Chapter 7

The Steel Industry

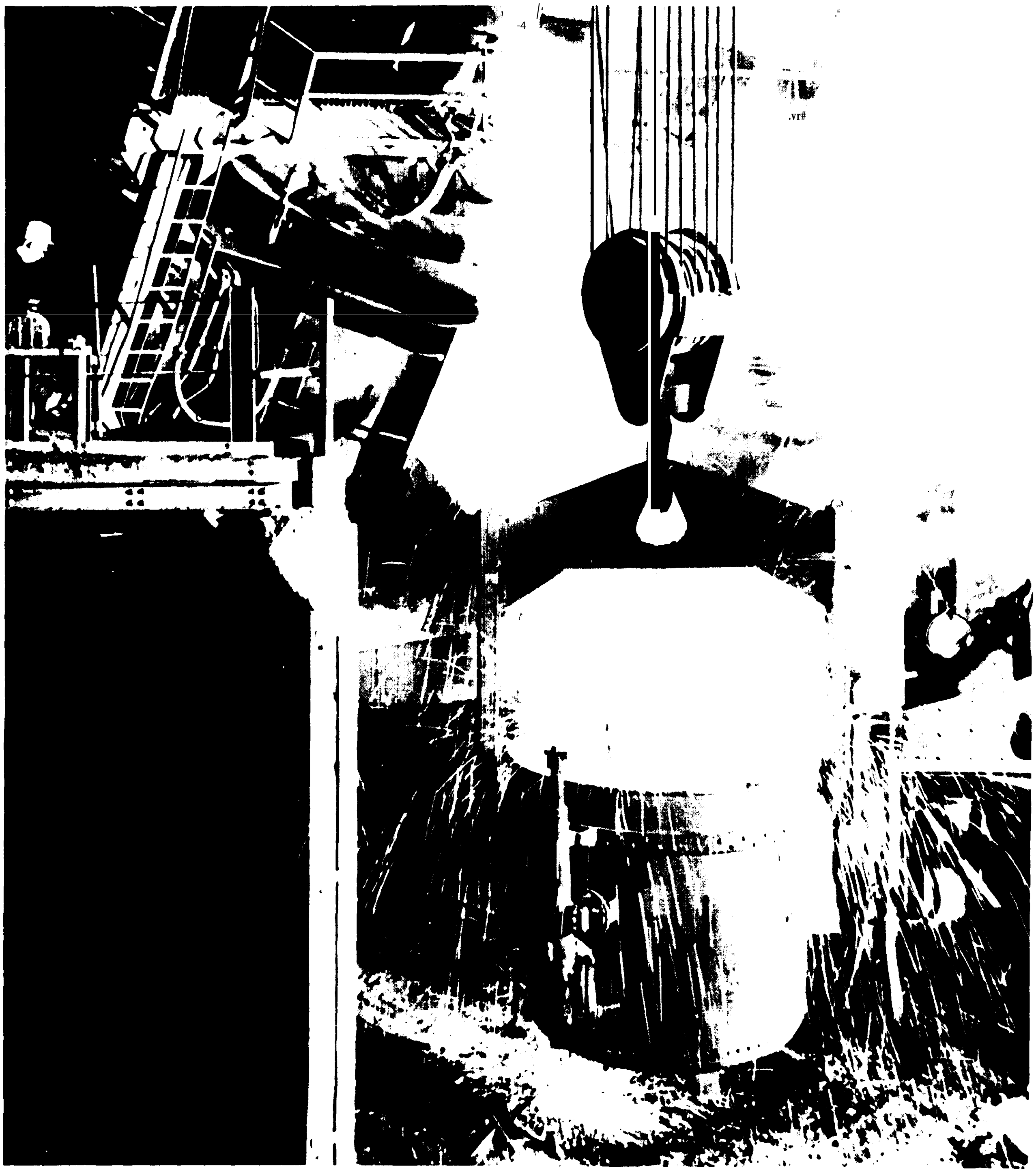

Photo credit American Iron and Steel Institute

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INDUSTRY OVERVIEW

Steel is made from iron ore, iron scrap, coal (converted to coke), and limestone. it is one of the largest and most versatile bulk commodities in commercial use, having many structural applications and competing successfully with other structural materials, such as aluminum, plastics, and wood, for a variety of markets. International competition within the steel industry has reduced U.S. production and is forcing major modernizing investments, despite dim future prospects and relatively limited investment capital. Among other efficiency gains, these investments are dramatically reducing the energy input per ton of steel. *

Historically, steel production has followed the business cycle because a large share of steel is used for highly cyclical construction and consumer durables.[1] After hitting a peak of over 100 million tons of steel shipped in 1979, the industry has been especially hard pressed because the Nation has experienced its worst recession since the 1930's and because import competition has steadily intensified.[2] In 1981, the domestic steel industry shipped 87 million tons of product (up 4 million tons from 1980) and on the average about 79 percent of raw steel making capacity was in operation. In 1982 shipments plummeted to just under 60 million tons and less than 50 percent of capacity was utilized.[3]

Industry Structure

The domestic steel industry, classified as SIC 3312 includes blast furnace-based integrated steelmaker, nonintegrated minimills, and independent producers of wire, bars, and pipe who purchase and process semifinished steel (see table 46). In 1977, 396 companies operated 504 plants and employed 442,000 people. The 91 million tons of steel they shipped had a value of $36.2 billion and represented about 1.9 percent of the U.S. gross national product (GNP).[4] Of these companies, the top 16 companies accounted for approximately 83 percent of blast furnace and steel mill product shipments (see table 47).

Steel producers can be classified as either integrated or nonintegrated. Nonintegrated mills are further divided into minimills and specialty

Table 46.—Definition of SIC 33—The Primary Metals Industry

This major group includes establishments engaged in the smelting and refining of ferrous and nonferrous metals from ore, pig, or scrap; in the rolling, drawing, and alloying of ferrous and nonferrous metals; in the manufacture of castings and other basic products of ferrous and nonferrous metals; and in the manufacture of nails, spikes, and insulated wire and cable. This major group also includes the production of coke. Establishments primarily engaged in manufacturing metal forgings or stampings are classified in Group 346.

The major 3-digit industries are:

SIC	Title
331	Blast furnaces, steel works, and rolling and finishing mills
332. . . .	Iron and steel foundries
333. . . .	Primary smelting and refining of nonferrous metals
334. . . .	Secondary smelting and refining of nonferrous metals
335. . . .	Rolling, drawing, and extruding of nonferrous metals
336. . . .	Nonferrous foundries (castings)
339. . . .	Miscellaneous primary metal products

Within SIC 331, 4-digit industries include:

SIC	Title
3312 . . .	**Blast furnaces (including coke ovens), steel** works, and rolling mills
3313 . . .	Electrometallurgical products
3315 . . .	Steel wire drawing and steel nails and spikes
3316 . . .	Cold rolled steel sheets, strips, and bars
3317 . . .	Steel pipe and tubes

SOURCE: Office of Management and Budget, Standard *Industrial Classification Manual. 1972*

● For more information, see table 53 and fig. 37.

[1] *Technology and* Steel *Industry Competitiveness, ch. 5 (Washington,* D. C.: U.S. Congress, Office of Technology Assessment, OIA-M-122 June 1980)

[2] Robert W. Crandall, *The U.S.* Steel *Industry in Recurrent Crisis: Policy Options in a Competitive World* (Washington, D. C.: The Brookings Institution, 1981); and American Iron and Steel Institute, *Steel at the Crossroads: The American Steel Industry in the 1980s,* ch. 2, 1980.

[3] American Iron and Steel Institute, *Annual StatMlca/ Report* for 1981 (May 1982) and 1982 (unpublished).

[4] Ibid., and U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1980,* pp. 437, 444.

Table 47.—Steel Shipments by Major U.S. Companies, 1976

	Steel shipments	
	Thousands of net tons	Percent of total
United States Steel Corp.	19,486	21.8
Bethlehem Steel Corp.	12,600	14.3
National Steel Corp.	7,644	8.8
Republic Steel Corp.	6,535	7.3
Inland Steel Co.	5,600	6.3
Armco Steel Corp.	5,082	5.7
Jones & Laughlin Steel Corp.	5,097	5.7
Lykes-Youngstown Corp.	3,388	3.8
Wheeling-Pittsburgh Steel Corp.	2,816	3.1
Kaiser Steel Corp.	1,616	1.8
McLouth Steel Corp.	1,639	1.8
CF&I Steel Corp.	1,101	1.2
Interlake, Inc.	797	0.9
Northwestern Steel & Wire Co.	839	0.9
Cyclops Corp.	849	0.9
Allegheny -Ludlum Industries, Inc.	383	0.4
Major company total	75,872	84.7
Industry total	89,450	100.0

SOURCE: "1976 Steel Industry Financial Anal@ s," Iron Age, *Apr. 25, 1977.*

steel **companies (see table 48). In integrated plants, the primary** source of iron is iron ore in the form of lump ore, sinter, or pellets. Iron ore is converted into steel through a series of processing steps, including production of coke, pig iron, raw steel, and steel products. Minimills are generally much smaller, have more limited product lines, and one less stage of production since the process begins with steel scrap or directly reduced iron, feedstocks that do not require gross refining in a blast furnace (see table 48). Specialty companies are also smaller, but have a much larger number of specialized products than do minim ills. Both smaller operations rely primarily on the electric arc furnace to make molten metal, but the specialty producer tends toward higher grade ferrous scrap and refined alloy metals in order to make high performance goods.

The annual production capacities of steel plants operated by the three major sectors of the steel industry are shown in table 48. With respect to the scale of production in U.S. plants, **46 of the 50 plants with raw steel productive capacity above 1 million** tons per year in 1978 **were owned by the 17 integrated companies. In contrast, all but one of the 54 plants operated by 43 scrap-based companies had annual production capacities below 1 million tons. All but nine of the scrap-based plants had less than half of that**

Table 48.–Capacities of Steel Plants in the United States, 1978

	Number of plants operated by the —			
Size-range raw steel capacity, tonnes/yr	17 integrated companies	33 speciality companies	43 scrap/DRI[a] companies (minimills)	Total number of plants in size range
7,256,000-8,162,999	2	0	0	2
6,349,000-7,255,999	1	0	0	1
5,442,000-6,348,999	1	0	0	1
4,535,000-5,441,999	3	0	0	3
3,628,000-4,534,999	4	0	0	4
2,721,000-3,627,999	9	0	0	9
1,814,000-2,720,999	11	0	1	12
907,000-1 ,813,999	15	3	0	18
816,300- 906,999	1	0	0	1
725,600- 816,299	0		1	2
634,900- 725,599	0	0	1	1
544,200- 634,899	1	3	3	7
453,500- 544,199	1	1	3	5
362,800- 453,499	1	1	4	6
272,100- 362,799	2	1	5	8
181,400- 272,099	2	2	14	18
144,190- 181,399	1	2	6	9
126,980- 144,189	0	2	4	6
90,700- 126,979	0	10	9	19
68,025- 90,699	0	3	2	5
45,350- 68,024	2	10	9	21
22,675- 45,349	0	5	0	5
0- 22,674	0	3	0	

[a] DRI = directly reduced iron (see p. 153).

SOURCE: American Iron and Steel Institute.

productive capacity because, in general, profit rates were greater for small plants that bought scrap and sold products within a single region.

