Energy use in US minerals and primary metals industry

by Dan Nilsson

In the 1970s the energy costs increased fast and many steps were taken to reduce energy consumption in the mineral industry.
This article describes the trend in energy consumption in the mineral industry and the primary metals industry for production of selected mineral commodities during the last decades.

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In the mid 70s, the energy cost increased fast and the interest for energy saving grew. Many steps were also taken to reduce the energy consumption in the mineral industry as well as in other industries.

There are of course many reasons to keep an eye on the energy consumption. During the last decade, a new reason has appeared. Energy production and consumption is closely connected with the emissions of gasses, which many believe can be dangerous to our atmosphere.

Sources

Information about energy consumption in the mineral industry can be found in publications from the Bureau of the Census, US Department of Commerce. Economic Census have been taken since 1809 and are performed every five year: 1977, 1982, 1987 etc. The mineral industry includes mining and processing of metallic ores, coal and nonmetallic minerals. Oil and gas extraction is also included.

Information about the energy consumption in the primary metal industries is nowadays collected and published by the Energy Information Administration, US Department of Energy. The latest study is from 1988. For earlier years, such information can be found in publications from the Bureau of the Census.

This paper is based upon these sources. In some cases, production data has been completed with data published by the US Bureau of Mines.

Describing primary energy consumption requires careful attention to the way energy is consumed and produced. This problem is discussed in publications from the Energy Information Administration, and will not be repeated here.

Table 1
Convertion to Btus

	kBtu
Electric energy, 1 000 kWh	3 412
Coal, short tons	22 360
Fuel oil, distillate, barrel	5 825
Fuel oil, reidual, barrel	6 287
Natural gas, 1 000 cu.ft	1 031

Note: 1 barrel = 42 gallons

Convertion to Btus

Energy data are converted to Btu to provide comparable figures, as shown below. A Btu is the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit. (Btu = British thermal unit).

In the figures, attached to this text, the energy consumption is shown in Btus per ton, but also converted into kWh-equivalents per ton as in table 1, page 20.

By using these energy conversion factors, one gets the net energy consumption. In reality, the energy consumption is higher. This is realized if one considers that much of the heat value in coal used in power plants, when generating electricity, is lost through chimneys and cooling towers. Energy is also used for production and transportation of coal and oils to the consumers in the mineral industry. However, it has not been possible to consider that here.

Total energy consumption

In 1987, the US mineral industry consumed 1968.4 trillion Btu, which was 40 per cent higher than 30 years ago, but 2 per cent lower than in 1982. Trillion $=10^{12}$.

The corresponding consumption in the primary metal industries in 1988 was 2 875 trillion Btu. The primary metal industries is thus a larger consumer of energy than the mineral industries.

Energy consumption by industry group

Establishments classified as oil and gas extraction industries were the largest consumers of energy in the US mineral industry in 1987, table 2, page 21, with 70 per cent of the total consumption. However, 55 per cent of that is produced and consumed at the same establishment.

In the metal mining industry, the iron ore industry is the largest consumer, followed by copper mining. The figures for iron ore

Table 2
Energy consumed 1987 in the US mineral industry by industry group

	Trillion Btu	Per cent
Metal mining	119	6
of which iron ore	48.3	
copper ore	48.3	
lead and zinc	2.2	
gold ore	13.4	
silver ore	2.4	
Coal mining	163	8
Oil and gas extraction	1 381	70
of which purchased	611.0	
Nonmetallic minerals	305	16
of which chemicals and phosphate	116.0	
Total	**1 968**	**100**

mining includes pelletizing, which is a very energy consuming operation.

In the nonmetallic mineral industry, mining and processing of chemical and fertilizer minerals is the largest consumer of energy, with 38 per cent of the total consumption in that group.

From 1982 to 1987, the consumption of energy increased in metal mining and processing with 13 per cent, increased in coal mining and processing with 8 per cent, increased in mining and processing of nonmetallic minerals (except fuels) with 21 per cent, but decreased in oil and gas extraction with 8 per cent.

In the primary metal industry group, blast furnaces with steel mills is by far the largest consumer, with 72 per cent of the total consumption in 1988, table 3, page 21.

Unfortunately, it is not possible any longer to get energy consumption information for other industry groups, such as copper smelters etc.

Energy consumption by kind of energy

Energy is used by companies as fuel oil, coal, coke, natural gas, electric power etc. The consumption in the mineral industry in 1987 is shown in Table 4, page 21, oil and gas extraction included.

