CHAPTER 7

Technology and Raw Materials Problems

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Summary

Coke and scrap are essential raw materials for the steel industry: coke is the basis for reducing iron oxide to metallic iron in blast furnaces; scrap is the major input to electric steelmaking furnaces. The adequacy of future supplies of both is uncertain.

A shortage of cokemaking facilities, not of metallurgical coal from which to make coke, is the problem. Coke, used by the integrated steel companies as a feedstock in ironmaking, is mostly produced in byproduct ovens from high-grade metallurgical coals. About one-third of all domestic coke ovens are considered old by industry standards. These older ovens are less efficient than newer ones and tend to produce a poorer quality coke. The domestic steel industry has a much higher coke oven obsolescence rate than do other major steel-producing countries, and the actual productive capability of U.S. coke ovens has declined by almost one-fifth since 1973. The major reasons for this capacity decline are growing capital costs and regulatory requirements, both of which discourage new coke oven construction.

As cokemaking capacity declines, coke imports are growing and employment is falling off in this phase of steelmaking. Domestic coke consumption has been higher than production during 3 of the past 6 years. In 1978, domestic consumption was 5.4 million tonnes, an amount 16 percent higher than domestic production. One estimate is that by 1985, the coke shortage will increase to about 9 million tonnes, or 20 percent of domestic production, as capacity declines further and demand grows. However, a different study indicates that ample domestic cokemaking capacity exists,

Several options, with varying degrees of effectiveness, could help stabilize or reduce current coke shortages. These include: importing more coke, using more direct reduced iron (DRI), importing more semifinished or finished steel products, increasing the use of electric arc steelmaking (which would also require more scrap), and improving the coke-use rate in blast furnaces.

The steel industry is also a major consumer of commodity ferrous scrap. Although scrap prices have doubled since 1969, in real terms scrap remains an economical source of iron input for steelmaking. However, the future physical availability of high-quality scrap and its price are matters of some concern. Scrap industry processing capability and the availability and cost of transportation may affect scrap supply; however, the problems that exist in these areas are being remedied to some extent.

Scrap supply projections range from adequate, though at higher prices, to inadequate, even at higher prices. Because the substitution opportunities for scrap are limited, demand does not decline significantly when supplies diminish and prices increase. Most near-term technological changes will tend to increase the use of scrap; these changes include the growing use of electric furnaces and continuous casting and the modification of basic oxygen furnaces to increase the proportion of scrap used. At the same time, demand is growing for high-performance specialty steels, which incorporate a higher proportion of alloy and other materials that make scrap recovery difficult.

The growing demand for scrap places the steel industry in an increasingly difficult position. The energy-efficient, nonintegrated producers will be affected most severely by scrap price increases and supply problems. There are statutory resource conservation targets that apply to scrap, but these do not distinguish scrap-use problems by industry

segment. Furthermore, for economic or technical reasons, these targets are not always feasible on a plant basis.

Options that might be used to offset scrap supply problems and to maintain existing scrap inventories include expanding the use of DRI and imposing scrap export controls. Scrap exports have been relatively stable so far, but they are expected to increase because of worldwide increases in electric furnace use. U.S. scrap is attractive to many foreign buyers because of favorable currency exchange rates. The bleak outlook for scrap has prompted steel industry interest in export controls, but the scrap industry opposes such measures.

Iron ore supplies do not appear to pose a substantial problem that calls for, or affects, new technology. Although about one-third of iron ore is imported, the United States has substantial domestic ore resources and modern, efficient ore mines and processing facilities. Nevertheless, industry economics are such that imports will continue,[1] Observations by World Steel Dynamics confirm this outlook:

> The North American iron ore business has a unique industrial structure, resulting from the combination of economics (huge capital and economy of scale requirements), traditional factors, and the longer-term strategic perceptions of the various players.
>
> Until the 1960's there was always a major advantage for the steel producer to operate its own iron ore mines. And these mines were developed jointly in view of the huge capital requirements, economy-of-scale factors, and long lead times, The self-producers' advantage eroded during the 1960's as numerous foreign ore properties were developed and technological changes brought down transportation expenses. However, the nationalization of iron ore properties was important for long-term economic survival. There are not many iron ore properties in North America whose output is sold on a year-to-year basis to the highest bidder. The mentality of steel producers is that they have preferred long-term arrangements,
>
> Today, with steel production at high levels in the United States and inventories depleted by the iron ore strikes, demand is strong for the output of North American iron ore properties. Should the Western World economy be stagnant in the years ahead, economic forces will push down the profit margins of North American iron ore producers—as was the case during the 1960's and early 1970's. Conversely, if Western World economy is strong, Rotterdam iron ore "spot" prices will rise sharply within the next few years.[2]

[1]*Iron* Ore, Bureau of Mines, MCP-13, May 1978.

[2]World Steel Dynamics, Core Report A, ch. 12, 1979.

Coke Supply and Demand

A recent study for the Government concludes that the United States faces a shortage of metallurgical coke that is expected to worsen in the next 3 to 5 years.[3] Coke is an essential, coal-based industrial material used primarily in the steel industry's blast furnaces to reduce iron ore to iron, which is subsequently refined into steel. The United States holds the most favorable world position in terms of the size and quality of its coking-coal reserves and the technological capability for their commercial development. Nevertheless, as a result of coke oven obsolescence and declining capacity, the Nation's metallurgical coal reserves are being underutilized. Domestic coke producers are unable to satisfy consumer demand and substantial quantities of coke are being imported to supply the domestic deficit. Under current conditions, it is possible that this situation will not improve and that dependence on imported coke will increase, in which case domestic iron and steel production may eventually be

[3]Most of the material on coke presented in this chapter was obtained from William T. Hogan, S. J., and Frank T. Koelbe, Analysis *of* the U.S. Metallurgical Coke Industry, prepared for the Economic Development Administration and Lehigh University, October 1979.

curtailed. Alternatively, the use of steelmaking technologies not based on coke will increase and improvements in the technology will result in ample domestic cokemaking capacity.'

U.S. Metallurgical Coke Industry: Process and Age Distribution

The U.S. coke industry consists of 34 companies with 59 plants in 21 States. The current annual capacity of these plants is about 57.5 million tonnes (table 89). Forty-six of these plants are "furnace" plants, operated by iron and steel companies that produce coke primarily for use in their own blast furnaces; the other 13 are "merchant" plants that generally sell their coke on the open market to foundries and other consumers. Furnace plants produce 93 percent of the Nation's coke output (table 90).

Ninety-nine percent of all domestic "oven" coke is produced in byproduct ovens. * Byproduct ovens use a distillation process that heats metallurgical coals to high temperatures to drive off their gaseous content. The resulting coke is hard, porous material, high in fixed carbon and low in ash and sulfur, which is used as a reductant in the blast furnace for the ironmaking phase of steelmaking. A major advantage of byproduct coke ovens is that they permit the recovery of salable, petroleum-type products, whose value is rapidly increasing.

About one-third of total coke oven capacity is 25 or more years old, and nearly one-fifth is in the 20- to 25-year age category (see table 90). Domestic coke oven obsolescence rates are high compared to those in other major steel-producing countries. About two-thirds of all coke ovens in the European Economic Community (EEC) countries are less than 20 years old, and in Japan nearly 70 percent of the coking capacity is less than 10 years old and none of it is more than 25 years old.[5]

The generally accepted standard for the normal, effective lifespan of a coke oven is 25 to 30 years. Compared to newer coke ovens, those installed 25 to 30 years ago are less efficient, generate more pollution, require greater maintenance, produce lower quality coke, and contribute less to the overall productivity of the blast furnaces using that coke. Based on this standard, facility obsolescence is an acute problem for the domestic coke industry.'

[4]C. A. Bradford, "The Phantom Coke Shortage, " Merrill Lynch Pierce Fenner & Smith, 1980.

*An alternative coking method, the beehive process, is used by only two plants. They produce relatively minor quantities of "beehive" coke, most of which is marketed for blast furnace use and classified separately for statistical reporting purposes.