The centers of integrated steel production continue to be in the traditional industrial areas of the North Central and Eastern States (see table 49). The smaller, scrap-based companies tend to be distributed more uniformly among general population and manufacturing centers.

The major forms of steel are sheet and strip, structural and plate, bars, pipes and tubes, wire and wire products, and tin mill products. Major markets for steel include the automotive, construction, machinery and equipment, containers and packaging, and oil and gas industries and steel service centers. In 1980, the distribution of steel products by grades was 84.7 percent carbon steel, 13.8 percent alloy steel, and 1.5 percent stainless steel. A projection of steel product mix is shown in table 50.

Economics of Steel Production

Profitability

In recent years, the slowing demand for U.S. steel has resulted in low or negative profits for many U.S. steel producers. Capital-intensive industries like steel are the most severely penalized by accelerating inflation and highly cyclical economic conditions. From 1967 to 1980, steel mill product prices rose 22.6 percent faster than consumer prices, while the average real rate of return after inflation in the steel industry, which remained around 10 to 11 percent throughout the early 1950's, declined steadily after 1955 and fell **to below zero in the mid-l970's. Moreover, profitability in steel production was not uniform.** The average rate of return on investment for major integrated steel companies was 1.4 percent in 1977 and 6.2 percent in 1978. Nonintegrated steel companies had an average rate of return on investment of 6.2 percent in 1977 and 12.3 percent in 1978. Alloy and specialty steel companies had average rates of return on investment of 9.1 percent in 1977 and 11.1 percent in 1978.[5]

Table 49.—Raw Steel Production by State, 1980

States	Thousands of tons
Pennsylvania	23,517
Indiana	19,820
Ohio	16,100
Illinois	8,961
Minnesota, Missouri, Oklahoma, Texas, Nebraska, and Iowa	8,642
Michigan	7,877
Virginia, West Virginia, Georgia, Florida, North Carolina, South Carolina, and Louisiana	6,066
Rhode Island, Connecticut, New Jersey, Delaware, and Maryland	5,161
Arizona, Colorado, Utah, Washington, Oregon and Hawaii	4,795
Alabama, Tennessee, Mississippi, and Arkansas	3,452
New York	2,675
California	2,628
Kentucky	2,141
Total	111,835

SOURCE: American Iron and Steel Institute,

Table 50.—Projection of Product Mix in U.S. Steel Production, 1976-2000

Product	Distribution in percent			
	1976[a]	1980	1985	1990
Structural	10	12	12	12
Plate	9	10	10	10
Rails	2	2	2	2
Hot-rolled bars	9	7	7	7
Other bars ... ,	7	9	9	9
Pipes and tubes	9	11	13	15
Wire	3	3	2	2
Tin mill products	7	7	6	6
Hot-rolled sheet and strip.	17	15	15	14
Cold-rolled sheet and strip	20	17	16	15
Galvanized sheet	7	8	8	8

[a] Average of 1975.77 used to eliminate fluctuations.

SOURCE: American Iron and Steel Institute and the Office of Technology Assessment,

After-tax profits as a percentage of stockholder equity in the steel **industry were** below that for all manufacturing (often by a substantial margin) in every year since 1957, except during the severe recession of **1974.** In fact, for most of the 1970's the after-tax rate of return on stockholder equity in the steel industry was below the prime lending rate (quite the reverse of the 1950's and 1960's).[6]

Capital Investment

High inflation and high interest rates during the 1970's contributed to: 1) slowing the overall investment in the steel industry, 2) reducing the ability of the industry to borrow funds to make

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[5] *Technology and Steel Industry Competitiveness,* ch, 4, op. cit., pp. 119-124.

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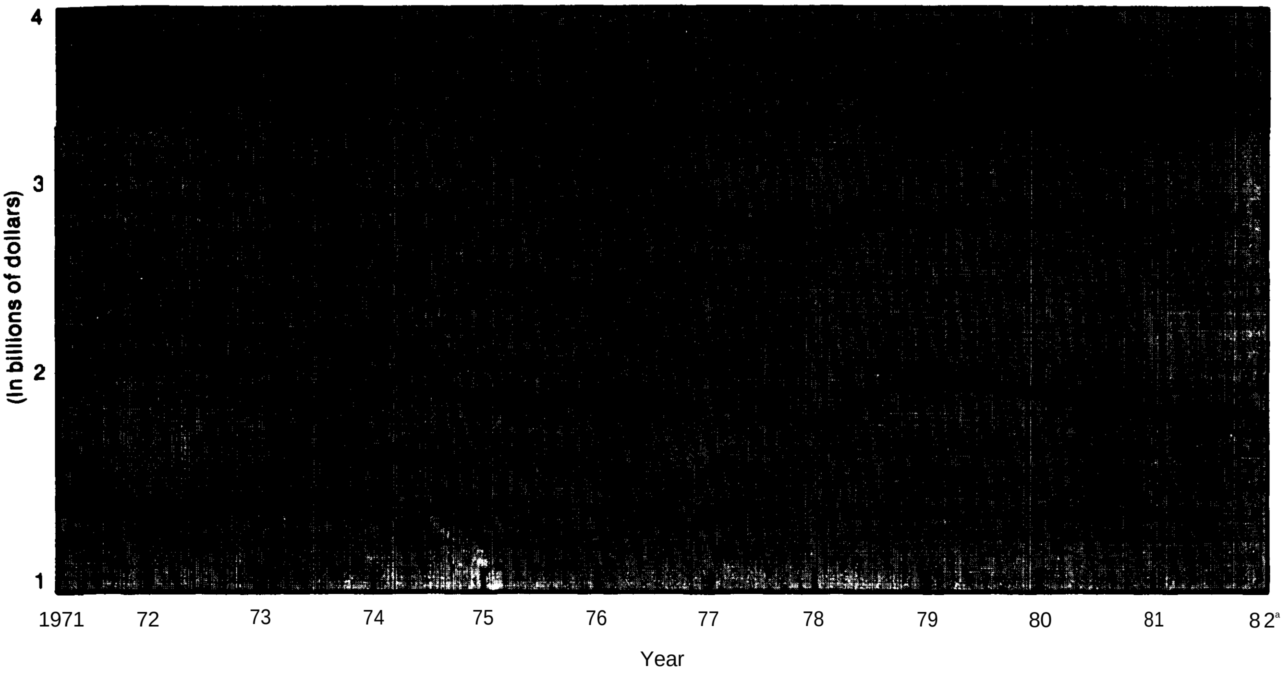
long-term investments at a time when firms were becoming more dependent on external financing of investments (because of low profit levels), 3) discouraging long-term investment (because **of** increased uncertainty about economic conditions), and 4) decreasing growth prospects for the U.S. steel industry. *

As shown in figure **33,** steel industry capital investment increased substantially between **1972 and 1975; the level more than doubled even if the figures are discounted** for inflation. However, after 1975, there has been a significant decline in investment in terms of both current and constant 1972 dollars. This decline shows no sign of reversing itself.

One consequence of declining profitability of steel production in the United States during the 1970's was the shift from internal to external financing of capital investment. While capital expenditures in the steel industry increased from an average value of $1.46 billion for the 1970-73 period to $2.79 billion for the 1975-78 period, capital expenditures as a percentage of net internally generated funds increased from an average value of 78.2 percent for the 1970-74 period to 142.1 percent for the 1975-78 period. In addition, there was a perceptible increase in the debt-equity ratio, from 39.7 percent in 1971 to 49 percent in 1980.[7]

As in other industries, accelerating inflation and economic instability encouraged a slow drift away from long-term financing to short-term financing of investments as interest rates increased and real rates of return diminished, and away from less liquid long-term asset holdings to more liquid, short-term asset holdings. That kind of shift toward the short end on both the asset and liability side—although rational, given general economic conditions—reflected the decreasing abili-

Figure 33.–U.S. Capital investment in Steel industry, 1971=82



[a]Estimated.

SOURCE: Office of Technology Assessment.

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*Steel production in the United States is on a long-term downward trend as measured by the ratio of steel produced to GNP. OTA analysis indicates that the most optimistic forecast for steel through the 1990's would have production well within current production capacity.

[7] *Technology and Steel Industry Competitiveness,* **op. cit.**

ty of the steel industry to finance the kind of long-term, fixed capital investments necessary for preserving or enhancing the competitive position of U.S. steel producers in the domestic and foreign markets.

Furthermore, despite the availability of accelerated depreciation throughout the period 1954-79, inflation increased sufficiently to erode the capital purchasing power of depreciation allowances. Between 1954 and 1961, the purchasing power of depreciation allowances declined a modest 4.3 percent relative to the construction price index, and 2.8 percent relative to the GNP deflator. As inflation accelerated during the 1962-74 **period, the capital purchasing** power of recovered depreciation allowances declined 35.1 percent relative to the construction price index, and 15.2 percent relative to the GNP deflator.

Without analyzing specific expenditures it is impossible to determine to what extent capital investments for pollution control improved yields and lowered material or energy costs. Obviously, such gains would have diminished the net cost of pollution control investments. Nonetheless, these investments did place an additional strain on the steel industry's ability to invest in productive capacity and technological improvements. pollution control expenditures increased from **$448.4 million** for the period 1951-65 ($29.9 million per year), to $572.8 million for the period 1966-70 ($1 14.56 million per year), to $1,229.9 million for the period 1971-75 ($246 million per year), to $2,643.3 million for the period 1976-80 ($528.7 million per year).[8]

Finally, to gain a broader economic perspective, it is appropriate to compare U.S. steel investment figures with those of the energy industries. U.S. petroleum and gas companies invested about $76 billion in 1980.9 The highest projected capital investment requirement for maintaining the U.S. steel industry in a competitive position during the 1980's is $7 billion per year.[10]

Employment

In 1976, Pennsylvania, Ohio, Indiana, Illinois, and Michigan accounted for 72.4 percent of raw steel production out of a total of 128 million net tons. By 1980, they accounted for only 68.2 percent of raw steel production out of a total national production of 111.8 million net tons.11 The decline in the share of these five States in total raw steel production corresponds to their disproportionate share of the decline in total employment in the steel industry—from 674,872 in 1974 to 568,958 in 1980 (or 15.7 percent). The visible consequences of decreased steel production and employment, when concentrated in specific communities, are more difficult to dismiss as market adjustment **processes.**

Employment trends cannot be understood without some reference to employment costs. During the period 1971-80, in which U.S. employment in steel production declined substantially, total employment costs per **hour rose from $6.261 per** hour to $18.451 per hour (about 13 percent per year).[12] As a benchmark, the **rate of** inflation in the consumer price index during the 1970's was approximately 8 percent per year. In short, employee compensation in the steel industry increased at a rate about 50 percent greater than the annual rate of inflation. The Council on Wage and Price Stability report in 1977 indicated that during the period 1952-77, total hourly costs increased 450 percent for steel production, compared to an increase of 297 percent for all manufacturing workers.[13]

Production Costs

The costs of producing plain carbon steel products vary markedly between companies and plants, depending strongly on the product mix and particular requirements and costs of raw materials and energy. Furthermore, the costs are substantially higher for the integrated steel companies than for scrap-based mini mill companies. *

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[8] American Iron and Steel Institute, *Annual Statistical Report for 1980, 1981, p.* 10.

[9] *0il and Gas Journal, "Spending* Plans by U.S. Firms 9.5% Less Than Outlay in 1982," Feb. 28, 1983, p. 40.