Some of the energy is converted to other types before final use, which means that the final consumption of electric power is 8–9 per cent higher than what the above figure indicates.

Table 5, page 22 shows the corresponding picture for primary metal industries.

Table 6, page 22 shows the energy consumed by type. Oil and gas extraction has been excluded. The table shows that electric power is the most important type of energy consumed in the mineral industry. Coal is the most important energy source for the primary metal industry, used mainly by the steel industry.

During the last decades, there has been a slow change in the mix of energy used. The proportion of coal and natural gas has decreased, and the proportion of diesel fuel and electricity has increased.

The relation between different types of energy is quite different in different industry groups. For iron ore, the consumption of coal and natural gas is high. The reason is that coal and gas is used in pelletizing, which is included in the definition of the mineral industry. The copper mining industry requires more diesel fuel, and less electric power, than the mining of lead and zinc, because copper is mainly mined in open pits, but lead and zinc underground,

Table 3

Energy consumed 1988 in the US primary metal industry by industry group

	Trillion Btu	Per cent
Blast furnaces and steel	2 067	72
Primary aluminium	258	9
Others	550	19
Total	**2 875**	**100**

Table 4
Energy consumed 1987 in the US mineral industry in physical units

	Purchased	Other	Total
Coal (1 000 metric tons)	2 560	251	3 011
Crude Oil (1 000 barrels)		10 843	10 843
Fuel oil (1 000 barrels)	31 862		31 862
Gasoline (million gallons)	254		254
Gas (billion cubic feet)	444	686	1 130
Electric energy (million kWh)	68 176		68 176
Others, undistr. (USD millions)	682		682
Total (trillion Btu)	1 192	776	1 968
Per cent	60	40	100

Note: Energy produced and consumed at same establishment, mainly for oil and gas extraction.

Table 5
Energy consumed 1988 in the US primary metal industry in physical units

	Purchased	Other	Total
Coal (1 000 metric tons)	2 404	35 807	38 211
Coke and breeze (1 000 metric tons)	13 535	607	14 142
Fuel oil (1 000 barrels)	8 782	881	9 663
Gas (billion cubic feet)	710	20	730
LPG (million gallons)	60	6	66
Electric energy (million kwh)	150 834	-1 632	149 202
Total (trillion Btu)	1 773	1 102	2 875
Per cent	62	38	100

Note: Mainly coal in the steel industry.

where more electric-driven equipment is employed.

Energy consumption for production of selected minerals

The energy consumption figures above can be used to calculate the amount of energy needed to produce one ton of different mineral products. Such figures represent averages for the whole US industry. However, each mine is unique, different flow sheets are used in processing plants, magnetite requires less energy than hematite in pelletizing etc. The figures can therefore not be applied to a single mineral producer.

Mining and ore processing

Table 7, page 22 summarizes the energy consumption per ton of crude material mined and processed in 1987. The high figure for iron ore is explained by the fact that pelletizing is included. Mining and processing of phosphate rock have the lowest energy requirement.

Figures 1a and 1b, page 24 shows the trend during the last decades.

The figure shows that the energy consumption for iron ore mining and processing increased fast during the 50s and 60s. The reason is that iron ore mining shifted away from the direct shipping types of ore to low-grade taconites, which require processing and pelletizing and a corresponding high energy consumption. However, during the last 15 years, the reduction in energy consumption has been considerable.

For lead, zinc and copper ores, there have been a rather even decrease in energy consumption. This is also true also for gold ores, although not shown on the figure.

For coal, the energy consumption per ton is almost the same as before. But mining and processing of phosphate rock show a significant reduction in energy consumption.

However, it is of greater interest to calculate and compare the energy consumption per ton of output from the mineral industry. This is calculated in Table 8, page 23. The table shows that gold concentrate has the highest energy requirement, followed by copper.

Figure 2, page 25 shows the trend during the last decades for some of the products. The figure illustrates not only the trends in

Table 6
Energy consumed by type 1987, per cent of energy content

	Mineral industry	Primary metal industry
Electric power	24	18
Fuel oils	22	2
Coal	11	39
Coke and breeze	–	13
Natural gas	20	26
Gasoline	2	–
Others and undistr.	21	2
	100	100
Total, trillion Btu	587	2 875

Note: Excl Oil and Gas extraction.