'International Iron and Steel Institute Survey, 33 *Metal* Producing, December 1979.

[6]Hogan and Koelbe, op. cit., p. ix.

Table 89.—Geographic Distribution of U.S. Coke Oven Capacity

States	Number of plants	Number of batteries	Number of ovens	Capacity in existence	Percent of total
Alabama	7	25	1,215	5,182,338	9.02
California, Colorado, Utah	3	14	710	3,273,472	5.70
Connecticut, Maryland, Massachusetts, New Jersey, New York	4	18	1,074	4,987,013	8.68
Illinois	4	7	326	1,807,560	3.14
Indiana	6	25	1,076	9,926,684	17.27
Kentucky, Missouri, Tennessee, Texas	5	10	415	2,094,916	3.64
Michigan	3	8	508	3,338,690	5.81
Minnesota, Wisconsin	1	2	100	163,210	0.28
Ohio	12	35	1,878	8,619,017	14.99
Pennsylvania	12	46	2,962	14,679,309	25.54
West Virginia	2	9	519	3,411,191	5.93
Total	59	199	11,413	57,483,400 [b]	100.00

aTonnes of Potential maximum annual capacity in existence on JuIy 31.1979, as determined by Fordham University survey.
b51.8 million tonnes are in operation, while actual p[roductive capacity has been estimated at 476 million tonnes (see table 98)

SOURCE William T Hogan, *Analysis of the U.S. Metallurgical Coal Industry, 1979*

Table 90.—Age Distribution of U.S. Coke Oven Capacity

Age in years[a]	Number of batteries	Number of ovens	Capacity[b]	Percent of total
Furnace plants				
0-5	24	1,437	12,028,221	22.66
5-10	7	526	4,687,077	8.83
10-15	6	330	1,583,767	2.98
15-20	20	1,225	5,737,183	10.81
20-25	40	2,383	10,746,376	20.24
25-30	37	2,216	9,793,931	18.45
30-35	17	1,071	5,072,425	9.56
35-40	12	650	2,728,886	5.14
Over 40	6	238	705,809	1.33
Total	169	10,076	58,083,675	100.00
Merchant plants				
0-5	4	242	901,132	20.48
5-10	2	95	419,778	9.54
10-15	4	201	827,638	18.81
15-20	1	60	217,834	4.95
20-25	0	0	0	0.00
25-30	7	298	947,810	21.54
30-35	1	47	86,074	1.96
35-40	3	100	256,899	5.84
Over 40	8	294	742,556	16.88
Total	30	1,337	4,399,721	100.00

aAge dates from first entry into operation or from last date of rebuilding.
bTonnes of potential maximum annual capacity in existence on July 31, 1979, as determined by Ford ham University survey.

SOURCE Willlam T. Hogan, *Analysis of the U.S. Metallurgical Coke Industry, 1979*

Most of the coking equipment being retired is 25 to 30 years old. Many ovens in this critical age category cannot be upgraded to meet pending environmental regulations and have been earmarked for abandonment.' Pennsylvania, Indiana, and Ohio are the sites of 57 percent of total in-place coking capacity (see table 89) and would be affected most by future plant closings.

Actual Productive Capability and Declining Capacity

When discussing coke oven capacity, it is important to differentiate between several measures of available or effective capacity. First, 5 to 10 percent of all ovens are offline at any point in time for rehabilitation or major repairs. Second, coke ovens will seldom, if ever, sustain a 100-percent operating rate over an extended period of time; periodically, they must be shut down for maintenance and minor repairs. Thus, some additional percentage of ovens will be temporarily out of service at any time. In recent years, pollution control has required a number of output-reducing modifications in coking practice. As a consequence, the maximum annual operating rate attainable by active coke plants throughout the industry is currently about 92 percent of their aggregate capacity.'

Coke oven capacity may be measured in three ways, according to operating conditions:

- capacity in existence (gross capacity, includes ovens out of order for rebuilding and major repairs, used to measure historical trends and age of equipment);
- capacity in operation (potential maximum productive capacity, excludes facilities that are offline for rebuilding and major repairs); and
- actual productive capability (excludes ovens shut down for minor repairs and maintenance, in addition to those out for rebuilding and major repair).

'Ibid., p. 48,

'Ibid., p. 43.

Existing capacity has declined by 15 percent since 1973 and is now 57.5 million tonnes. A decrease of similar magnitude has taken place in operating capacity, which is now 51.8 million tonnes. Actual productive capability has fallen since 1973 by an even greater amount—17 percent. This may be attributed to the aging of cokemaking facilities and to the expansion of regulatory requirements affecting cokemaking. During the past 6 years, 10 million tonnes of capability have been lost, and current actual productive capability is no more than 47.6 million tonne/yr (see table 91).

U.S. Production and Consumption: A Growing Shortage

Total coke production has declined considerably since 1950—and dramatically since 1976. Production decreased by 20 percent between 1950 and 1976, and by 33 percent between 1976 and 1978. * Coke consumption also declined during this time, but at a much slower rate: 23 percent between 1950 and 1978. More importantly, consumption has been higher than production during the past few years. During 1978, for the first time in nearly 40 years, the coke industry produced less than 44 million tonnes of coke, thus falling almost 15 percent below the Nation's consumption of 51.3 million tonnes (table 92).

The loss of coking capacity has resulted from a number of interrelated economic, technical, and regulatory causes, the most significant of which are:*

- long-term limitations on market growth and producer profits, which restrict the flow of investment capital into coke oven replacement and modernization;
- the consequent problems of coke oven age and obsolescence, reduced operat-

*Earlier production decreases were largely the results of improved blast furnace efficiency; more recent decreases are also the result of capacity reduction.

*These causes are listed without regard to ranking or degree of importance.

Table 91.—Estimated Decline in Actual Productive Capability of Coke Oven Plants in the United States: 1973 v. 1979a (millions of tonnes)

	Capability			Capability change			
				1973-79		1979-85 est.	
	1973	1979	1985 est.	Tonnes	Percent	Tonnes	Percent
Capacity in existence. .	68.0	57.5	52.7	10.5	15.5	4.8	8.3
Capacity in operation.	61.2	51.8	—	9.4	15.4	—	—
Actual productive capability	57.6	47.6	42,6	10.0	17.3	5.0	10.4

aComparison of estimated average levels for 1973 and levels on July 31, 1979, as determined by Fordham University survey

SOURCE William T Hogan, *Analysis of the U..S Metallurgical Coke Industry, 1979*

Table 92.—U.S. Coke Consumption (thousands of tonnes)

Year	Total production	Imports	Exports	Net stock change	Domestic consumption
1950	65,955	397	361	– 598	66,589
1955	68,299	114	482	– 1,132	69,063
1960 ., ...	51,907	114	320	+ 51	51,650
1965	60,637	82	756	+ 663	59,300
1970	60,338	139	2,248	+ 901	57,328
1971	52,094	158	1,369	-506	51,389
1972	54,880	168	1,117	– 532	54,463
1973	58,343	978	1,265	– 1,594	59,650
1974	55,854	3,210	1,159	– 226	58,132
1975	51,887	1,652	1,155	+ 3,688	48,694
1976	52,908	1,189	1,193	+ 1,356	51,548
1977	48,533	1,658	1,126	–43	49,109
1978	44,074	5,189	629	-2,674	51,309

NOTE Totals may not add due to rounding

SOURCE U S Departments of the Interior Commerce, and Energy ing efficiency, and increased oven emissions;

- the fluid state of cokemaking technology and the uncertainty of investing in unfamiliar equipment that may soon become obsolete;
- the escalating capital costs of coke oven facilities, attributable to inflation and the need to install complex pollution control and occupational safety equipment;
- additional obstacles to investment that derive from regulatory uncertainty as to future rules governing coke oven facilities;
- environmental control regulations which have contributed to the closing of older coke plants and to the curtailment of operating rates and output levels in remaining plants; and
- environmental restrictions on the construction of new and replacement coke ovens in certain geographic areas.