[10] American Iron and Steel Institute, *Steel at the Cross Roads: The American Steel Industry in the 1980s,* chs. III and VII, 1980.

[11] American Iron and Steel institute, *Annual Statistical Report for 1980, p. 57.*

[12] 1 bid., p. 21.

[13] Council on Wage and Price Stability, *Report to the President on Prices and* Costs *in the U.S.* Steel *Industry,* 1977.

*Many financial experts have predicted that the scrap-based companies will account for 25 percent of domestic steel production by 1990. There is no technical barrier to such growth. Growth in excess of this rate will depend on the ability of the scrap-based companies to develop competitive quality in other product lines.

The following figures are broad average estimates of production costs for plain carbon steel products in integrated and scrap-based companies:

	Costs per ton of shipments	
Categories	*Integrated*	*Scrap based*
Raw materials	$105.00	$100.00
Energy and fuels	125.00	75.00
Labor	175.00	**100.00**
Total	$405.00	$275.00

At market prices of $410 to $500 per ton, only $5 to $95 per ton remain for capital costs in the integrated sector. *

Product Demand

One deterrent to capital investment in the steel industry during the late 1970's and early 1980's was the slackening of product demand, particularly in the construction and automobile industries. The downturn in steel shipments to the construction and auto industries between 1973 and 1980 accounted for nearly 60 percent of the 27.6-million-ton decline in U.S. steel shipments. To the extent that depressed conditions in both these sectors are likely to persist throughout the early 1980's, the short-term prospects for growth in U.S. steel production are likely to remain modest at best. On the other hand, it should be noted that between 1973 and 1980, steel shipments to the oil and gas industry increased 57.7 percent, from 3.4 million tons in 1973 to 5.4 million tons in 1980.[14]

The downturn in steel demand decreased capacity utilization rates. while utilization rates are always subject to measurement errors, the cycle in raw steel production capacity utilization rose from 80.9 percent in 1976 to 87.8 percent in 1979, and declined to 72.8 percent in 1980 and to 50 percent for the first 9 months of **1982,** as estimated by the American Iron **and Steel Institute (AISI). AISI estimates that the current combined capacity utilization rate of the East European** countries, Japan, and the United States has been below 60 percent for much longer. With projected rapid expansion of steel capacity in the developing countries to more than 100 million tons in 1985, the continued pressure on the East European, Japanese, and U.S. steel mills is evident.

Imports and Exports

The U.S. average share of world raw steel production has declined from 60.1 percent in the post-war 1940's to 45 percent in the 1950's, 32 percent in the 1960's, and 25 percent in the 1970's. During this same period, imports as a percentage of apparent U.S. domestic steel supply—negligible during the first half of this century—rose from 0.24 percent in the 1940's to 15.5 percent in the 1970's. Imports represented approximately 20 percent of apparent domestic steel supply in 1981 and 25 percent by the second quarter of 1982.[15]

The primary source of competition for U.S. steel sales in the U.S. market has come from Japan, whose production costs are about **20** percent lower. The U.S. Council on Wage and Price Stability compared production costs in dollars per net ton of finished steel products, assuming the U.S. product mix for 1976. The two primary sources of the Japanese cost advantage were associated with higher U.S. labor costs ($1 00.24 per ton in the United States, compared to $60.48 per ton in Japan) and the lower yield in converting raw steel into finished steel in the United States compared to that in Japan (0.710 and 0.75, respectively).[16]

Focusing more directly on labor costs and labor productivity, it is clear that among major competitors only Japan has maintained a substantial advantage relative to the United States. The productivity of a dollar spent on labor in steel production in Japan was more than three times as great as that in the United States in 1964 and more than twice as great in 1975.

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*These estimates do not apply to periods of abnormally low demand such as the industry experienced during the second quarter of 1982. During these times, cost per ton can be much higher since large fixed costs must be spread over fewer units of product.

[14] American Iron and Steel Institute, *Annual Statistical Report for 1980, pp. 30-33,*

[15] American **Iron and** Steel Institute, Annual Statistical Report for 1981 (May 1982) and 1982 (unpublished).

[16] Council on Wage and Price Stability, *Report* ***to the President*** *on Prices and* **Costs** *in the U.S.* **Steel** *Industry,* 1977; *Technology and Steel Industry Competitiveness,* ch. 4, op. cit.

For the period 1957-75, the hourly labor costs rose more rapidly in West Germany, France, and Japan than they did in the United States. For example, hourly employment costs in steel production in Japan rose 806 percent, from $0.65 in 1957 to $5.89 in 1975. From 1964 to 1975, output per man hour increased 167 percent (from $3.51 to $9.35) in Japan, yet only 17.5 percent (from $6.92 to $8.13) in the United States.[17]

The more rapid rise in hourly employment costs in Japan and West Germany helps explain the decline in the index of output **per dollar spent** on labor in Japan relative to that in the United States–from 3.22 in 1964 to 2.58 in 1975–and the decline in the index of output per dollar spent on labor in West Germany relative to that in the United States–from 1.55 in 1964 to 1.09 in 1975. If the U.S. steel industry continues to modernize its capital equipment and to diminish the share of non production employees in the work force, the comparative advantage of these foreign producers in output per dollar spent on labor will continue to decline. However, the United States may still face stiff competition from developing nations such as Brazil and Korea, where plant and equipment are very modern and wage rates are very low.

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[17] Ibid.

ENERGY AND TECHNOLOGY

Production Processes

Energy is consumed in steel production during the processes of six major stages: preparation of raw materials, ironmaking, steel making, primary finishing, secondary finishing, and heat treating. Table 51 lists major process technologies for each stage of production and figure 34 combines them in a flow chart.

Table 51.—Energy Services and Major Processes in the Iron and Steel Industry

Energy service	Major processes
Beneficiation	Sintering Pelletizing
Coking	Byproduct coke oven/wet quench Byproduct coke oven/dry quench Formcoking
Ironmaking	Blast furnace Blast furnace with hydrogen injection Direct reduction—gas Direct reduction—coal
Steelmaking	Basic oxygen furnace Electric arc furnace Open hearth furnace
Primary finishing	Ingot casting/soaking/breakdown mill Continuous casting Ladle preheating
Secondary finishing	Batch reheating/rolling Continuous reheating/rolling Electric induction reheating/rolling Direct rolling Cold rolling
Heat treating	Direct tube furnace Radiant tube furnace Electric furnace

SOURCE Office of Technology Assessment

Preparing Raw Materials

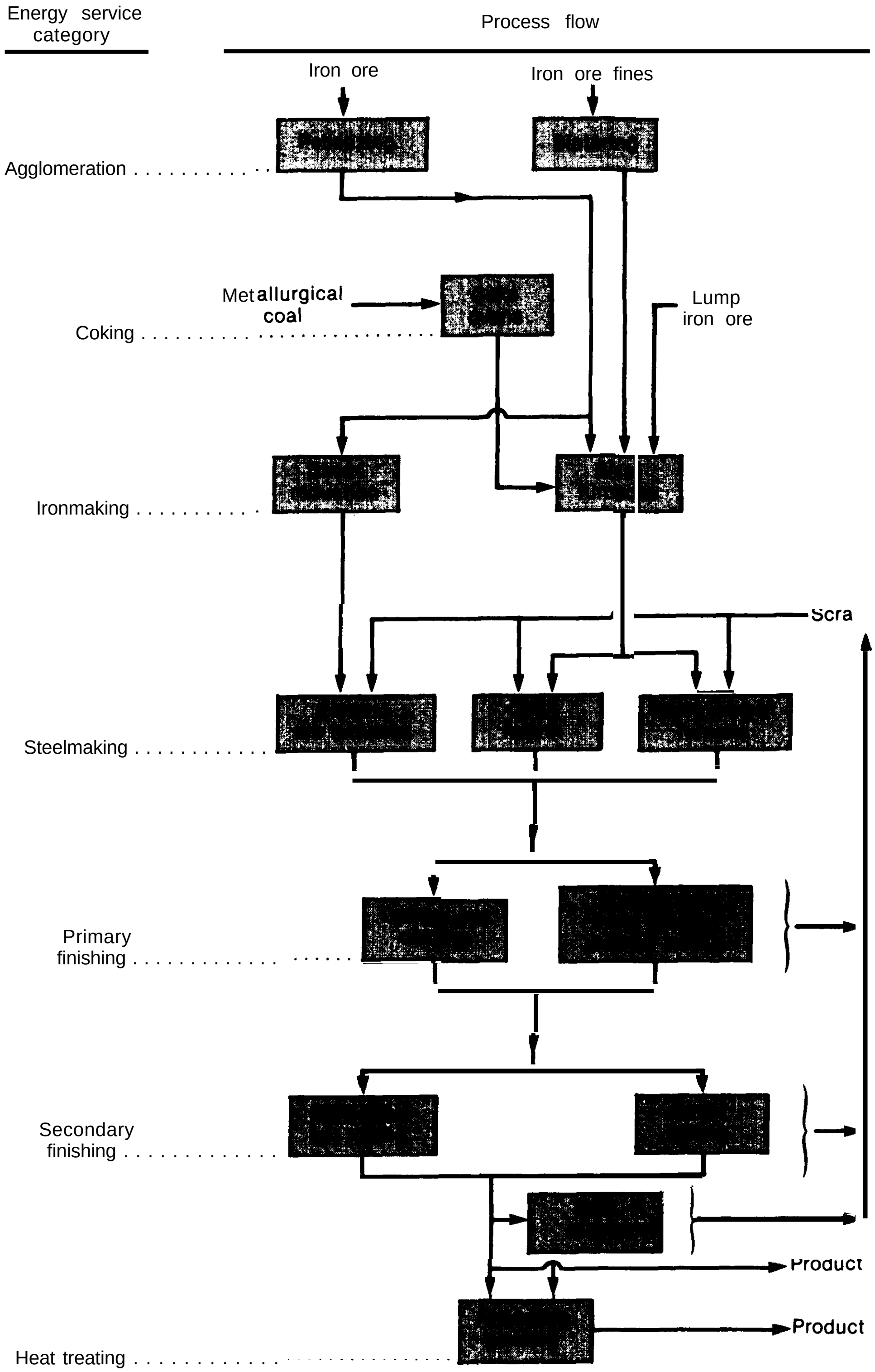
Iron ore, coal, and limestone are the raw materials of making steel. After preparation, they are combined in a blast furnace, where the iron ore is smelted to metallic ore. Coal, which is first converted to coke, supplies the carbon necessary for generating the terrific heat and reducing gases necessary for smelting. Limestone is used to combine with the impurities in the molten iron to form slag, which floats atop the liquid and can be removed.

During materials preparation, two processes are particularly energy intensive.

Beneficiation of Iron Ore.–Through several processes known generally as beneficiation, iron ore chunks are first crushed and ground, then refined. They are then agglomerated, that is, sintered (heated to form a mass) and formed into marble-sized pellets. The agglomeration processes are particularly energy-intensive,

Coking.–The reduction of iron ore to metallic iron is most economically accomplished by carbon. In modern ironmaking, the source of carbon is coke, a solid, relatively nonvolatile product, about 90 percent pure carbon, that remains when coal is heated at 1,650° to 2,000° F for 12 to 18 hours to boil off its volatile components.