Table 7
Energy consumed 1987 for US mining and processiong of selected types of ores

	Mine production Mt of crude ore	Trillion Btu	Thusand Btu/ton of crude ore
Metal mining			
Iron ore	146.9	48.3	329
Coper ore	246.1	41.0	167
Lead and zinc ore	9.6	2.2	229
Gold ore	79.5	13.4	169
Silver ore	9.2	2.4	261
Non metallic minerals			
Coal (cleaned)	833.7	163.1	196
Phosphate rock	146.0	16.2	111

Table 8
Energy consumed 1987 in US mining and processing for production of selected types of concentrates

	Mt of concentrate	Trillion Btu	Million Btu/ton of concentrate
Iron ore products	47.7	48.3	1 013
Coper conc (s t)	3.4	41.0	12 060
Lead and zinc conc	0.7	2.2	3 140
Gold conc. (s t)	0.3	13.4	44 700
Silver conc	n a	2.4	–
Phosphate (s t)	60.9	16.2	266

Note: Mainly pellets.

Table 9
Energy consumed 1987 in US mining and processing per ton of recoverable metal

	Mt of rec metal	Trillion Btu	M Btu/ton of rec. metal
Iron	30.5	48.3	16
Copper	1.24	41.0	33.1
Lead and zinc	0.531	2.2	4.1
Gold	154.1	13.4	87.0
Silver	1 241	2.4	1.9

Note: Gold and silver metric ton.

Table 10
Energy consumed for US primary metal production

	Mt metal	Trillion Btu	Million Btu/ton metal
1988 – total			
Steel	90.6	2 067.0	22.8
Primary aluminium	3.95	258.0	65.3
1988 – purchased			
Steel	97.1	1 007.0	10.4
Primary aluminium	3.95	248.0	62.8
1981 – purchased			
Steel	109.6	1 288.8	11.8
Primary aluminium	4.49	312.8	69.7
Primary copper	1.54	62.4	40.5
Primary lead	0.50	12.7	25.4
Primary zinc	0.34	11.9	35.0

energy requirements but also the effects of changes in the relation between amount of concentrate and crude ore. A declining ore grade will thus result in less concentrate for sale and a higher energy consumption figure per ton of concentrate, even if the corresponding figure per ton of crude ore is constant.

For iron ore products, mainly pellets, the energy consumption has dropped during the last decade. For lead and zinc concentrate, the energy consumption per ton of concentrate dropped in the 50s and 60s but has stayed constant after that. For copper, however, the trend has been negativ, more and more energy has been used per ton of concentrate produced, which is a result of declining oregrades.

Finally it is of interest to study the energy consumption per ton of recoverable metal in the ore. This is the most proper way to describe the energy consumption and is shown in Table 9, page 23.

This calculation shows that mining and processing of copper ore require much more energy per ton of recoverable metal, than iron, lead and zinc. This is of course explained by the lower metal content in crude ore.

The corresponding figures during the last decades are shown in Figures 3a and 3b, page 25 and 26. For many years, the energy consumption per ton of recoverable metal increased for iron and copper, but during the last decades the energy consumption has dropped for iron, copper, lead and zinc.

Energy consumption for primary metal production

Energy consumption figures for all major metals are after 1981 available only for steel and aluminum.

During the years 1966 through 1981, the Bureau of the Census published data on the consumption of "purchased fuels and electric energy" for the major metals. The Department of Energy now publishes estimates of "Purchased Fuels and Electric Energy Consumed", as a continuation of the Census Data Series, but only for steel and

primary aluminum. Only for steel, there is significant diffrence between the consumption of purchased energy and the total energy consumption. The power consumption figures one gets for copper, lead, zinc, etc, by using purchased energy therefore give a ggood picture also of the total energy requirement.

Table 10, page 23 shows that smelting and refining of aluminum requires 65 M Btu per t metal, compared with only 22 M Btu for steel, of which 50 per cent are purchased.

Table 10 shows that the consumption of purchased energy decreased from 1981 to 1988 with 5 per cent per ton of steel and with 10 per cent for primary aluminum.

Figure 4 (page 26) shows the trend in consumption of purchased energy for primary metal production during the last decades. The figure shows a sharp reduction in energy consumption, especially for aluminum and zinc.

Of course, the figures above shall not be used for a comparison between the use of, for example, steel and aluminum in different applications, other factors must also be considered, such as the possibility to recycle the metal..