Capital Investment Requirements.—Coke oven costs have increased considerably during the past few years. These sharp cost increases have contributed to the shortage of coke ovens and coke. In 1969, the cost of installing a tonne of annual coke oven capacity was $82 to $94, or a total of $82 million to $94 million for a million-tonne battery of coke ovens. Installing a tonne of coke capacity now costs between $198 and $220, or between $198 million and $220 million for a million-tonne battery. This represents almost a 150-percent increase in 10 years, which partly results from the inflation that has driven up all capital costs.

Regulatory Requirements.—About one-fourth of the total capital investment in coke facilities is for environmental and occupational safety equipment. A recent estimate suggests that the capital cost for regulatory equipment may be as high as 30 percent.[9] The impact of regulations has been dramatic in certain elements of the cokemaking process, for example, on the quenching cars that receive the coke as it is pushed from the oven. A new car with gas-cleaning equipment involves an investment of $6.5 million, compared with $150,000 for a conventional quenching car purchased 10 years ago. The Environmental Protection Agency (EPA) maintains that environmental regulations have played a secondary role to economic and other causes in the loss of coke capacity; however, there is at least a similarity of timing between environmental regulations and capacity shutdowns.

Most of the Nation's coke oven batteries are located at steel plants that are in poor air quality, nonattainment areas. EPA has developed strict requirements for these areas. The most stringent requirements apply to new or rehabilitated coke oven batteries, but old facilities also have to be retrofitted with costly controls. In a number of cases, companies have decided that it would be more economical to shut down an operation and procure coke from outside sources because the remaining life of a battery was too short.

A considerable percentage of existing coke ovens is either in compliance with environmental standards or moving toward that goal. Batteries that have a number of years of life remaining have been or are being retrofitted with pollution control devices. The installation of pollution control equipment often requires increased energy consumption. The equipment may also require changes in operating practices, and these have slowed down the coking process considerably.

Environmental regulations have also contributed to limiting plans for cokemaking capacity expansion. Current industry plans call for less than a complete replacement of those ovens scheduled to be abandoned, and there are no announced plans to add capacity.

To install new coke oven capacity or replace existing ovens* in poor air quality regions, the following conditions must be met:

- high-performance environmental tech-

’33 Metal Producing, May 1979, p. 69.

*If a battery that has been in operation is torn down to be replaced by the same capacity, this is considered a new source of pollution that will have to meet the most stringent requirements.

nology, providing the least attainable emission rates, must be used;

- a company desiring to add a new installation must have all of its facilities within a State in compliance with EPA standards, or be under agreement to bring them into compliance; and
- the company must demonstrate continuing progress in reducing particulate matter so as to attain applicable air quality requirement levels.

In addition to these requirements, a company planning to expand cokemaking capacity in a nonattainment area must offset the additional pollution with pollution reductions in that area. This condition poses a serious problem for a new company moving into an area in which it has no other facilities for which pollution can be reduced. Even if a company has the necessary funds to build a coke oven battery in a nonattainment area, it may be difficult to make arrangements for a pollution tradeoff. * The increasing value of coke byproducts, however, is making such new ventures more attractive.

Coke Imports and Declining Employment

As a result of declining coke oven capacity and coke shortages, virtually every major steel producer has had to resort to imports—particularly since 1973. Coke imports, in turn, have contributed to reduced employment opportunities in the steel industry. Coke imports are expected to continue as present coke oven capacity is reduced.

Imports of MetaHurgical Coke.—Annual coke imports averaged about 16,326 tonnes between 1950 and 1972 and nearly 1,814,000 tonnes between 1973 and 1977. In 1978 they jumped to 5.2 million tonnes (table 92) or 10 percent of U.S. requirements, with almost 70 percent coming from West Germany. The balance came in relatively small amounts ranging from 12,000 to 300,000 tonnes from several other countries, including The Netherlands, Japan, the United Kingdom, Argentina, and Italy (table 93). * This marked the sixth consecutive year that imports were near or above the million-tonne level. Despite recent, temporary improvements in domestic availability and the current slowdown in steel activity, 1979 also saw a high level of imports.

The need for the United States, with the largest and best coking-coal reserves in the industrial world, to import substantial quantities of coke on a regular basis is an anomaly. It represents an example of the Nation's growing dependence on foreign suppliers for an industrial source of energy. This dependence on foreign coke may also present supply and price problems when steel industries in exporting countries are operating at a high rate. During the 1973-74 worldwide steel boom, U.S. companies imported a substantial amount of coke for $138/tonne, which was over $55/tonne more than it cost to produce coke domestically at that time. At the height of the 1974 boom, prices for spot sales were $143 to $154/tonne, and in one instance rose as high as $180/tonne. Should an increase in steel operations develop abroad, there is a real question as to whether the United States could count on obtaining coke from foreign sources. However, the present closing of much European steelmaking capacity and the Third World's ever-increasing use of direct reduction (DR) could make more coke available.

Trade and Employment Effects.—The 5.2 million tonnes of coke imported in 1978, including freight and insurance charges, cost close to $500 million. These imports contributed about 10 percent to the steel-related balance-of-payments deficit. Importing coke produced in part from foreign coal also carried a high price in the loss of job opportunities. If the 5.2 million tonnes of imported coke had been produced in this country from domestically mined coal, there would have been an additional 3,400 jobs at the coke ovens, plus as many as 6,000 jobs in the Nation's coal mines. It can also be argued that the loss of coke

*For additional comments, see ch. 11.

*Steel plants in Western Europe and Japan did not operate at maximum levels in 1978 as did domestic producers. As a consequence, they had excess coke capacity available.

Table 93.—U.S. Imports of Coke by Country of Origin, 1972-78 (thousands of tonnes)

Country of origin	1978	1977	1976	1975	1974	1973	1972
West Germany	3,604	1,108	808	1,259	2,505	664	—
The Netherlands	304	67	15	91	57	—	—
Japan	259	8	10	8	—	—	—
United Kingdom	213	17	—	44	347	8	—
Argentina	211	27	19	—	—	—	—
Italy	191	158	—	39	7	29	—
Canada	119	109	122	134	177	263	155
France	84	138	102	—	2	—	—
Australia	54	—	—	—	—	—	—
Norway	45	—	—	—	51	—	—
Belgium-Luxembourg	36	16	102	4	—	—	—
South Africa	33	—	11	54	31	—	—
Sweden	24	10	—	4	—	—	—
Austria	12	—	—	—	—	—	—
U.S.S.R.	—	—	—	—	26	—	—
Czechoslovakia	—	—	—	—	—	11	—
NewZealand	—	—	—	—	7	—	—
Hungary	—	—	—	—	—	3	—
Others	—	—	—	15	—	—	13
Total	5,189	1,658	1,189	1,652	3,210	978	168

SOURCE:US Departments of Commerce and the Interior

oven byproducts caused the use of more imported energy and an additional loss of jobs in the petrochemical industry.

Future Coke Shortages

Anticipated reductions in domestic coke oven capacity will force the domestic steel industry to depend on imported coke whenever steel demand is high. It has been estimated that coke imports are indispensable whenever the steel industry has an operating rate of 83 percent or more—as is expected to be the case often during the next several years. The current supply-demand imbalance is expected by some to lead to an annual shortage of 7 million to 11 million tonnes in domestically produced coke by 1985. Given likely increases in world steel demand, coke imports might not be readily available, or available only at high prices, unless additional coke oven capacity is constructed in the meantime.

Decline in Capacity.—Based on the excess of scheduled domestic coke oven abandonments over installations, it is expected that an additional 4.8 million tonnes of annual capacity (8.3 percent) will be lost by the end of 1985, thereby reducing total existing capacity to 52.7 million tonnes (see table 91), Ninety percent of this scheduled capacity loss is expected to occur by the end of 1982, when environmental control deadlines must be met. Of more immediate concern is the fact that 2 million of the 4.8-million-tonne loss is expected to occur by the end of 1980. Given the present decline in domestic steel consumption, however, this much reduction in cokemaking is not necessarily critical in the near term.