Figure 34.—Process Flows in the Iron and Steel Industry



SOURCE: **Energy Productivity Center, Mellon Institute,** *Final Report on Industrial Energy Productivity Project, Volume 4, The Iron and Steel Industry,* **September 1982.**

There are two proven processes for manufacturing coke, the beehive oven and the byproduct (slot) oven; although in the United States the byproduct process is used almost exclusively. In the byproduct process, coal is heated in chambers in the absence of air by the external combustion of fuel.

Ironmaking

Iron ore must be first transformed to metallic iron by the reduction of the iron oxides in the blast furnace–the conventional, and only, technology existing in the United States today to produce iron. To make iron, iron-bearing materials (iron ore, sinter, pellets, mill scale, slag, iron or steel scrap, and the like), fuel (coke), and flux (limestone and/or dolomite) are charged into the top of the blast furnace. Heated air (blast) and, in some instances, fuel (gas, oil, or pulverized coal) are blown in at the bottom. The hot air blast burns the coke to heat, reduce, and melt the charge as it descends through the furnace. The liquid iron and slag that collect in the furnace are tapped at regular intervals through separate tap holes.

Blast furnace capacities vary from 1,000 to 10,000 tons per day of hot metal. The industry trend is toward large furnaces. The two most recently built blast furnaces have a production capability in the range **of** 8,000 to 10,000 tons per day.

Steelmaking

Steelmaking is a refinement process whereby undesirable amounts of other chemical elements, such as carbon, manganese, phosphorus, sulfur, and silicon are reduced and removed from the pig iron, and small quantities of other elements (fluxes and alloying materials) are added to produce desired steel properties.

Steel is made in three types of furnaces–the basic oxygen furnace, the electric arc furnace, and the open hearth furnace. All three processes are used to produce carbon steel. Stainless steel is limited to basic oxygen furnaces and electric arc furnaces; the latter are also used to produce special alloys from select scrap feedstocks.

Now the leading and fastest steel making process, the basic oxygen furnace refines steel (in about 32 minutes per batch) by blowing oxygen into the furnace, producing an intense chemical reaction in the charge of scrap, molten iron, and lime. The basic oxygen process produced 61 percent of the Nation’s raw steel in 1979.

The electric arc furnace refines molten iron and produces steel by electric arcing between three carbon electrodes and the scrap iron charge. In 1980, such furnaces produced 27 percent of the Nation’s raw steel.

The open hearth furnace is charged by scrap limestone, and iron, followed by molten iron. Oxygen and natural gas, fed into the bath, produce the temperatures necessary to refine the mixture into steel. The open hearth process, which dominated steelmaking in the United States for many years, has steadily lost ground. Production in open hearth furnaces declined from 85 million tons (64 percent) in 1966 to 13 million tons (12 percent) in 1980.

Primary Finishing

Primary finishing includes the operations of casting—pouring liquid steel into its first solid form (raw steel)–and then converting the raw steel to semifinished shapes such as slabs, blooms, and billets. There are two casting techniques, ingot and continuous.

In ingot casting, the conventional casting method, liquid steel is tapped into a refractory-lined, open-topped vessel called a ladle. The ladle is moved by an overhead crane to a pouring platform where the steel is then poured or “teemed” into a series of molds. The steel solidifies in each of the molds to form a casting called an “in got.” Subsequently, the molds are removed, and the stripped, cooling ingots are placed in a soaking pit, where they are reheated to an even temperature for rolling (shaping). After soaking, the molds are transported to mills for rolling into blooms (rectangular forms) and billets (square forms) for use in structural shapes and bars, and slabs, for use in all flat-rolled steel.

Continuous casting is a newer process in which liquid steel is directly cast into the desired semi-

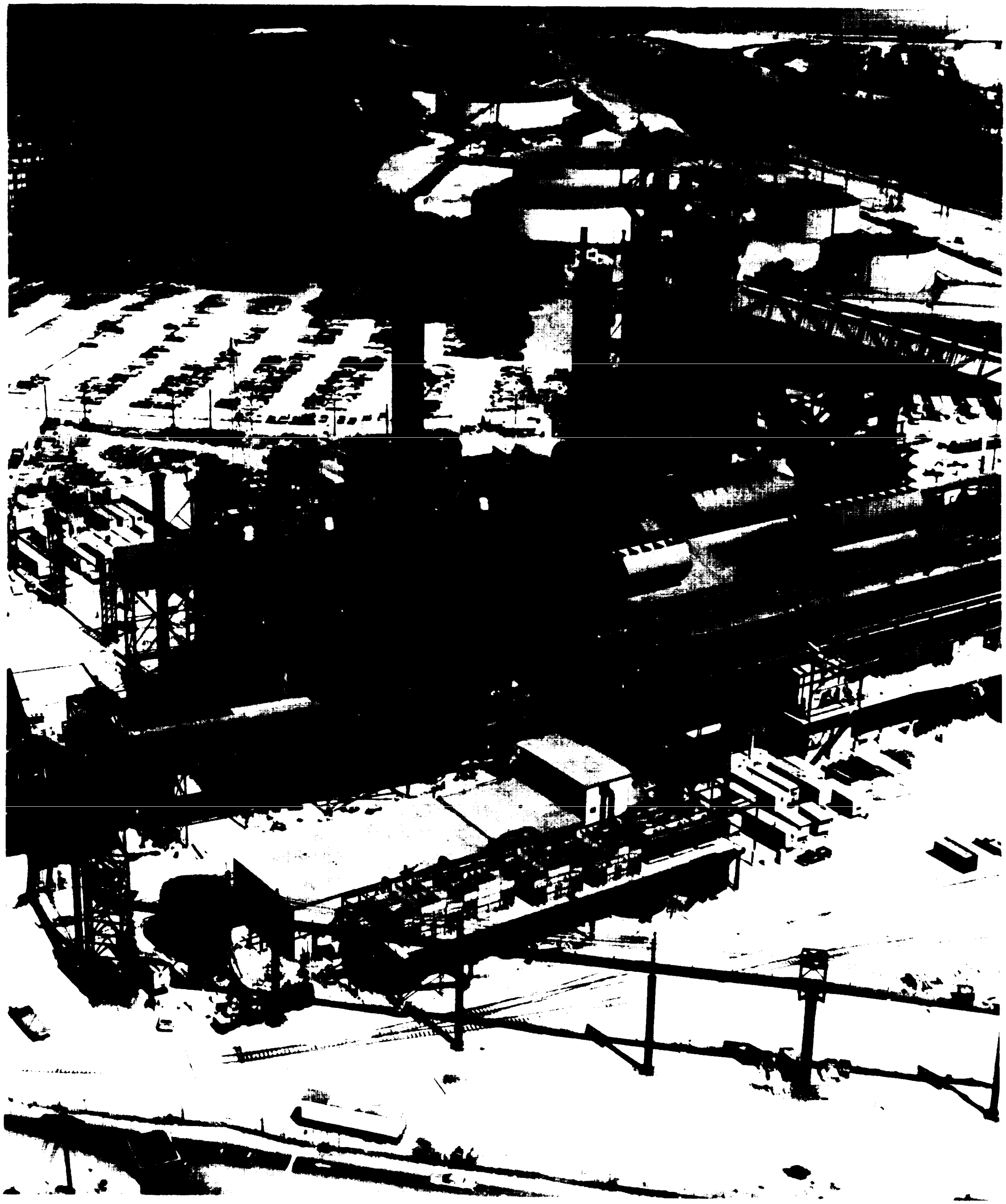


Photo credit: American Iron and Steel Institute

Blast furnace complex

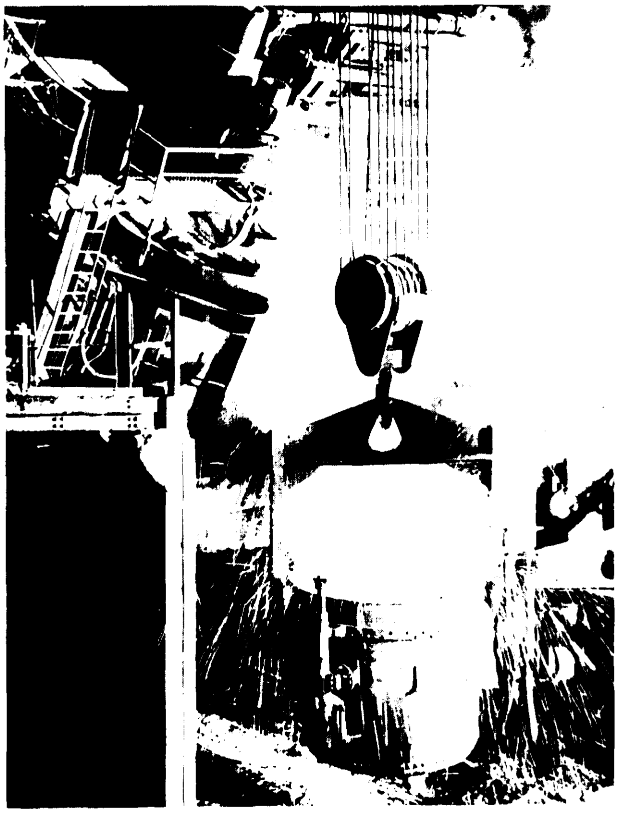


Photo credit: American Iron and Steel Institute

Steel from the electric furnace is being poured into ladle for processing in the continuous caster

finished shape, thus eliminating the intermediate steps of ingot casting and reheating, and lowering the energy **per final ton of product. Figure 35 shows a cross-section of a typical caster.**

Secondary Finishing

Secondary finishing includes the operations of reheating the slabs, blooms, and billets produced **in primary finishing and transforming them through hot and cold rolling steps into final products. Reheat furnaces** are used to heat steel shapes to temperatures of 2,300° to 2,400° F prior to rolling operations. Such furnaces can be classified into two types—batch and continuous—based on their mode of operation. Fossil fuels are the usual energy sources in these furnaces, but electric furnaces are also used.