Table 11

Total energy consumption for US production of selected metals million Btu per metric ton metal

	Mining and processing	Metal production	Total
Iron (steel)	2	22	>24
Copper	33	41	74
Lead	4	25	29
Zinc	4	32	36
Aluminium	?	65	>65

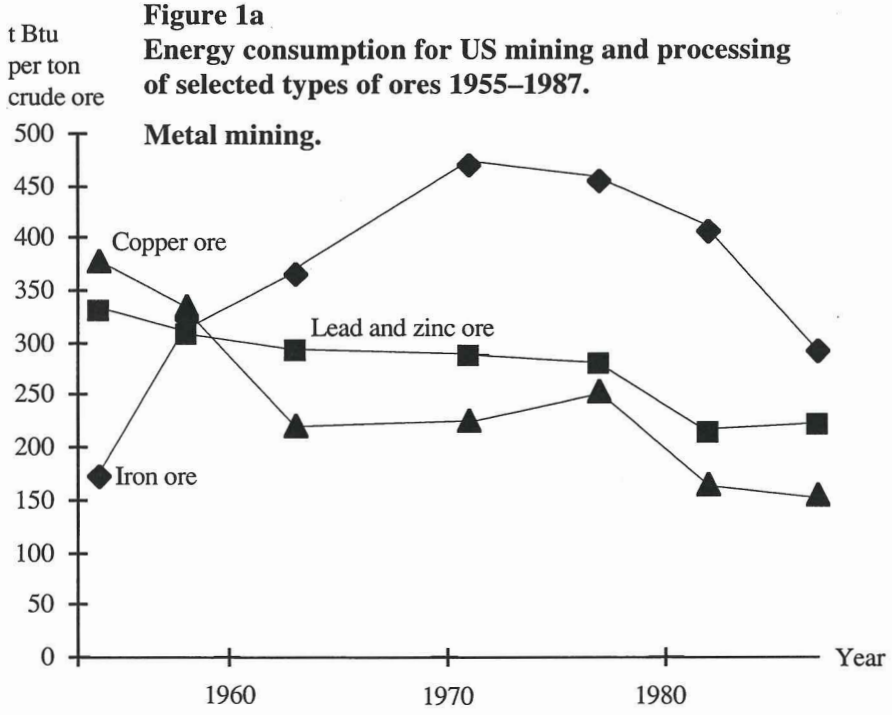


Figure 1a
Energy consumption for US mining and processing of selected types of ores 1955–1987.
Metal mining.

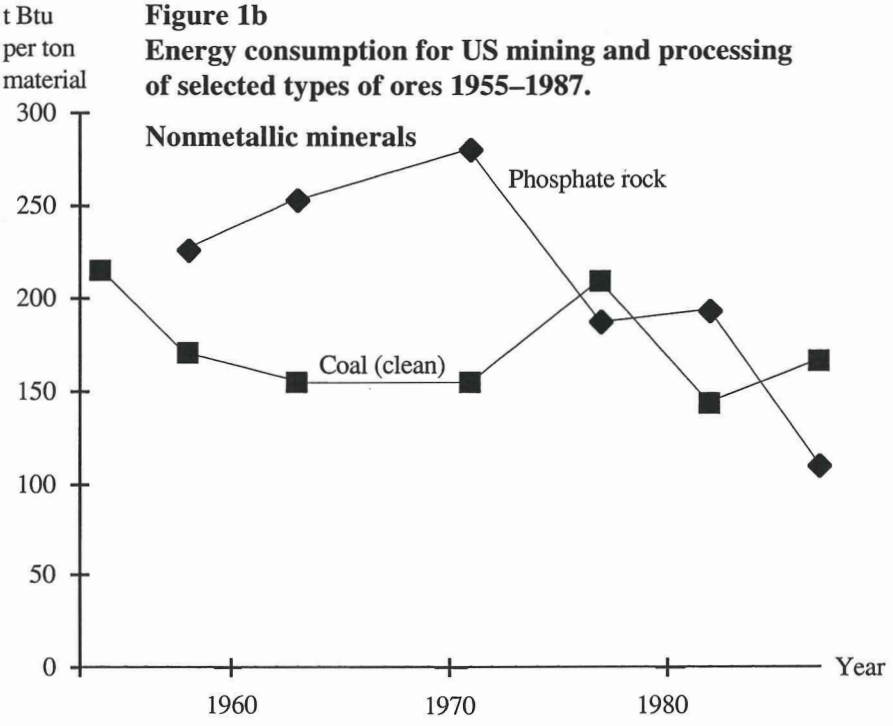


Figure 1b
Energy consumption for US mining and processing of selected types of ores 1955–1987.
Nonmetallic minerals

Figure 2
Energy consumption for US production of selected types of concentrates 1955–1987.