Actual productive capability is expected to decline even more than total existing capacity. When production losses from facilities scheduled to be rebuilt or repaired, from maintenance operations, and from environmental constraints are taken into account, it is estimated that the industry's actual productive capability will decline by 10.4 percent by 1985, to a maximum level of approximately 42.6 million tonnes.

Increased Demand.—Assuming a 2-percent-per-year growth rate in domestic steel output and the need for 0.56 tonne of coke to make 1 tonne of pig iron, approximately 53.5 million tonnes of coke would be needed to meet demand in 1985. The domestic coke shortfall would be about 11 million tonnes. Barring coke importation, a shortage of that magnitude would result in a 15.4-million-tonne decline in the amount of blast furnace iron available for steelmaking; raw steel output would then be short of demand by some 26.3 million tonnes, the equivalent of 19.5 million tonnes of finished steel products. * A l-percent-per-year increase in domestic demand for steel would require 49.9 million tonnes of coke in 1985, leaving a shortfall of 7.3 million tonnes of coke from domestic sources, enough to have a significant negative effect on pig iron and steel production. Without coke imports and without an increase in domestic capacity, the steel industry could have finishing facilities that are standing idle while the country imports the steel it needs.

Changing Technology.—A recent analysis[10] concludes that even with a steel boom in 1985 domestic demand would only be 41.7 million tonnes of coke, which implies that adequate capacity would exist. The critical difference between this analysis and others is its optimism about future reductions in the amount of coke needed to produce a tonne of pig iron in blast furnaces: it forecasts a usage rate of 0.50 tonne of coke per tonne of pig iron for the United States in 1985. Modernization of existing blast furnaces appears likely, and this forecast may thus be correct. Other factors which lead to the conclusion of ample coke capacity include the increasing replacement of open hearths with electric furnaces, and continued improvements in existing cokemaking facilities to provide greater capacity.

Although OTA has not performed its own detailed analysis of future cokemaking capacity and demand, the above conclusions are consistent with other OTA findings: the increasing use of electric furnace steelmaking (especially by nonintegrated steelmaker), and a modernization and expansion program for the coming decade aimed at improving the performance of existing integrated facilities (see ch. 10). Hence, although there is uncertainty about future coke shortages, only the combination of very low capital spending and high domestic steel demand would likely lead to a severe coke shortage in the coming decade.

*This projection for 1985 is based on the following assumptions: growing emphasis on scrap-based electric furnace steelmaking: no major use of direct reduction; 0.580 of iron output for each tonne of steel output.

“’Bradford, op. cit.

Potential Solutions to Coke Shortages

Domestic coke shortages, should they occur, could be remedied in part by purchasing coke elsewhere. An active worldwide steel market, however, could significantly reduce the likelihood that imported coke would be available, and whatever coke did become available would be at very high prices. Another alternative would be for steel consumers to import up to 19.5 million tonnes of finished steel products. Occurring at a time when steel demand is expected to be high all over the world, this would also mean exorbitant prices for steel imports. * A third alternative would be to increase domestic coke oven capacity. This course would make the steel industry more self-sufficient by reducing coke imports, would improve the Nation’s balance of payments, and would increase domestic job opportunities. The ever-increasing price of petroleum may also provide ample motivation for expanding coking capacity, because the coke byproducts that can substitute for petroleum products in some uses will have more value. Byproduct sales would help to reduce the real cost of coke for blast furnace use.

Additional solutions to the coke shortage are available, but each presents problems of its own:

- The use of electric furnace steelmaking based on scrap iron could be increased. The limitations to this option are that it does not use virgin ore and thus does not add to the available iron supply; a shortage of scrap iron may occur, or markedly higher prices may reduce the competitiveness of this steelmaking technology; ** and there may be inadequate domestic supplies of electricity.

*Whenever steel imports enter the United States under domestic shortage conditions, rather than in competition with domestic steel, prices reflect what the market will bear. This was borne out in 1974, when import prices for steel were between $55 and $110/tonne higher than domestic production prices.

**See following section on scrap.

- DR could supplant or complement blast furnace technology based on coke. Available projections suggest that the use of DR will increase. However, construction of domestic DR facilities will depend on additional coal-based DR technology becoming available for large integrated plants or small nonintegrated plants, or both. The availability of imported DRI depends on developments in a number of less developed countries and is still somewhat speculative. (See ch. 6.)
- Semifinished steels could be imported to bypass the need for domestic blast furnace operations. It would be better to import semifinished rather than finished steel, because domestic capital investment for primary ironmaking and steelmaking would be greatlv reduced while profitable secondary steel processing and finishing would be done domestically. Nevertheless, imports of semifinished steel would still add to already sizable balance-of-trade deficits.
- Blast furnace-based plants could change processes to reduce the amount of coke they use. Such changes might have a major impact because of the large number of old and small domestic blast furnaces currently in use.
- Formcoke technology could be adopted to promote the use of cheaper, nonmetallurgical-grade coals. This technology may offer environmental advantages, but it has not yet been demonstrated on a large scale. Furthermore, there are indications that capital costs and energy use may be high. *

*See case study of formcoke in ch. 9.

Ferrous Scrap Supply and Demand

Recent testimony by the chairman of the Ferrous Scrap Consumers' Coalition provides an introduction to the issues that currently confront the domestic steel industry with regard to the demand and supply of ferrous scrap:

> The recent rate of United States ferrous scrap exports has reached record levels. Current exports parallel those experienced in 1973 and 1974, a period in which Commerce imposed export restraints, During 1978, domestic consumption of ferrous scrap approached the 100-million-ton level, 54 percent greater than in 1977. Japan accounted for almost all of the increase in the United States exports. Between 1977 and 1978 domestic exports of ferrous scrap to Japan increased by 208 percent to more than 3 million tons. Scrap exports to Canada, Italy, Mexico, Taiwan, South Korea and Spain also increased. During the last six months of 1978, as domestic demand rose and exports skyrocketed, inventory stocks of industrial ferrous scrap purchased on the open market declined by 6 percent.[11]

Ferrous scrap is an important raw material in steelmaking, and the demand for it is growing rapidly, partly as a result of increasing worldwide use of the electric furnace. Scrap can be viewed as embodied energy; as such, it is a valuable domestic resource, and there are advantages to maximizing its domestic use. However, to produce high-quality steels with minimum impurities, it is necessary to have the domestic steel industry convert ore into new iron units, some portion of which will eventually become available as ferrous scrap. There are also limits to increased domestic steel production unless new iron units are produced from ore.

The availability and quality of scrap will also affect the development and adoption of

"W, J. Meinhard, testimony before International Finance Subcommittee of Senate Banking Committee, Mar. 12, 1979.

new steelmaking technologies. DRI, for instance, could partially substitute for scrap, and the possible development of domestic coal-based DR technology and the availability of foreign DRI may reduce the future demand for scrap. Scrap availability and price, in turn, will determine to some extent how viable DR will be.

U.S. Ferrous Scrap Industry

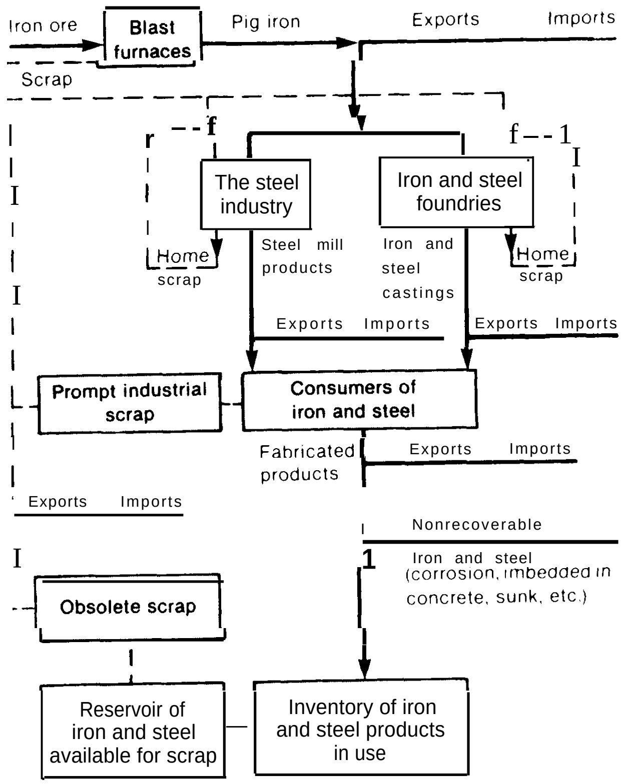
Ferrous scrap is often defined as the portion of ferrous material that can be economically recycled. This economic definition is significant because scrap is not a homogeneous commodity. Ferrous scrap normally originates from three sources:

- Home or revert scrap is discarded material generated in the iron and steel industry itself during the primary and secondary steelmaking operations.
- Obsolete or capital scrap is wornout or discarded material from diverse sources such as industry, consumers, or municipal dumps. This scrap is often mixed and contaminated with other materials. Several of these materials, such as copper, are difficult to remove and are deleterious to the steelmaking process or the final steel products.
- Prompt industrial or process scrap is discarded material generated in manufacturing operations using steel, which cannot be recycled in the same plant.