Photo credit: American Iron and Steel **Institute**

Molten iron is being tapped and taken away from the blast furnace for further processing into steel

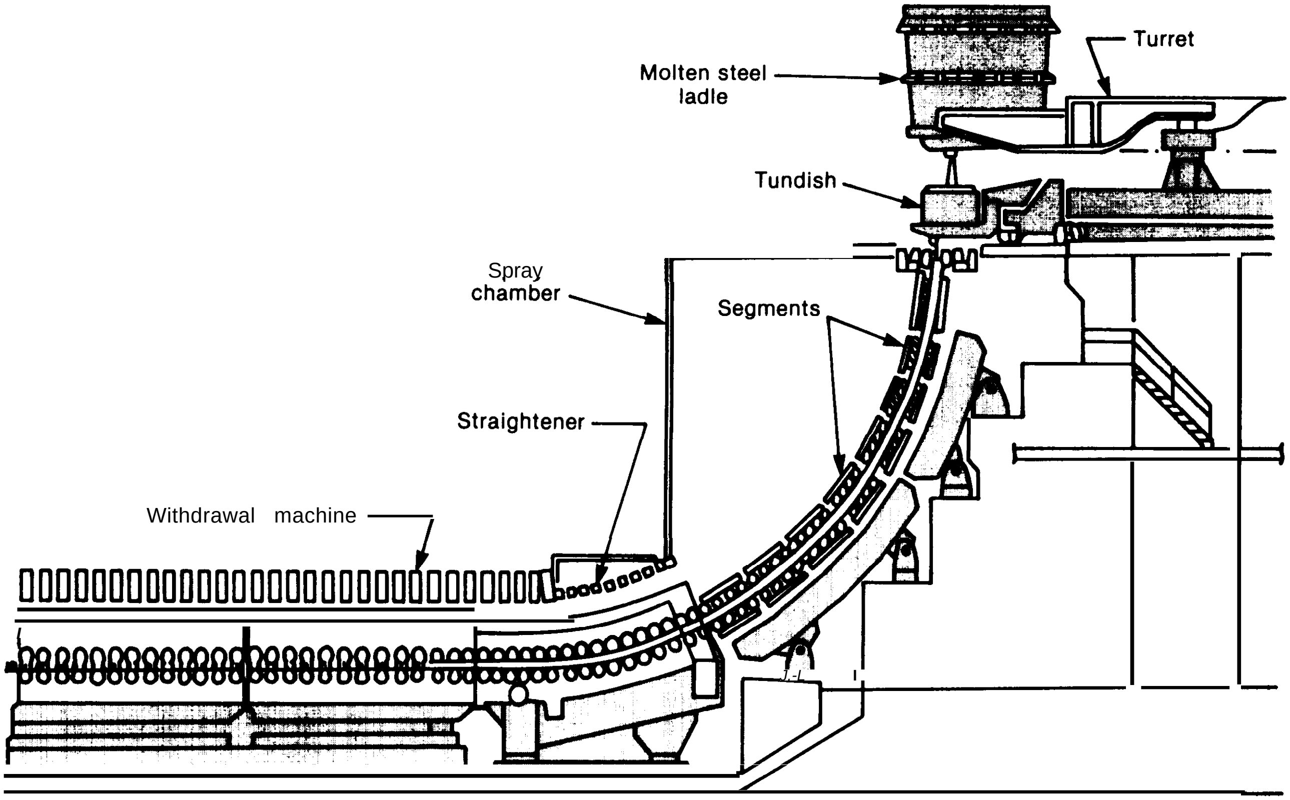
Heat Treating

The final step in the finishing operations is heat treating. Cold-working steel results in a highly stressed product with low ductility. The principal purposes of heat treating are to relieve these stresses, obtain full recrystallization to a more uniform grain structure, and improve ductility to a level suitable for forming operations. This goal is accomplished by heating the steel to a specified temperature at which it is held for some time (soaking), followed by gradual cooling. The most common heat treatments performed are annealing, normalizing, spheroidizing, hardening, tempering, carburizing, and stress relieving. Of these, annealing is done on the largest scale within the U.S. steel industry.

Energy Use

All of the stages of steel production use energy to alter the chemical composition of the metal

Figure 35.—Cross.Section of a Typical Continuous Casting Machine



SOURCE: American Iron and Steel Institute, 1976

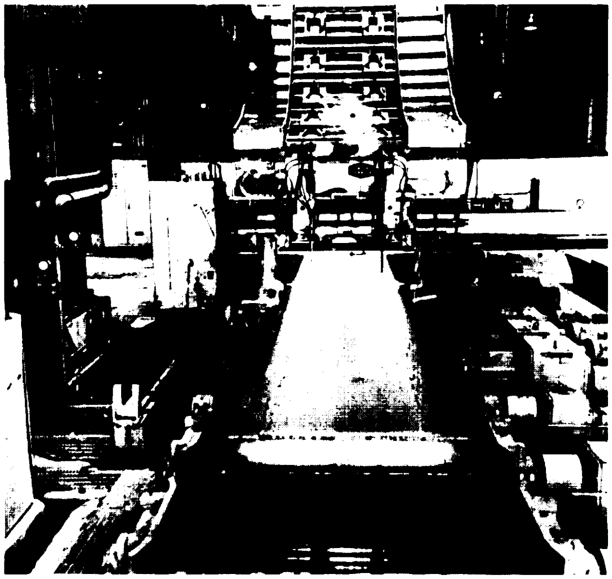


Photo credit: **American** *Iron and Steel Institute*

The slab is being torch cut after emerging from the continuous slab caster

or to work the metal into useful forms and shapes. Every plant and company has its own unique mix of process efficiencies, for a variety of reasons such as the age of the plant, the design of equipment, and the mix of products. As an illustration, the mix of primary and byproduct fuels for one major integrated steelmaker is presented in figure 36.

Under the most ideal circumstances, the energy required to produce solid iron from iron oxide can never be less than 7 million Btu per ton (MMBtu/ton). Since the energy required to melt iron under the most ideal circumstances is about 1 MMBtu/ton, the inherent thermodynamic advantage of making liquid steel from scrap rather than from iron ore is about 6 MMBtu/ton. When process heat losses are included, the advantage falls in the range of 9 to 14 MMBtu/ton. *

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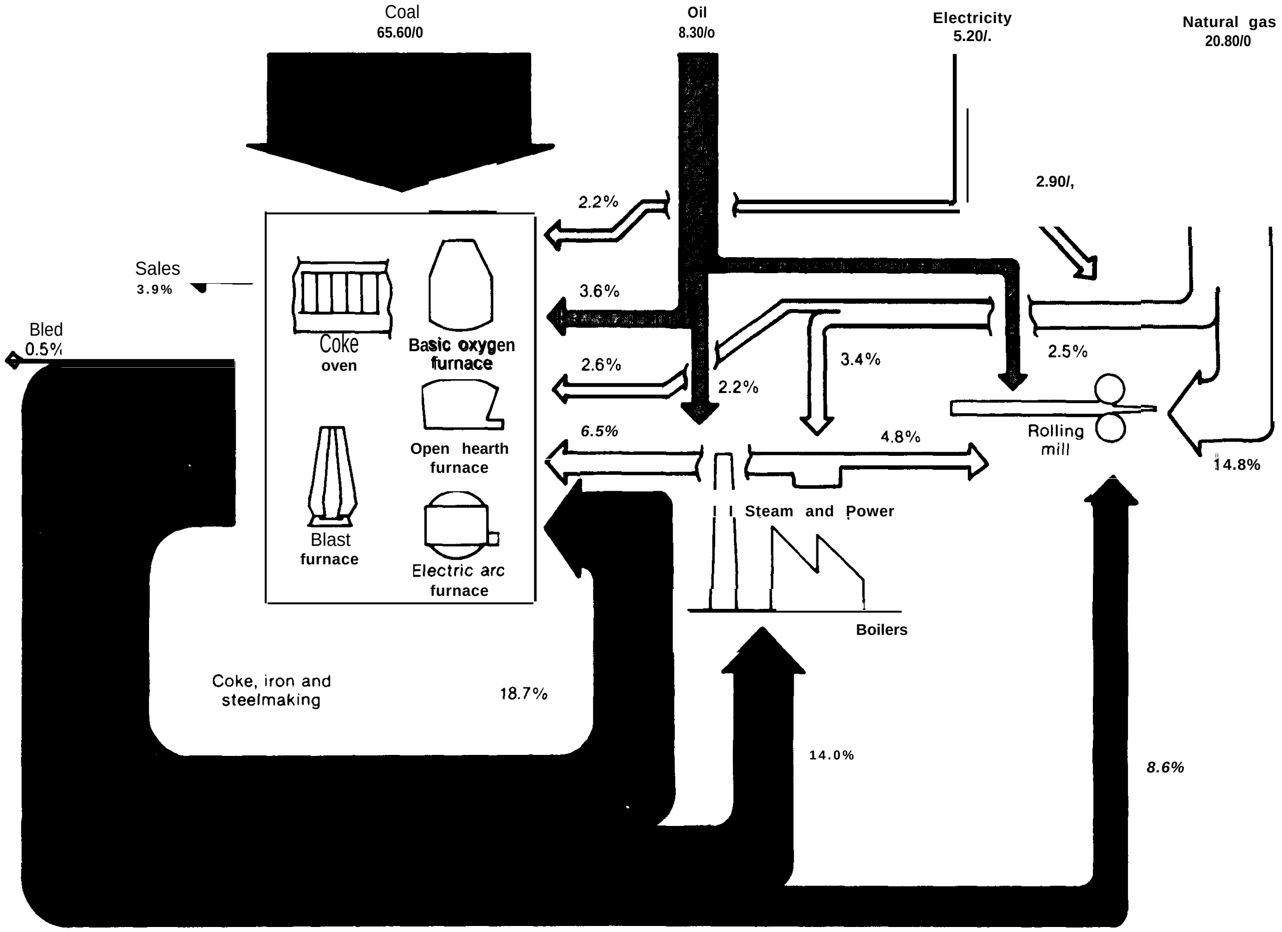
*These estimates include the energy value of coal at the power generator–i.e., a conversion factor of 10,494 Btu/kWh has been applied.

Figure 36.— Energy Consumption by Production Process in a Typical Integrated U.S. Steelmaker



SOURCE Off Ice of Technology Assessment

current total energy requirements for the production of finished steel products in different plants and countries from iron ore range from 25 to 35 MMBtu/net ton. A review of alternative energy sources used in steel production, along with relative shares for the period' 1972-80 leads to several points worth noting. First, coking coal, steam coal, and purchased coke consistently provide nearly two-thirds of the energy used in U.S. steel production (see table 52). Natural gas accounts for about 25 percent; petroleum, less than 5 percent; and purchased electricity, which has **risen significantly in recent years, about 7** percent. The increase in electricity is due primarily to increased use of the electric arc furnace. Electricity in this case is generated to a great extent by coal or nuclear fuel.

Petroleum provides only a small amount of energy, although the substitution of petroleum and natural gas for coal and other energy sources frequently results in net total energy savings in ironmaking and steel making. For example, total energy requirements in the iron blast furnace can be reduced by the injection of oil or gas in the blast, and total energy requirements in the steelmaking electric arc furnace can be reduced by in situ heating of scrap with oxyhydrocarbon burners,

A summary of fuel use, scrap use, and process use during the period 1976-80 is presented in table 52. The data are normalized on the basis of tons of shipments. Several important trends are evident. With the addition of continuous casting

Table 52.—Fuel Use and Energy. Related Trends in the Steel Industry

Fuel use per ton of steel shipments (10° Btu)[a]	1976	1977	1978	1979	1980	1981
Coal, coke	22.4	20.0	17.2	17.9	18.2	16.0
Coal, steam	0.8	0.8	0.8	0.8	0.8	0.8
Natural gas	6.7	6.2	6.1	6.4	6.7	7.0
Purchased coke	1.7	1.2	1.7	1.9	1.2	0.8
Fuel oil	2.7	2.8	2.9	2.1	1.3	1.1
Liquefied petroleum as	0.7	1.0	0.6	0.3	0.2	0.2
Purchased electricity	1.7	1.7	1.7	1.7	1.8	1.9
Totals, 10^6 Btu	36.5	33.7	30.9	31.2	30.0	27.8
Cost,[c] 1982 dollars	128.4	120.6	113.7	114.0	109.4	105.6
Recent *trends~*						
Shipments, 10^6 tons	89.4	91.1	97.9	100.3	83.9	87.0
Raw steel, 10° tons	128.0	125.3	137.0	136.3	111.8	119.9
Yield, %	69.8	72.9	71.5	73.6	75.0	72.6
Continuous cast, %	10.6	12.5	15.2	16.9	20.3	21.1
% of raw steel:						
Open hearth	18.3	16.0	15.6	14.0	11.7	11.2
Basic oxygen process	62.5	61.8	60.9	61.1	60.4	61.1
Electric arc furnace	19.2	22.2	23.5	24.9	27.9	27.7
Total purchased scrap, %	36.0	40.0	40.0	43.0	48.0	

[a] Based on preventative calorific values.