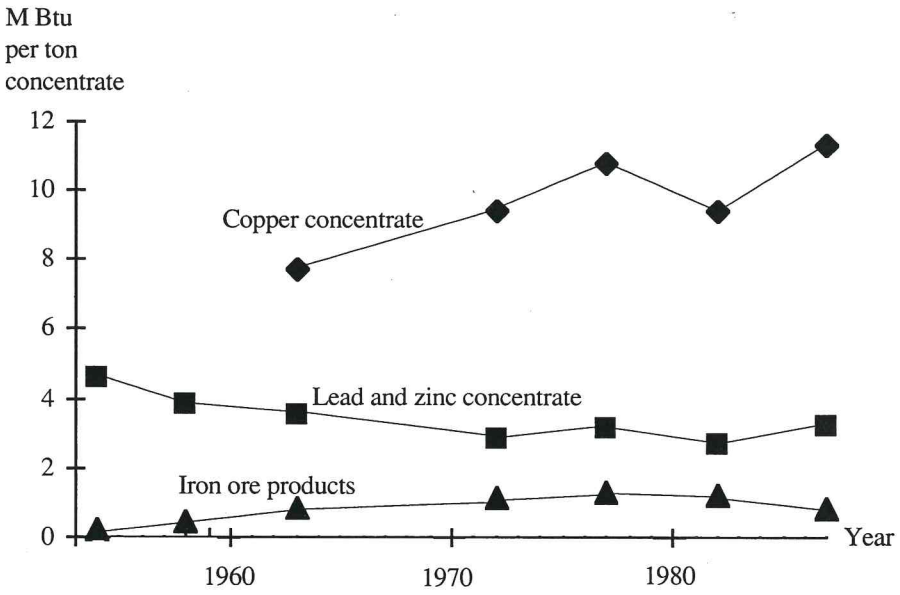
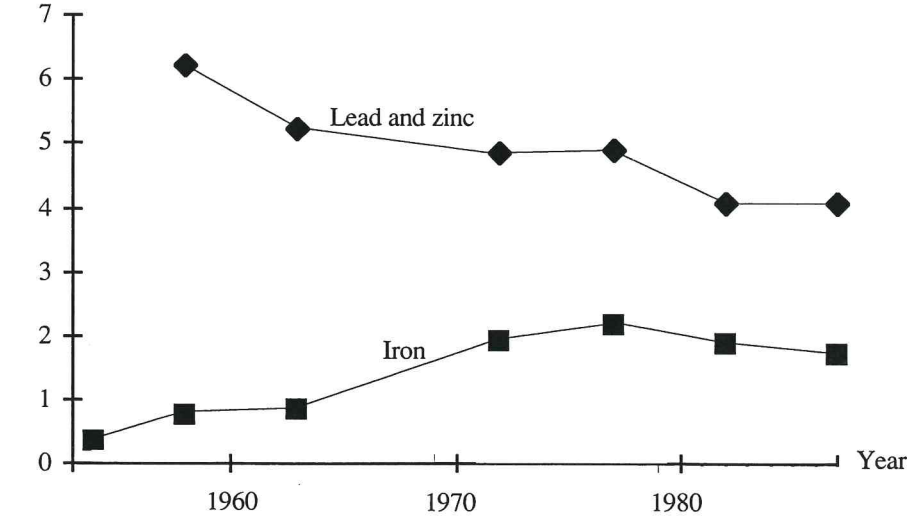


Figure 3a
Energy consumption for US mining and processing per ton of recoverable metal 1955–1987.

Lead, zinc and iron.



Total energy consumption for production of selected metals

With information now available about the energy consumption per ton metal in mining and processing as well as in metal production, it is possible to add them together to get a picture of the total energy consumption. This is done in Table 11, page 24 and in figure 5, page 26.

The table shows that production of copper has the highest energy requirement, some 74 M Btus per ton metal, compared with only 24 for iron (steel).

However, production of steel may require more energy than what is shown above, because energy needed for transportation of the iron ore products between the mine area and the steelwork is not included.

For all the metals, it must also be remembered that there is an energy content in the export and import of semi-finished products used in the production of the refined products. For example: for aluminium, energy is needed for mining, processing and transportation of bauxite and aluminumoxid, used for aluminum metal production. This has not been included here. The total energy consumption for production of aluminum is therefore higher and probably also higher than for copper.

The table above also shows that the relation between the energy used in the mineral industry (mining and processing) and the primary metal industry is quite different for the different metals. Mining and processing accounts for over 40 per cent of the total energy consumption for copper, but less than 15 per cent for the others. ■