Home and prompt industrial scrap generally represents higher quality iron than obsolete scrap. It is estimated that about 45 percent of all scrap in North America is home or prompt industrial, and 55 percent is obsolete. Because it is such a heterogeneous commodity, scrap is classified according to a complex set of specifications based on such factors as physical-chemical properties, origin, and consumer requirements. * Scrap that requires a great deal of treatment to improve its physical or chemical characteristics may be an uneconomic source of iron units.

The scrap industry is noted for its involved, integrated market structure (figure 33). The industry can be divided into four discrete functions—collection, dealing, brokerage, and processing. These functions may be completely segregated in different firms or combined in firms with some degree of vertical integration. A collector gathers the scrap and sorts it into useful and nonuseful material; most collection is now carried out by dealers who classify the scrap before processing it to meet customer's requirements. A broker generally acts as the middleman between dealer and customer, making arrangements on be-

Figure 33.— Flow Chart of Ferrous Metallics



SOURCE U S Department of Commerce

*More than 10 different grades of scrap are widely used. These grades have various characteristics with respect to bulk density, size coating, and chemical impurities.

half of a customer for the purchase of specified grades of scrap on a contractual basis. Scrap processors are usually fully integrated companies that process material, such as autos and appliances, into acceptable grades for use in steel production. Scrap processing is a major business, often involving high investment in such processing equipment as shears, slabbers, crushers, and shredders.

Supply, Demand, and Price

The steel industry is the major consumer of ferrous scrap, although other consumers such as foundries offer competition for scrap supplies in many areas. Total scrap consumption has gradually increased over the years, while home scrap production has declined somewhat. Scrap prices fluctuate considerably with demand and availability, although the general trend has been upward, with a more than twofold increase in price from 1969 to 1978 (table 94).

Not all types of scrap are equally important when considering availability, Home scrap is not a primary concern. It is completely internal to the steel mill and bears no relationship to the price of scrap, except that a reduction in home scrap could lead to greater demand for purchased scrap. Purchased scrap is a mixture of obsolete and prompt industrial scrap. The availability of obsolete scrap, particularly, is at the core of the question of whether the U. S. steel industry has adequate supplies of domestic scrap. The major and contradicting views on this question have been presented in the Nathan study for the research arm of the Institute for Scrap Iron and Steel[12] and the Fordham University study for the American Iron and Steel Institute (AISI).[13] The Nathan study was conducted for scrap suppliers and the Fordham study for scrap users.

The main thrust of the Nathan study is that adequate domestic supplies of obsolete scrap exist and that a shortage is unlikely, although prices could increase substantially. Nathan started with a 1955 estimate of the total pool of domestic obsolete scrap[14] and added to it his estimates of subsequent annual iron and

[12]Robert R. Nathan Associates, Inc., *Price-Volume Relationship for the Supply of Scrap Iron and Steel:* A Study of the Price Elasticity of Supply, for the Scrap Metal Research and Education Foundation, Washington, D. C., Jan. 8, 1979.

"William T. Hogan, S. J., and Frank T. Koelbe, Purchased Ferrous Scrap: United States Demand and Supply Outlook, for AISI by Industrial Economics Research Institute, Fordham University, New York, June 1977.

[14]Battelle Memorial Institute, "Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, " for Scrap Metal Research and Education Foundation, Washington, D, C., 1972.

Table 94.—Measures of U.S. Ferrous Scrap Use, 1969-78

Year	Total domestic purchased scrap[a] for Total pig iron	Purchased scrap for steelmaking[b] for Pig iron in steel	Purchased scrap for steelmaking[c] for Raw steel	Purchased scrap for Steelmaking[d] Steel shipments
1978	.53	.36	.22	.31
1977	.52	.34	.21	.29
1976	.48	.32	.20	.29
1975 ..., ...	.48	.32	.20	.29
1974	.54	.38	.24	.32
Average.	.51	.34	.21	.30
1973	.44	.32	.21	.28
1972	.47	.33	.21	.31
1971	.42	.28	.18	.25
1970	.37	.28	.18	.26
1969	.39	.28	.18	.28
Average.	.42	.30	.19	.28

aFor regression fit between ratio and time, correlation coefficient = 0.86, growth rate = 0.017 per year.
bFor regression fit between ratio and time, correlation coefficient = 0.74, growth rate = 0.008 per year.
cFor regression fit between ratio and time, correlation coefficient = 0.63, growth rate = 0.004 per year.
dFor regression fit between ratio and time, correlation coefficient = 0. 55, growth rate = 0.004 per year

SOURCES Total domestic Purchased scrap from Bureau of Mines, other data from American Iron and Steel Institute steel discards.* This made it possible to estimate current total obsolete scrap reserves. The Nathan study indicates that there were 577 million tonnes of potential reserves at the end of 1975 and 609.8 million tonnes at the end of 1977. This study used the concept of "potential reserves" of obsolete scrap, defined as quantities recoverable with the use of existing technology at high but realistic prices—that is, prices possibly several times higher than present levels. Specifically, the definition of potential reserves implies a positive price-supply relationship. At any given price above the present price, an additional amount of scrap will move into the hands of processors and, through them, to the iron and steel industry. Thus, price increases trigger larger supplies of difficult-to-process scrap, although not necessarily in a linear relationship—dramatically higher prices would be required to extract the last increment of scrap from potential reserves and place that increment in the ferrous supply system.

Hogan and Koelbe, in the Fordham study, reached the converse conclusion, that scrap would be in short supply in the early 1980's. Unlike Nathan, they did not use the total pool of obsolete scrap reserves as the basis for their current and 1982 estimates of available domestic scrap. Rather, they looked at the discarded materials from the Nation's total iron and steel inventory that it would be economically and technically feasible to recycle. They determined the current and 1982 projected iron and steel inventory by making annual additions to a 1954 Battelle estimate. They then estimated the portion of recyclable material by using the 1974 maximum discarded-materials withdrawal rate of 1.63 percent. This approach led to the conclusion that there will be a shortage of 9.9 million tonnes of obsolete scrap by 1982.

Like the Nathan study, the Fordham study considered the effect of scrap price on supply. The Nathan data showed greater sensitivity to changes in price than did the Fordham data. Using 1973-74 data, Hogan and Koelbe found that a 100-percent increase in price would yield a 7-percent increase in scrap supply. The Nathan report found that a price increase of that magnitude would yield an increase of somewhat more than 83 percent in the supply of obsolete scrap. * Thus, Nathan's finding of significant supply elasticity for scrap supports his conclusion that scrap supplies would be adequate under conditions of rising prices, while the finding of limited supply elasticity underlies Hogan and Koelbe's prediction of a future scrap shortage. Neither study, however, is impressive in its methodology or precision.

