plant blowdown WWTP effluents Slag granulation water Spent furnace brick Slurried APC dust Baghouse incinerator ash Ferrosilicon Tower blowdown Goethite Spent cloths, bags, filters Synthetic gypsum Surface impoundment solids Zinc-rich slag Zinc-lean slag	Sulfur dioxide Mine water Spent leaching solution Sulfuric acid Waste rock Spent ore Filter cake Gangue Slag WWTP sludge Spent furnace dust	Rock dust Phosphorus pentoxide Carbon monoxide Precipitator slurry Phossy water Furnace scrubber blowdown Furnace building washdown WWTP liquid Anderson filter media Slag Furnace offgas solids Wet process waste streams	Carbon dioxide (Lime) Rock dust

Sources: U.S. EPA, Office of Solid Waste, *Identification and Description of Mineral Processing Sectors & Waste Streams*, 1998.

Environmental Aspects of Mineral Extraction and Beneficiation

The term "mining" is used in a broad sense to include beneficiation. Beneficiation operations typically serve to separate and concentrate the mineral values from waste material, remove impurities, or prepare the ore for further refinement. Beneficiation activities generally do not change the mineral values themselves other than by reducing (e.g., crushing or grinding), or enlarging (e.g., pelletizing or briquetting) particle size to facilitate processing.

It is important to note that blasting activities can cause carbon monoxide poisoning of nearby residents if precautions are not taken. In recent years, there have been several instances of gases entering homes near blasting operations. Residents living in the homes were overcome by the gas, sickened, and rendered unconscious. When it is necessary to blast in close proximity to buildings, it is recommended that blasts be designed to allow for the gases to escape.

Environmental Aspects of Mineral Processing

Mineral processing operations are generally done after beneficiation and serve to change the concentrated mineral value into a more useful chemical form. This is often done by using heat (e.g., smelting and refining) to change the chemical composition of the mineral. Typically, beneficiation wastes are earthen in character, whereas mineral processing wastes are derived from melting.

Environmental Aspects of Mine Reclamation

Mine reclamation is the utilization and improvement of water and land resources for agricultural and other purposes. However, good-intentioned reclamation projects can potentially have harmful effects on the environment. Application of fertilizers and other chemicals on irrigated land increases the salt content of the soil and of the water returning to the source of irrigation.

Many abandoned mines cause environmental and aesthetic problems, damaging land and water, thereby limiting their usefulness. The benefits derived from eliminating these types of problems are many and varied. The land-oriented benefits include hunting, recreation, aesthetics, timber production, agriculture, and land values. Water-oriented benefits include fishing, re-establishment of natural stream biota, non-fishing stream recreation, and reduction in water treatment costs.

Reclamation of abandoned mines in rural areas, particularly in wildlife habitat management, is implemented to encourage the presence of game species and having a positive impact on hunting. Introduction of game food vegetation and fringe areas created through diversity of revegetative planting increase the availability of food to game and non game species while providing excellent habitat for wildlife. Reclaiming abandoned mines may not only enhance wildlife habitat, but also increase its aesthetic appeal and accessibility to the public. Abandoned mine lands can be reclaimed to open up new areas to nature walks, hunting, hiking, wildlife photography, bird-watching, picnicking, and camping.

Financial benefits from forest production on abandoned mine lands are other potential reclamation benefits. There are local markets for paper pulp, mine timbers, studs, wood chips, and fence posts. With careful planning, the needs of both wildlife and timber management may be met on reclaimed lands. Trees and other woody plant materials provide food and cover for a variety of wildlife species, while providing timber and wood products.

Abandoned mine reclamation and associated drainage abatement to provide protection for existing recreational fishing streams, reduces stress in the aquatic environment caused by water pollution, removes potential pollution sources which could harm the fishery resources, and restores streams that could support a fish population. More fishable streams provide benefits to increasing numbers of fishermen.

Swimming, wading, picnicking, camping, hiking, photography, and similar activities, are dependent upon, or enhanced by, high quality water resources. Reclamation of abandoned mine lands has opened up many new recreation areas that are otherwise good sites for these pursuits.

Subsidence from Underground Mining

Mine subsidence is movement of the ground surface as a result of the collapse or failures of underground mine workings. In active underground mining operations using longwall mining or high extraction pillar recovery methods, subsidence can occur concurrently with the mining operation in a predictable manner. In abandoned mines where rooms and unmined coal pillars are often left in various sizes and patterns, it may be impossible to predict if and when subsidence will occur. Mine subsidence resulting from abandoned room and pillar mines can generally be classified as either sinkhole subsidence or trough subsidence.

Sinkhole subsidence occurs in areas overlying underground mines that are relatively close to the ground surface. This type of subsidence is fairly localized in extent and is usually recognized by an abrupt depression evident at the ground surface as overburden materials collapse into the mine void. Sinkhole subsidence is perhaps the most common type of subsidence that occurs and has been responsible for extensive damage to many structures throughout the years.

Subsidence troughs over abandoned mines usually occur when the overburden sags downward due to the failure of remnant mine pillars, or by punching of the pillars into a soft mine roof or floor. The resultant surface effect is a large, shallow, yet broad, depression in the ground that is usually elliptical or circular in shape. Subsidence is usually greatest at the center of the trough and it progressively decreases until the limit of the surface area is reached. Horizontal ground movements also occur within a subsidence trough. Structures near the center of the trough can experience damage caused by the compression of the ground surface, and structures near the edges can be damaged by tension or stretching of the surface. Ground movement within a subsidence trough can result in damage to buildings, roadways, bridges, railroads, underground pipelines and utilities, and practically any other structure or feature that may be present. In addition, the flow of streams may be altered or disrupted, and surface cracks may occur, particularly near the edges of the trough.