[b] Assuming 3,412 Btu/kWh.

[c] 1982 average prices applied to yearly figures.

[d] Shipments divided by raw liquid steel, The decline in 1981 is an artifact of a sharp increase in inventory

[e] Percent of total metallic feedstocks.

SOURCE: American Iron and Steel Institute and the Office of Technology Assessment.

equipment the yield of steel shipments from raw **liquid steel** has increased at a steady rate. The **increasing** role of electric arc furnaces has brought a-bout a concomitant increase in the use of scrap for steel production. While the use of coal and petroleum products has declined over the last 5 years, the use of natural gas per ton of shipped steel has remained relatively constant. These and other trends and their significance in assessing the possible impacts of legislative options are discussed in the following sections.

Energy Conservation

Steelmaking has a number of investment opportunities to save energy or to switch to lower cost fuels, and many have been exploited in the past decade. A comparison of energy and production data indicates that almost 17 percent less energy was used per ton of product in 1981 compared to 1972 (see table 53 and fig. 37). Most of the investments that have brought about this energy reduction can be described in terms of specific technologies, but some save energy as an incidental benefit of any modernization that shortens times for processing and handling of hot metals. A sample of these opportunities is summarized in table 54.

While there are many energy-saving technologies, the substitution in the last 5 years of continuous casting for ingot casting and the displacement of the basic oxygen furnace or open hearth furnace by the electric arc furnace are pivotal for economic as well as energy efficiency reasons. In fact, analysis of 1976 and 1980 data shows that actual reductions in energy per ton of steel shipments can be almost entirely explained by the increased use of continuous casting and the melting of scrap in electric arc furnaces. *

Electric Arc Furnace

Electric arc furnace (EAF) technology saves energy by allowing the substitution of scrap metal for iron ore. Expansion of scrap-based production has been encouraged recently by relatively low scrap prices, leading to a cost advantage of

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*This analysis is contained in a separate contractor report.

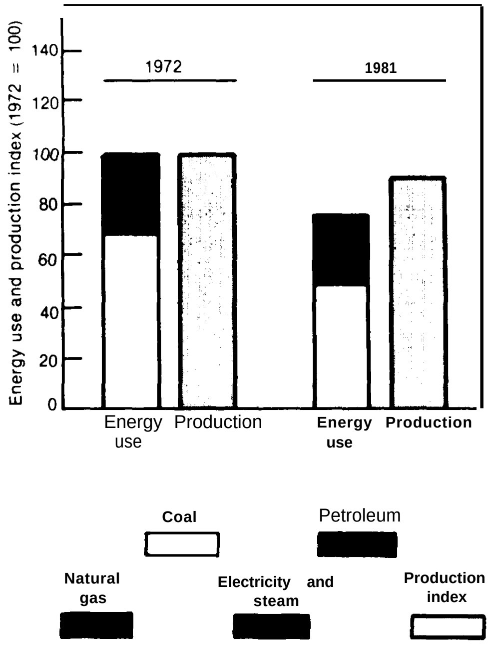
Table 53.—Comparison of 1981 and 1972 Energy Consumption for U.S. Steel Companies

	For corporations using 1972 as the reference year	
	1981 consumption (trillion Btu)	1972 consumption (trillion Btu)
Bituminous coal[b,c]	1,144	1,944
Metallurgical	1,082	1,854
Boiler	60	83
Other	2	7
Anthracite coal	3	—
Coke (purchased)	182	110
Coke oven gas (purchased)	2	4
Tar or pitch (purchased)	3	1
Total coal	1,335	2,059
Natural gas	508	667
Distillate fuel oil	9	13
Residual fuel oil	81	187
Gasoline	1	—
Other petroleum products	4	1
Propane	—	1
Other liquefied petroleum gas	—	1
Total petroleum	96	204
Electricity	119	125
Purchased steam	1	—
Total energy consumptions	2,059	3,055

[a] All consumption figures shown are net of sales, inventory changes, and excluded usage. Due to historical data collection procedures for individual fuels, some grouping of particular fuels occurs.
[b] Bituminous coal may include a small amount of anthracite coal.
[c] Energy content of coal byproduct sold is not included in this figure (i.e., subtracted from the gross figure).
[d] Other petroleum products may include some gasoline.
[e] Propane consumption may include a small amount of other liquefied petroleum gases.

SOURCE: American Iron and Steel Institute, data for 51 companies operating in 1961.

Figure 37.—Comparison of Steel industry Energy Use and Production Output, 1972 and 1981



SOURCE" American iron and Steel Institute

over $125 per ton of shipments. Furthermore, if total demand for steel products remains steady or grows very slowly, supplies of scrap should continue to balance demand and thus hold scrap prices at favorable levels for steelmaker. This expectation is reinforced by growing supplies of directly reduced iron (DRI) from nations that have inexpensive supplies of natural gas or electricity. DRI is an excellent EAF feedstock because it is free of trace elements that contaminate scrap; therefore, mixtures of DRI and scrap may be used in the future to produce higher quality steel products.

Continuous Caster

Continuous casting is more energy efficient than ingot casting for two reasons. First, the use of continuous casting eliminates the need for ingot stripping, reheating, and primary rolling. Second, the yield of slabs and billets from continuous casting is much greater than that from ingot casting because less metal must be returned to the

Table 54.-Technologles for Improving Energy Efficiency in the Steel Industry

Investment option	Energy efficiency-improving characteristics
Dry-quenching of coke	Recovers waste heat of hot coke from ovens; saves coke; reduces environmental pollution because coke is quenched in a closed system.
Coke-oven gas desulfurization	Natural gas substitute. Some loss of calorific value, but improved product quality.
Blast furnace top gas turbine	Recovers waste energy by cogeneration. Only possible with the best high-pressure furnaces.
External desulfurization of hot metal	Saves coke by allowing lower slag volume and hot metal temperature in the blast furnace. Some energy used in desulfurization.
High-pressure blast furnace	Lowers coke consumption.
Electric arc furnace (EAF)	Allows for increased use of scrap, thereby lowering overall energy requirements for steel production.
Water-cooled panels, EAF	Allows for higher productivity and net energy savings in melting when refractory consumption is considered.
Oxy-fuel burners, EAF	Saves electrical energy and reduces melting time. Total energy consumption may be increased.
Open hearth, shrouded, fuel-oxygen lances	Reduces fuel requirements in the open hearth. May prolong useful life of open hearth.
BOF gas collection	Recovers calorific value of carbon monoxide with net energy savings.
Scrap preheating, BOF	Allows for greater use of scrap, thereby saving energy in ironmaking.
Secondary, ladle refining, EAF (e.g., AOD)	Saves electrical energy by removing refining function from EAF.
Closed system ladle preheating	Saves natural gas used for preheating ladles.
Continuous casting	Increases yield, thereby decreasing overall energy requirements; saves fuel gas in ingot reheating.
Continuous slab reheaters	Saves clean fuel gas through increased efficiency.
Continuous annealing and reheating systems	Saves clean fuel gas through increased efficiency.
Direct rolling	Saves clean fuel gas through the elimination of slab reheating.
Indication heating of slabs/coils	Allows fuel switching to electricity, conserves total energy, and increases yield.
Steam-coal injection into the blast furnace	Allows fuel switching from more expensive gas or oil. Technology should be available in 5 years.

SOURCE: Office of Technology Assessment.

steelmaking processes in the form of waste and unfilled ingot molds. Specifically, the use of continuous casting represents a saving of about 2 MMBtu/ton in clean gaseous fuels used in reheating and about 2.5 MMBtu/ton in the general plant fuel mix from increased yield.

In 1981, 21.1 percent of U.S. steel was continuously cast. For comparison, continuous casting percentages of East European countries and Japan in 1980 were 39.2 and 59.5, respectively. If U.S. industry could invest in continuous casting equipment to raise its percentage to 60 percent, about 5 MMBtu/ton of shipments could be saved without any other changes,

Although all of the technological options have been demonstrated in domestic plants, not all of them will be competitive investments in every situation. Many of these options require retrofitting existing equipment. In some instances, older equipment cannot be modified at a reasonable cost to take advantage of the opportunity. Sometimes physical plant layout prevents adoption of a specific technology.

In addition, it should be noted that new technologies often result in benefits that are difficult to evaluate. For example, besides saving energy, continuous casting and improved reheating facilities improve steel quality as well as reduce environmental problems.

INVESTMENT CHOICES FOR THE STEEL INDUSTRY

Investment Strategy

Firms that have traditionally been in the steel business are not really in business to make steel, but to make profits. The two objectives–profits and steel—are not necessarily in conflict, as demonstrated by mini mills, but for a broad cross section of major integrated and specialty steel producers, profitability in steel appears to be a distant future goal. Certainly, given the recent capacity utilization rates under so percent and the long downward trend for domestic steel production, the steel industry is not a strong magnet for new investments.

With the exception of minim ills, which use scrap metal feedstocks instead of iron ore and coke, existing steel firms are now deciding whether to invest more in steel or not; if they do, large investments are required just to match their foreign and domestic competition. Profits can still be made, but current low operating rates make investment difficult because they severely limit internal funds. Attempts to raise outside capital can lower credit ratings and sharply discount stock values. In these circumstances, many existing firms are forced into triage, writing off their least competitive shops in order to keep their best capacity on line.

Negative investment prospects would turn around if general economic activity were to pick up sharply. When industry experts were asked to comment on the impacts of the four policy options analyzed by OTA, they generally couched their responses in terms of the need for product demand to increase, followed by concern about high interest rates as they affect both product market demand (i e., steel-intensive products are often investment goods) and the cost of borrowing for steel industry investments. High interest rates reduce the leverage of all four policy options by making it more difficult to achieve efficient capacity configuration. Both of these general economic concerns, the depressed GNP and high interest rates, were often raised to suggest that the steel industry's present **use of energy was justified by existing product and factor markets.**

Closely following is a third broad economic issue—steel imports. Among integrated and specialty steelmaker, there is the widespread belief that many exporting countries are unfairly subsidizing steel exports to the United States and that such imports have been a major reason why domestic capacity is below the 50 to 60 percent levels necessary for breaking even. Consequently, a large cross section of firms believes that restriction of steel imports is a top priority for Government action.

Appropriately, in an economy based on notions of free trade, steel industry proposals for import restriction are controversial. Critics question the steel industry's willingness and ability to meet legitimate foreign competition. They point out that research, development, and demonstration efforts have been minimal for several decades, despite the growing foreign competition. They also identify important inefficiencies in major integrated mills that can be traced to longstanding company and union policies, practical only when U.S. technology was preeminent. Finally, several major companies have recently demonstrated a clear lack of confidence in their ability to compete by abruptly closing down existing plants without replacement and by diversifying into nonsteel activities.

In addition to this general economic background, an energy-related discussion of steel industry investment should take into account the industry's legitimate strategic goals of overall cost minimization and product market growth. Within total costs or total cost per ton, energy (including coke) constitutes 25 to 30 percent, which is somewhat less than the cost share for labor and only somewhat larger than shares for materials and capital. Furthermore, by far the largest energy expenditure is for coal (on the average around 66 percent, excluding coal-fired electricity), which is the most abundant energy resource in the United States. If special attention for energy is justified, it must be primarily because natural gas (a premium fuel) accounts for about one-fourth of total steel energy.