Very little attention has been paid to demand elasticity for scrap. Rossegger found that the demand for scrap is price inelastic. " In other words, demand for scrap is quite insensitive to changes in price, because the possibilities of substituting other materials are presently quite limited. Increases or decreases in the price of scrap will trigger only very modest decreases or increases in demand. Rossegger's findings have been confirmed in recent years, when demand for scrap has not decreased with high prices. In fact, several measures of domestic scrap use indicate that the trend is toward increasing consumption (table 94). The proportion of scrap to either pig iron (blast furnace output), raw steel (steelmaking furnace output), or steel shipments over the past decade has increased significantly.

Thus, on the basis of these studies, scrap supply can be expected to range from inadequate to adequate (at much higher prices) and scrap demand to grow regardless of price. The steel industry, as a major scrap consumer, has few options. To reduce the impact of cyclical shortages, it could maintain scrap inventories. In the long run, it could substitute other raw material, such as DRI, and support the imposition of export controls. **

*There has not been a net withdrawal from the total pool of domestic obsolete scrap since 1956.

*Nathan's data show a supply elasticity of 0,83 for obsolete scrap for the 1961-76 period. For 1973-74 the elasticity was higher than 1.0.

[15]J. Rossegger, Human Ecology, vol. 12, November 1974.

**See below for a discussion of the latter two options.

As a rule, steel companies do maintain substantial inventories, in absolute terms and in relation to use, in order to offset short-term scrap supply and price problems. As prices rise, inventories decline, and when prices fall, inventories increase. This requires substantial investment: the domestic steel industry invests more than $500 million annually in carrying scrap inventories, and more in providing space and facilities to handle those inventories.

Recently, increasing demand for scrap has altered this traditional pattern of curtailing scrap purchases when prices are high. Scrap inventories are drawn down during periods of rising price, but net purchase receipts of scrap by steel mills and other consumers have continued to move upward to satisfy the less flexible requirement for scrap. This trend appears attributable to the increasing use of electric furnaces and to the growing exports of scrap.

Availability Concerns

Future availability at reasonable prices is not the only concern with regard to scrap. Other concerns include the adequacy of the scrap industry's processing capabilities in the face of growing demand; the availability of railroad cars to ship scrap; the structure of freight rates; and finally, the effect on the use of scrap of fiscal incentives for mineral exploration and mining. Some of these problems appear to have little effect on scrap supplies and steel production costs; others are now being remedied.

Processing Capabilities of the Scrap Industry.-A recent Battelle report concludes that present scrap-processing facilities can easily process enough scrap even when the demand is much greater than current levels. 'G No consideration is given to questions of cost and price. The report claims that 47.3 million tonnes of scrap were processed (operating an average of 50 hours per week) in the peak year of 1974. The report also claims that an additional 41.7 million tonnes or more of scrap could be processed under the following conditions:

- optimum raw material supply and market demand: 9.1 million to 11.8 million tonnes;
- improved scrap operations and maintenance programs: 7.3 million to 9.1 million tonnes;
- addition of a full second shift: 22.7 million to 27.2 million tonnes; and
- improved materials handling and plant flow: 2.7 million to 4.5 million-tonnes.

The report predicts that by 1980, 131.2 million tonnes of ferrous scrap could be processed annually. Thus, this report (without addressing the scrap cost issue adequately) supports the position that adequate scrap supplies exist for the future if scrap-processing capabilities are viewed as the primary problem. But because scrap suppliers are forecasting scrap shortages, the Battelle report's conclusions can be questioned.

Gondola Railroad Cars.—Scrap is moved via rail in gondola cars. Because most scrap is moved from scrap processors to steelmaker by rail, the gondola supply is a critical link in the availability of scrap. Many incidents of ferrous scrap supply shortages have been attributed to the unavailability of gondola cars.

The pool of gondolas available to scrap processors has been declining for some time. '7 Every year, more gondolas are retired than are added. From 1970 to 1979, there was a 23-percent decrease (37,878 cars) in the number of general-purpose gondolas. Daily shortages during 1978 were in the 3,000-to 5,000-car range.

One of the Interstate Commerce Commission's (ICC's) regulatory responsibilities under the Interstate Commerce Act is to make sure that railroads supply sufficient cars to satisfy shipping needs. To increase the gondola supply, ICC has approved an incentive per diem (IPD) system, although its decision is being appealed. IPD adds to the basic gondola

[16]Battelle-Columbus Laboratories, *The* Processing Capacity *of the* Ferrous *Scrap* Industry, Columbus, Ohio, Aug. 10, 1976.

[1] Phoenix *Quarterly*, September 1978,

rental fee an extra cost that simultaneously penalizes railroads borrowing gondolas and rewards those railroads investing in gondolas.

The gondola-supply situation appears to be improving. In 1979, 6,000 replacement cars were scheduled for construction by 1980. This would slow down the loss of gondolas. Continued increases in rail capability for scrap shipment may occur but are not certain.[18]

Railroad Freight Rates.—A longstanding issue is whether railroad freight rates discriminate against ferrous scrap shipment and, hence, limit the supply of scrap. ICC recently found that discrimination against ferrous scrap exists in some parts of the country.[19] A study by OTA concluded that discrimination against scrap exists but that the effect on supply is small:

> The conclusion of this analysis is that substantial discrimination against secondary materials is found, if one adopts cost-based or equivalency-based railroad ratemaking.
>
> For example, a 36-percent decrease in the rail rate for iron and steel scrap would increase rail shipments by an estimated 0,2 million to 1 million tons (about 0.5 to 2.9 percent), but would cause a reduction in rail revenues of $100 million to $110 million per year. This loss is equivalent to about $100 to $550 per ton of additional scrap moved, and is not economically justifiable from the railroad’s perspective when iron and steel scrap is selling in the neighborhood of $50 to $100 per ton.[20]

Tax Disparities.—Federal tax regulations explicitly encourage exploration for minerals and the mining of virgin ores. The regulations that have most significance for scrap use are:

- depletion allowances—i. e., flat percentage deductions from gross income—for iron ore mining operations;
- expensing of exploration and development costs—i.e., immediate deductions for iron ore exploration and development expenses;
- capital gains tax rates on royalty payments to landlords that lease land for production of iron ore; and
- tax credits for payment of foreign taxes.

To the extent that these tax regulations apply only to the exploration and mining of virgin ore, they implicitly discriminate against the use of iron scrap. But a number of studies undertaken by various Federal agencies as well as by industry suggest that the impact of this discrimination is not substantial. For example, the 1975 total tax benefits from using virgin ore to produce a tonne of raw steel were found to be $1.38, or 1.7 percent of the cost of producing the raw steel,[21] an amount that could only marginally affect the use of ferrous scrap. The Department of Treasury recently concluded that “it is extremely unlikely that the tax subsidies could reduce the amount of recycling of scrap steel by more than one percent.[22]

Scrap Exports: Growing World Demand and Price Impact

Whether or not current and future exports of scrap by the United States will have adverse impacts on the domestic steel industry is an acute, highly debated issue. Scrap exports had been fairly stable since at least 1969, but they rose sharply in 1979 to approximately 10 million tonnes (table 95). Unlike the United States, many, if not most, of the steel-producing nations have very limited domestic supplies of scrap, and eight countries (Japan, Italy, Spain, Mexico, Canada, South Korea, Turkey, and Taiwan) accounted for 85 to 90 percent of U.S. scrap exports between 1973 and 1979.

[18] American *Metal* Market, Aug. 9, 1979.

[19] Interstate Commerce Commission, “Further Investigation of Freight Rates for the Transportation of Recyclable or Recycled Materials,”' Apr. 16, 1979.

[20] Office of Technology Assessment, Materials and Energy From Municipal Waste, July 1979.

[21] Booz-Allen and Hamilton, “An Evaluation of the Impact of Discriminatory Taxation on the Use of Primary and Secondary Raw Materials,” 1975.

[22] U.S. Department of the Treasury, Federal Tax *Policy and* Recycling *of* Solid Waste Materials, February 1979, p. 87.