The U.S. Department of Interior, Office of Surface Mining (OSM), Reclamation and Enforcement maintains the Abandoned Mine Land Inventory System (AMLIS). The AMLIS is an inventory of land and water impacted by past mining. The inventory contains information on the location, type, and extent of abandoned mine land (AML) impacts and reclamation costs. Table 1-7 shows subsidence-prone area measured in acres. OSM defines a subsidence-prone area as any surface expression of AML-related subsidence such as tension cracks, potholes, troughs, shearing faults, or caving caused by AML-related underground mine voids which damages property and poses danger to human safety, health and general welfare. The age of the subsidence occurrence is limited to the past five years. There are 11,658 acres of subsidence prone area attributed to strictly underground mining, 326 acres attributed to strictly surface mining, and an additional 2,503 attributed to a combination of underground and surface mining.

Table 1-7.
Mine Subsidence in the U.S. by Mine Type and Processing – 2000 (Acres)

Underground	Surface	Both Underground & Surface	Processing	Total
11,658.5	326.0	2,503.0	5.4	14,492.9

Sources: U.S. Department of the Interior, Office of Surface Mining, *Abandoned Mine Land Inventory System*, 2000.

Environmental Protection Standards

Environmental protection standards in the U.S. are some of the most stringent in the world and often serve as models for developing nations. These laws cover our land, air, water, historic sites, endangered species, and other important areas of concern. America's modern mining industry is also proactively involved in environmental mitigation, spending billions of dollars each year to enhance the air and water quality, reclaim mined land, provide habitat for wildlife, and create wetlands for migratory waterfowl and recreation.

The Environmental Protection Agency reports that more than $1.5 trillion dollars has been spent in the U.S. on pollution abatement and control since 1982. Each year more than $100 billion is added to that figure.

As public concern about the quality of the environment has intensified in recent decades, laws and regulations have been written and enforced that prescribe the quality of land, air, and water that must be maintained during mining operations and left when mining ceases. However, frequent fluctuations and uncertainty regarding the future of standards can reduce the economics of mining particular deposits. Table 1-8 is a list of federal environmental laws and the provisions that affect mining. State laws also govern all aspects of mining under a state's jurisdiction.

Table 1-8. Federal Requirements Affecting the Mining Industry

Requirement	Provisions that Affect Mining
Anthracite Mine Water Control Act	Regulates the drainage of water from anthracite coal mines
Archeological Resources Protection Act of 1979	Protect archeological resources on public and Indian lands from activities such as drilling, mining, quarrying, and the construction of access roads
ATF Explosives Regulation	Regulates distribution of explosives
Clean Air Act of 1955 and its amendments	Sets air quality standards
Clean Water Act	Directs standards to be set for surface water quality and for controlling discharges to surface water
Comprehensive Environmental Response, Compensation and Liability Act	Owners/operators required to report releases of hazardous substances to the environment and inventory chemicals handled; remedial actions established
Emergency Planning Community Right to Know Act	Requires annual reporting of chemicals released or recycled
Endangered Species Act of 1973	Plants and animals listed that are threatened; protection plans mandated
Environmental Policy Act of 1969	Requires interdisciplinary approach to environmental decision-making
Federal Land Policy and Management Act	Prevents undue and unnecessary degradation of federal lands
Federal Mine Safety & Health Act of 1977	Protects the health and safety of miners
Forest Service Regulations	Provides for a minimum adverse environmental impact on the National Forest System surface resources from mining operations
Historic Preservation Act	Protects historic sites
Migratory Bird Treaty Act	Prohibits killing of nearly all bird species
Mineral Exploration Act of 1995	Guidelines for mineral exploration on public lands
Mining and Minerals Policy Act of 1970	Encourage orderly and economic development of domestic mineral resources
Mining Law of 1872	Directs land management policy
Multiple Surface Use Act of 1955	Curtails non-mining use of surface mining claims
Occupational Safety and Heath Act	Assures safe and healthful working conditions for working men and women
Organic Act of the National Park Service	Regulates the use of National Park System areas
Outer Continental Shelf Lands Act	Provides for orderly and safe environmental development of the shelf
Pollution Prevention Act of 1990	Pollution reduction
Resource Conservation and Recovery Act of 1976 (RCRA)	Statute governing solid wastes
Safe Drinking Water Act	Directs standards to be set for quality of drinking water supplied to the public (states are primary authorities) and regulating underground injection operations
Solid Waste Disposal Act of 1965	Regulates generation, storage and disposal of hazardous waste and manage solid, non-hazardous waste (states)
State Regulations	Permitting
Surface Mining Control and Reclamation Act of 1977	Prevents and repairs environmental damage from coal strip mining
Surface Resources Act of 1955	Governs the disposal and removal of certain mineral waste materials
Toxic Substances Control Act of 1976	Requires regulation of chemicals that present risk to health or environment
Uranium Mill Tailings Radiation Control Act of 1978	Provides for the stabilization, disposal, and control of radioactive uranium mill tailings at mill operations
Wild and Scenic Rivers Act of 1968	Mining regulations shall provide safeguards against pollution of system rivers and related scenery
Wilderness Act of 1964	Prohibits new mining activity in these areas
Wildlife Refuge System Administration Act of 1966	Regulates and controls activities such as hunting, fishing, and mining on these designated lands

Source: National Mining Association, *Facts about Minerals*, p. 41, 1999-2000.
U.S. Environmental Protection Agency, www.epa.gov
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