In other words, energy investments must compete for scarce funds along with all other profitable technologies, and in order to examine energy impacts of Federal policy options, the full range of technical investment alternatives must be considered. Fortunately, as discussed above, this does not really stretch the analysis far from energy because the two primary energy-saving technologies, continuous casters (CC) and EAFs, are also two of the best investments to reduce total costs per ton of steel. In fact, CCs and EAFs are virtually mandatory investments for any firm wishing to modernize itself. Without continuous casting, low-product yields and quality, as well as high energy costs, diminish sales and profits. Similarly, without expanding EAF capacity to maximize scrap utilization to produce lower grade carbon steel products, a firm can have costs in excess of $100 per ton higher than those of its competitors. Consequently, with significant opportunities remaining for both technologies in the United States, CC and EAF investments act as bellwethers for domestic steel. Investment in additional CC and EAF capacity amounts to a greater commitment to stay in the steel business and thus **to** invest in other projects that improve product quality and reduce total costs.

Specific Energy-Related Investments

While the following policy analysis will focus on generic CC and EAF technology, there are many other energy investments that save energy and reduce energy costs to a lesser extent. Significant energy savings may also be achieved indirectly when large investments in product finish**ing motivate complementary plant reconfiguration that reduce delays in product handling, and thus heat losses** in reheating (see table 54).

When all of these direct and indirect routes to energy saving are added together, they can save as much energy as the addition of CCs or an EAF. But project economics vary a great deal from plant to plant, making it difficult to describe generic projects. Several have been included along with the given CC and EAF in the illustrative internal rate-of-return (1 RR) calculations, but it is important to remember that all such calculations when applied to real investment planning are highly site-specific.

POLICY IMPACTS ON THE STEEL INDUSTRY

policy impacts on energy consumption by the steel industry are defined by comparison to a reference case projection that assumed no change in current policies, including the accelerated depreciation section of the Economic Recovery Tax Act of 1981 (ERTA). Safe harbor leasing provisions are not included in the projections made below, although the steel industry has been among the largest users of this opportunity to raise investment capital by reducing corporate income taxes.

The Reference Case

The steel industry is currently making investments that sharply lower production costs by increasing energy efficiency, among other improvements in **process efficiency and product quality. Besides investments in EAF and CC, significant savings in** energy costs are expected in the 1990's, when technology will be available for substituting steam coal for natural gas and oil as hydrocarbon, which is injected directly into the blast furnace.

In this reference case, OTA assumed the fuel price growth rates, general economic growth rates, and steel industry growth rates shown in table 55. Figure 38 shows that OTA projects energy efficiency in the production of steel to decline from 31 MMBtu/ton of shipments to about 19 MMBtu/ton by 2000, an improvement predicated on slow but steady growth in shipments. This growth in demand for domestic products is important to assure the availability of investment funds, especially **for the large, integrated producers who in the fall of 1982 were operating well under .50 percent of their available capacity. If this growth in demand does not** occur, improvements in efficiency will occur more slowly, although total energy use may not

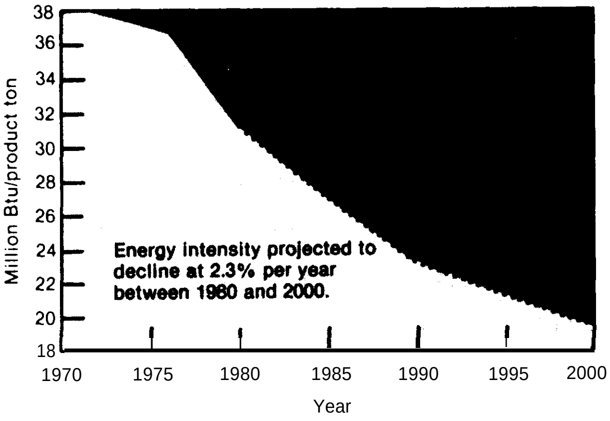
Table 55.—Historical and Projected Growth Rates for Production and Fuel Prices, 1976-2000

	1976-80	1980-85	1985-WI	1990-2000
All manufacturing FRB[a] growth rate	3.25°/0	3.9%	4.30/0	3.7%0
Iron and steel industry	–1.6			0.8
Fuel price, gas($MMBtu)	—	5.0	6.3	9.0
Fuel price, residual ($/MMBtu)	–	**5.0**	**6.2**	**9.0**
Fuel price, coal ($/MMBtu)	–	**2.2**	**2.3**	**2.4**
Fuel price, electricity ($/MMBtu)	–	**13.8**	**13.7**	**13.8**

[a] Federal Reserve Board.

SOURCE' Office of Technology Assessment

Figure 38.—Iron and Steel Industry Energy Intensity Projections, 1970-2000



SOURCE Office of Technology Assessment

exceed projected levels because of the shutting down of older, fuel-inefficient capacity.

As part of this general, energy efficiency improvement, the reference projection calls for a steady decline in the use of both oil and gas, shown in table 56, as both premium fuels are displaced in reheating (of in-process ingots, slabs, and billets) and in blast furnace injection. Use of metallurgical coal is also expected to decline, primarily because of the displacement of hot iron from the blast furnace by melted scrap and by directly reduced iron from the EAF. There will also be major declines in the coke rate per ton of hot iron due to the direct injection of cheaper hydrocarbons (steam coal) into the blast furnace.

Table 56.—Fuel Use Summary: Reference Case, 1980-2000 (In trillion Btu)

***Total fuel* Use**

Year	Natural gas	Residual oil	Distillate oil	Metallurgical coal	Steam coal	Electricity	Other fuels	Total primary fuels
1980	448	175	33	1,675		213	0.8	2,615
1985	438	136	20	1,617	: :	244		2,543
1990	**368**	**117**	**15**	**1,417**	**111**	**262**	**1.0**	**2,291**
2000	**297**	**95**	**10**	**979**	**400**	**307**	**1.0**	**2,088**

Fuel use as percent of total purchased fuels

Year	Gas	Oil	Steam coal	Metallurgical coal	Electricity
1980	17	8		64	8
2000	15	3	20	47	15

Fuel use as percent of total purchased fuels minus metallurgical coal

Year	Gas	Oil	Steam coal	• Electricity
1980	43	20	7	20
2000	**27**	**6**	**38**	**29**

SOURCE: Off Ice of Technology Assessment.

The reference case and policy impacts are also illustrated in terms of the profitability of generic investment options. Table 57 describes eight generic investments, along with economic and energy assumptions used to dollars. The profitability of each project is reflected in the calculated IRR on investment (see table 58).

Projected Effects of Policy Options

Option 1: Removal of Accelerated Depreciation

Like all capital-intensive industries, the steel industry welcomes policies that reduce the tax burden on income. Safe harbor leasing conferred exceptionally large benefits on the steel industry—primary metals obtained the third largest share of leased property among two-digit SIC industries –because many modernization investments were well over due and because low profit rates would not otherwise have provided the opportunity to shelter income from taxes via accelerated depreciation.

The outstanding policy question, however, involves incremental investment activity. Has the steel industry made significantly greater investment in energy-saving equipment because of ERTA and can it be expected to do so in the **future? Equivalently, because energy saving and cost reduction** are more or less accomplished by the same key technologies, has there been significantly greater investment in general?

Table 57.—Steel Industry Projects To Be Analyzed for Internal Rate of Return (IRR) Values

1. ***Electric arc*** furnace. -This furnace is used to melt steel scrap into molten metal suitable for secondary refining, rolling, and casting. Assuming scrap is available at reasonable prices, this investment will substantially lower product costs as well as save energy.
   Project life—10 years.
   Capital costs—$20 million.
   First year cost savings—$12 million.
2. ***Reheat*** furnace.—Replacement of existing reheat furnaces improves energy efficiency because prolonged use would have degraded old unit and because the new unit embodies technological developments since the original unit was installed.
   Project life—10 years.
   Capital costs—$12 million.
   First year cost savings—$3.5 million.
3. ***Continuous*** caster.—Continuous casting lowers costs and saves energy by eliminating costs of ingot casting (e.g., stripping, reheating, and primary rolling) and by reducing waste in the form of metal which must be returned to the steelmaking process.
   Project life—10 years.
   Capital costs—$125 million.
   First year cost savings—$30 million.
4. ***Dry-quenching of coke.*** —Dry-quenching involves sealing the coke battery and thus in order to recover thermal and particulate emissions as finished coke is cooled. H results in higher yields and fuel savings besides reduced environmental emission.
   Project life—10 years.
   Capital costs—$16 million.
   First year cost savings—$2 million.
5. **Inventory control. -A** computerized system can keep track of product item availability, location, age, and the like. In addition, these systems can be used to forecast product demand on a seasonal basis. The overall effect is to lower inventory, yet maintain the ability to ship products to customers with little or no delay. In typical installations, working capital costs are dramatically reduced.
   Project life—5 years.
   Capital and installation cost–$560,000.
   Energy savings—O directly, but working capital could be reduced by $1.2 million.
6. Electric motors. -The steel industry uses electrical motors for rolling, mixing, pumping, and solid materials transfer. In this analysis, **OTA has assumed that five aging electric motors will be replaced with newer,** high efficiency ones.
   Project life—10 years.
   Capital and installation cost–$35,000.
   Energy savings–$16,000 per year at 4¢/kWh.
7. Computerized process control—The most common retrofit purchases being made for industrial systems are measuring gauges, controlling activators, and computer processors. The main accomplishment of such a process control system is to enhance the throughput and quality of a steel mill with only materials and small energy inputs.
   Project life—7 years.
   Capital and installation costs–$500,000.
   Energy savings—$150,000 per year.
8. Steel ***mill cogeneration*** project.—Installation of a turbogenerator unit to recover electrical power from steam production facility. Superheated steam is produced at 600 psi and then passed through a mechanical turbine to generate electricity. The turbine exhaust, which is 175 psi steam, is used then for normal plant production.
   Project life—10 years.
   Capital and installation cost–$231,000.
   Energy savings—$72,300 per year.

SOURCE: Office of Technology Assessment.

Table 58.—Effects of Policy Options on IRR Values of Steel Industry Projects

Project	Reference case	IRR with policy options		
		ACRS removed	100/0 EITC	$1/MMBtu tax no EITC
Electric arc furnace	57	55	63	57
Electric motors	43	43	48	43
Reheat furnace	31	29	35	37
Continuous caster	25	24	30	26
Process control	16	17	22	16
Dry-quenching	13	12	16	13
Waste heat boiler	11	11	14	16
Cogenerator	11	11	15	17

SOURCE Office of Technology Assessment.

There is no short, quantitative answer. OTA has only **scattered data on 1981 investment behavior and even with a complete data set, calculation of the incremental impact requires knowing what investment would have been without ERTA.** Furthermore, since only a year has passed since ERTA became law, actual investment data would not reflect many large projects that may have been initiated as a result but have not proceeded beyond the planning stage. From 1979 through 1980 announcements for planned investments were as high as $7 billion, a fact that strongly suggests that many steel firms believed that ERTA would sharply improve steel prospects. Unfortunately, many projects appear to have been shelved owing to deteriorating sales in 1982.

Regarding the CC and EAF, several pertinent observations can be made. Generic I RR calculations indicate that the accelerated cost recovery system (ACRS) marginally increases the profitability of both technologies (see tables 57 and 58). However, virtually all industry representatives indicated that such marginal improvement has almost nothing to do with actual investment decisions. For EAF, the very large potential reduction in cost per ton allows paybacks that are already in the range of 2 years. It takes longer to amortize a CC, but such investments must be made in order to meet the competition, both in quality and cost. The domestic industry realizes that both technologies are essential, and therefore these investments will proceed at a pace determined primarily by product market conditions and the availability of funds. Since most domestic steel firms are severely restricted **in their access to debt and equity markets,** ERTA has probably increased steel investment only to the extent that it has actually increased retained earnings. Highly profitable minimills are the exception because they have relatively easy access to outside capital and so the ERTA tax savings can be leveraged into much larger actual investments.

In the energy savings and energy use projections shown in figure 39, ACRS helps cogeneration potential in this industry and encourages improvement in blast furnaces rather than greater reliance on electric arc furnaces-hence, the increase in purchased electricity and lower metallurgical coal demand **shown without the** ACRS. Overall energy, however, is not affected significantly since the most promising technologies here (CC and EAF) are likely to penetrate without the help of a new depreciation scheme.

Option 2: Energy Investment Tax Credits

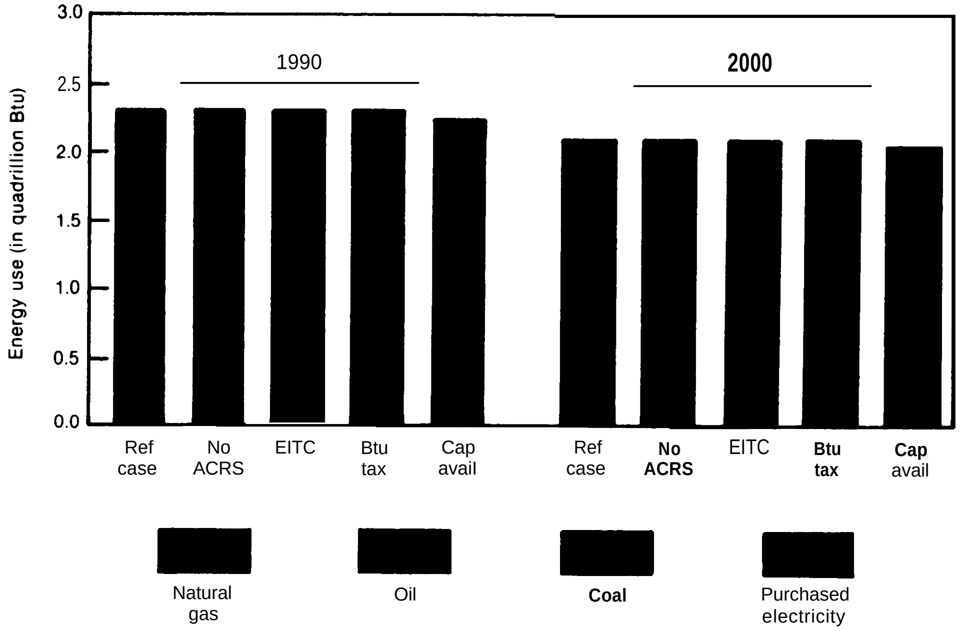
Like ERTA, the energy investment tax credit (EITC) would have its greatest impact on steel investment by increasing retained earnings. As shown in table 58, it would have a somewhat greater impact on IRR, based on generic project data, but again the increment in IRR would be of small consequence compared to product demand assessments in decisions of whether or not to invest in a CC or EAF.

Energy projections in figure 39 show that an EITC would help the steel industry displace some of its natural gas use in high-temperature heating, mostly through better and wider use of heat recovery equipment. It would have less impact on the use of oil, since oil is not used as widely as gas in applications with heat recovery potential. As a result, total energy demand would change very little in response to the incremental savings from heat recovery.

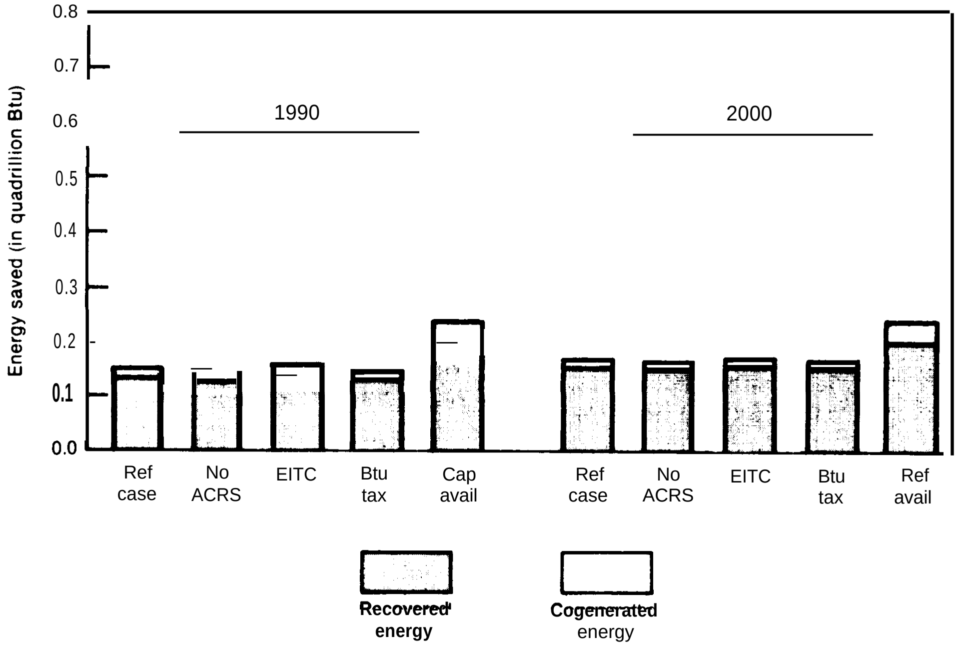
Offsetting these limited financial benefits, several industry experts were concerned about why tax credits should be targeted to energy use at all. in their view, just about every major investment will involve energy conservation, so targeting may just mean unnecessary administration. Since their primary goal is to reduce total costs, they see no obvious reason why energy deserves more attention than do labor, capital, or materials. ındeed, special tax incentives for retrofits

Figure 39.—Steel Industry Projections of Fuel Use and Fuel Savings by Policy Options, 1990.2000

Fuel Use Projections



Fuel Savings Projections



SOURCE: Office of Technology Assessment

(which presumably is how an EITC would apply) could delay or cancel construction of new plants, which many believe could be more efficient in the long run. They emphasized that they would be more concerned if oil were a significant fuel input. Instead, coal is by far the most important fuel, and at $2.50/MMBtu, there seems to be little economic incentive to subsidize coal conservation.

Furthermore, many in the steel industry are disillusioned by their experience with the original EITC passed in 1978. At that time, the Treasury Department narrowly defined the list of qualifying equipment, excluding specifically the CC because the CC could be justified on grounds other than energy savings. Based on that experience, industry representatives fear that any new EITC legislation would suffer the same fate. Thus, they would rather focus their attention on more pressing issues, such as legislation to restrict imports.

Option 3: Tax on Premium Fuels

Like virtually all materials-intensive industries, the steel industry does not welcome additional taxes on key energy inputs. Approximately 3 percent of total U.S. gas consumption is used for steel. Gas accounts for about 20 percent of the steel industry's total energy supply (including energy for coking coal). Although the steel industry does not use a significant amount of oil directly, steel's primary industrial customers do– especially the auto industry, but also industries involved with consumer durables and construction. All of these industries are affected by oil and gas prices, and an across-the-board tax on these premium fuels would tend to depress what are already depressed activity levels in these industries. Another major concern was that such a tax would disadvantage U.S. firms compared to untaxed foreign competition, causing exports to decline and imports to rise.

However, if an energy tax were to help balance the Federal budget, and thereby lower interest rates and generally improve growth prospects for the GNP, the net impact on the steel industry could be positive. This prospect was considered too speculative compared to the obvious bias in the short run against industries whose fortunes rise and fall with prices of premium fuels.

OTA modeling projections, as shown in figure 39 indicate that a tax on premium fuels, when compared to the reference case, would have little impact on either energy saved or fuel used. This is to be expected, since the steel industry uses predominently coal, and the policy option is designated not to apply to coal. The IRR calculations in table 58 also show little impact. However, despite its lack of effect on energy saved or used, the premium fuels tax would affect the steel industry in other ways, primarily by reducing demand for steel in autos and other consumer durables. industry managers and experts with whom OTA consulted were unanimous in their condemnation of an energy tax as being a burden the steel industry, in its current depressed state, could not well bear.

Option 4: Low Cost of Capital

All respondents from the steel industry would like lower interest rates, ideally as a result of a general decline in the real cost of borrowing. Lower interest rates would make all capital-intensive industries more competitive, including the steel industry; and it would make steel-intensive consumer durables, such as home appliances and autos, more attractive. However, this prospect is not directly relevant to this study because a general lowering of interest rates is not really an energy policy option.

Instead, what is meant is a special concessionary rate for energy-intensive industries in general and the steel industry in particular. This would lower investment costs, but in order to be realistic, this policy option must limit the total amount of debt that would be covered. To make a difference, at least $10 billion must be involved over a period of at least 5 to 10 years in order to convince a severely depressed industry to mount a large new effort to become more competitive. If $10 billion were outstanding for 10 years, and if the subsidy were 5 percentage points, then Federal outlays would be $5 billion, an amount that does not include *costs to the entire* economy as funds would be diverted from higher valued uses. A much smaller program could simply drive out privately placed debt with no net increase in total investment.

Assuming such a special program, however, this policy initiative would have greater impacts than the other policy options, both in terms of projected fuel use changes and in terms of illustrative rates of return for energy-related investment (compare tables 58 and 59). As seen in figure 39, natural gas and fuel oil use drops 3 to 5 percent, while coal and purchased electricity demand rise by compatible amounts. Total energy demand also drops (most noticeable in 1990) because of higher conservation through waste-heat recovery and higher investments in new energy-efficient technologies for processing and for cogeneration. Even though more in-plant electricity generation by utilities tends to increase the industry's fuel demand (since it is incurring more generation losses), the steel industry's total energy demand fell slightly. This decline results from the compensating factor of more efficient use of energy through increased waste-heat recovery.

Given that steel is not heavily dependent on oil, many respondents questioned how energy concerns could justify a large capital subsidy. Furthermore, a large subsidy offer may not be accepted if domestic firms still do not expect to produce competitively. Conversely, loans may be obtained and then defaulted as optimistic sales projections do not materialize and firms become insolvent. Given many marketing uncertainties and a highly charged political atmosphere where many jobs are at stake, market viability issues would be exceedingly difficult to resolve.

Table 59.—Effect of Lower Interest Rates on IRR Values of Steel Industry Projects

	Reference case IRR with 16°/0 interest rate	**IRR with policy options:** interest rate of 80/0
Inventory control	3850/o	370%
Electric arc furnace	101	107
Electric motors	93	97
Reheat furnace	54	60
Continuous caster	46	53
Computerized process control.	36	44
Waste heat boiler	24	27
Dry-quenching	17	25

SOURCE: Office of Technology Assessment.