Table 95.—Selected Data on Iron and Steel Scrap: Ferrous Scrap Relative to Scrap Consumption and the Impacts of Scrap Exports on Scrap Supply and Price (thousands of tonnes)

Year	Total scrap consumption	− Home scrap production	+ Change in consumer inventories	= Domestic net scrap receipts[a]	Ferrous scrap exports[b]	Total scrap shipments	Exports as a percent of total shipments	BLS scrap price index, 1967 = 100
1969	85,998	51,052	– 1,206	33,740	8,322	42,062	19.8	1 lo:5
1970	77,602	47,686	+ 1,012	30,928	9,401	40,329	23.3	138.9
1971 ... , . .	74,888	44,596	+ 749	31,041	5,674	36,715	15.5	114.6
1972	84,687	46,424	- 295	37,968	6,697	44,665	15.0	121.8
1973	93,955	52,426	- 977	40,552	10,210	50,762	20.1	188.0
5-year average. .	83,426	48,437	– 143	34,846	8,061	42,907	18.7	134.8
1974	95,673	50,112	+ 1,000	46,561	7,887	54,448	14.5	353.2
1975	74,674	41,760	+ 421	33,335	8,714	42,049	20.7	245.6
1976	81,548	45,374	+ 1,374	37,548	7,365	44,913	16.4	259.0
1977 ., ...	83,885	44,919	– 488	38,478	5,602	44,080	12.7	231.2
1978 (p)	89,889	47,110	- 979	41,800	8,197	49,997	16.4	264.6
5-year average. .	85,134	45,855	+ 266	39.545	7,553	47,098	16.1	270.7

aGross shipments minus shipments by consumers, receipts by mills and founding
b1979 exports 10 million tonnes
cDomestic net scrap receipts plus ferrous scrap exports
(p) Preliminary

SOURCES Bureau of Mines (scrap consumption, production, etc.): U S Bureau of Census (exports), and Bureau of Labor Statistics (price index)

About 75 percent of all scrap traded internationally is from the United States.[23] As worldwide use of electric furnaces grows, so will demand for ferrous scrap, and additional pressure will be placed on the United States to export more scrap. A recent analysis forecasts a 30-percent increase in foreign demand for U.S. scrap by 1982 (excluding Canada and Mexico) .24 A recent article on this issue stated:

> Whatever future export demand will be, it can be certain that world scrap requirements are going to grow. Preliminary results of a detailed study on ferrous scrap by the Steel Committee of the Economic Commission for Europe (ECE) underline future expansion in scrap requirements. The ECE indicates that the world requirement for obsolete scrap will increase (measured from 157 million tons in 1974) by 39 percent to 218 million tons by 1985 and by 50 percent to 235 million tons by 1980,
>
> Considering the expected growth in world scrap requirements, we can reasonably anticipate in the future strong demand for U.S. ferrous scrap exports. If history is a guide, demand should show sharp cyclicality, and at some point, market conditions that approximate the tight supply situation of 1970 and the exceptional period of 1973-74 (hopefully not too much like 1973-74). As you recall, increasing steel production in the U.S. and the rest of the world led to significantly increased demand for scrap.
>
> The composite price of No. 1 heavy melting scrap increased 25 percent from $43 per ton in December 1972 to $54 per ton in June 1973 and then by another 46 percent to $79 per ton by December 1973, reaching a high of $145 per ton in April 1974,[25]

Some exporters contend that exports of scrap do not result in increased domestic scrap prices. * The fundamental reason for this contention is that there exists in the United States a considerable volume of obsolete scrap that could be added to the supply as the demand increases, although the cost of

[23]I. M. J. Kaplan, "The Consumer's Viewpoint, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.

[24]W. W. Blauvelt, "A Free Market: Ferrous Scrap Demand and Supply, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.

[25]D. R. Gill, Exports of Ferrous Scrap, Iron and Steelmaker, March 1979, p. 30,

*For additional comments, see the discussion of the Nathan study above.

retrieving such scrap could be very high. Others, including most of the domestic steel companies led by AISI, argue forcefully for controls of scrap exports:

> . . . accordingly, it is the view of the U.S. steel industry that continuous monitoring of scrap exports by the U.S. government is essential. The industry has urged that the Congress revise the Export Administration Act of 1969 to require such monitoring. Additionally, the industry has recommended that a study be undertaken of policies other governments have implemented over the past decade with respect to exports of their ferrous scrap. Such a study should evaluate the extent to which the U.S. economy has been adversely affected by such policies.
>
> It can no longer be assumed that the U.S. can supply a growing world need for ferrous scrap while the rest of the world carefully guards its internal supplies. This policy will cause unacceptable domestic inflation, as is the case today, and if unchecked, will ultimately lead to domestic steel shortages. As the leading world supplier, the U.S. must assume a role of responsible leadership with respect to world access to the supply of ferrous scrap on a non-discriminatory, most favored nation basis conditioned upon full satisfaction of home demand.[26]

The proponents of scrap export controls also point to the conditions prevailing in the 1973-74 period. Steel demand was very high, and this caused large demand for both foreign and domestic scrap. Prices were very high. On July 2, 1973, the U.S. Department of Commerce imposed export restrictions on ferrous scrap under the "short supply" provisions of the Export Administration Act of 1969. No new orders for more than 454 tonnes of ferrous scrap could be accepted for the balance of 1973. Individual allocations were distributed according to exporter, country, and grade, based on each exporter's history of scrap exports during the base period, from July 1, 1970, to June 30, 1973.

Almost all of the domestic steel producers contend that the high prices of scrap experienced in the 1973-74 period will be repeated in the future unless some control of scrap exports is enacted. The domestic scrap exporters, on the other hand, argue that scrap exports have been stable over time, and therefore control of scrap is not necessary. Indeed, exports of ferrous scrap have been relatively stable when measured against total shipments. Furthermore, scrap exports make a relatively small, but positive, contribution to the balance of trade. In answer to the balance-of-trade argument, domestic scrap consumers point out that price increases spurred by exports more than offset the value of export tonnage. Moreover, much exported scrap contains valuable alloying elements which the United States must import. However, scrap with alloying elements is generally less marketable domestically than conventional carbon steel scrap.

Although scrap exports have been fairly stable, they do appear to correlate with price and price volatility of scrap (figure 34). A recent study of this issue states that:

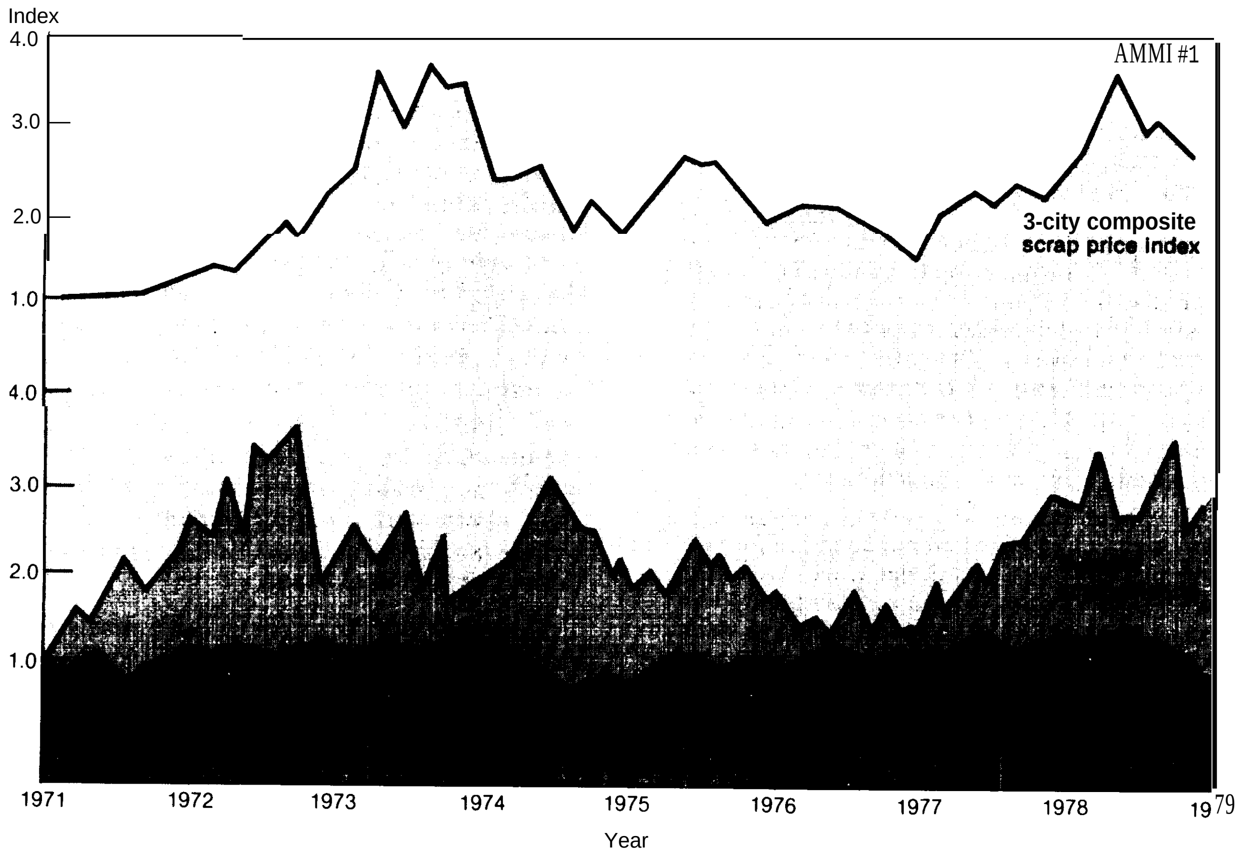
> This study is intended to provide additional insight into the rapid escalation in prices which has characterized the United States market for purchased ferrous scrap within the last year. Its focus is on measuring the relative influence of U.S. exports and domestic demand on domestic ferrous scrap prices. The results of a number of statistical analyses directed at this end indicate that the foreign component of total demand, which is represented by U.S. exports, has had a substantially greater impact on U.S. ferrous scrap prices than has domestic demand during the last two years (January 1977 through January 1979). The influence of the domestic component of total demand for ferrous scrap on domestic prices was found to be statistically insignificant.[27]

An earlier study, which examined the dependence of U.S. scrap prices for 1973-78 on 25 factors, found that the most statistically significant correlations were first with foreign scrap prices and second with EEC steel

[26] American Iron and Steel Institute, Ferrous *Scrap Supply and Demand Outlook*, June 1979.

[27] Economic Consulting Services, Inc., The *Impact of U.S. Exports of Ferrous Scrap on U.S. Ferrous Prices: An Empirical Analysis*, Washington, March 1979.

Figure 34.—Scrap: Price and Export Levels; Domestic Purchased Scrap Requirements, 1971-79



SOURCE: *American Mefal Market,* U.S. Bureau of Labor Statistics

mill operating rates.[28] The latter variable was more significant than domestic operating rate or domestic scrap consumption. A methodological problem with findings relating exports to domestic prices, however, is that the prices may not be representative of all or most scrap markets. Data on scrap prices for cities from which exports are significant distort the picture for the entire country, which includes many markets not influenced by exports.

Perhaps the most significant long-range consequence of increasing scrap exports to meet greater foreign demands is the possibly detrimental impact of such exports on the nonintegrated steel producers, the Nation's most efficient low-energy and low-cost steelmaker. Rising scrap prices, driven by high foreign demand, would put a substantial cost-price squeeze on these firms and could drive them out of the market, especially if steel prices are subject to formal or informal Government controls that cannot be released quickly enough to offset rapidly rising costs. This impact is particularly acute now, when DR is not widely used domestically and when DRI is not readily available as an import.

When domestic demand and export demand for scrap impact the market at the same time, the issue of adequate supply for domestic use becomes acute. Foreign nations have been much more restrictive of scrap exports than has the United States. The United Kingdom presently has a licensing system under which the quantity and grades of scrap exported are controlled from time to time.

'"World Steel Dynamics, Core Report A, November 1978.

Norway, Belgium, and Canada monitor and/or license scrap exports. Denmark, Ireland, and Italy ban scrap exports outside the EEC. Japan imports most of its scrap. The new Export Administration Act gives the U.S. Department of Commerce the right to ensure that an adequate supply of domestic ferrous scrap is made available to domestic consumers. Domestic steelmaker have already requested that permanent monitoring be established, but the scrap industry opposes this step.

Impacts of Technological Change on Scrap Demand

Four technological developments will affect the price of and demand for ferrous scrap:

- the growing use of electric arc furnaces by integrated and nonintegrated steelmaker;
- greater use of continuous casting and changes in the basic oxygen furnace;
- further increases in the use of high-quality, high-performance steels, which impose more stringent requirements on scrap quality while reducing the future supply of low-alloy scrap, desirable for most scrap applications; and
- increasing use of DRI as an input substitute for scrap.

Scrap-Based Electric Furnace Steelmaking. —The use of electric furnace processing is increasing rapidly in the United States and throughout the world because it has relatively low capital and operating costs. This process uses a higher proportion of scrap input than do other processes; it also reduces the amount of prompt industrial scrap generated per melting unit. Thus, increased use of scrap-based steelmaking will increase the demand for scrap, while putting additional downward pressure on available scrap supplies.

Domestically, the use of the electric furnace is growing rapidly among nonintegrated steelmaker, and some of the integrated steel mills are beginning to use more electric furnaces in combination with their other steel production facilities. Presently, about one-quarter (22.7 million tonnes) of domestic steel is made in electric furnaces. Although ferrous scrap consumption in open hearth production in the United States has declined, this trend will be offset by growth of scrap consumption in electric furnaces by 1982, when new electric furnace installation, now underway or planned, will have been completed. It is likely that as much as half of future domestic new capacity will eventually be based on electric furnaces.[29]

Electric furnace use has grown at an even faster rate abroad. In the last 10 years, world electric furnace steel production has increased by nearly 75 percent, or almost 39 million tonne/yr. Almost 30 percent of the growth in world steel production has been in the electric furnace. One forecast suggests that worldwide electric furnace use will increase by more than 50 percent from 1978 to 1985, and by 1985 will account for 38 percent of the increase in world steel output .30

Continuous Casting and Basic Oxygen Furnace Changes.—These technological changes also have increased steel industry use of purchased prompt industrial and obsolete scrap. The increased yield from continuous casting, compared to conventional ingot casting, causes less inplant scrap to be produced. Thus, purchased scrap must replace "lost" home scrap in order to maintain liquid-iron-to-scrap ratios for steelmaking furnaces. This also assumes increased shipments of finished steel at existing levels of iron production (see ch. 9). In 1978, 32 percent or 28.5 million tonnes of all steel shipped was derived from purchased scrap. If continuous casting were increased to a 50-percent level on the 1978 base and produced a 12-percent increase in

[29]Hogan forecasts an increase in electric furnace raw steel from 29.2 million tonnes in 1978 to 46.3 million in the mid-1980's. (W. T. Hogan, "Growth of the Electric Furnace, " paper presented at the Ferrous Scrap Consumer's Coalition symposium, Atlanta, Ga., February 1980.) A supplier of electric furnaces forecasts that "by IWO, half of all the steel will be made in electric furnaces, " (*Iron* Age, Feb. 4, 1980, p. MP-7.]

[30]American *Metal* Market, Jan. 17, 1980.

yield, then an additional 5.7 million tonnes of scrap would have to be purchased to satisfy steel production needs. * Under such circumstances, 36 percent or 34.3 million tonnes of all steel shipped would be derived from purchased scrap.

Equipment changes in basic oxygen steelmaking furnaces (BOFs) also permit a substantial increase in the amount of scrap used in production. These changes allow traditional scrap charges of 28 percent or less to be increased to 30 or 40 percent. Using a combination of preheating and silicon carbide, for instance, scrap use could be increased to the 35-percent level, with a net cost saving.[31] The economic advantage depends on the cost of scrap compared to that of hot metal from the blast furnace. For plants attempting to increase steel output without incurring the capital costs of installing new blast furnace capability, this approach may be attractive.

A more recent variation is to remodel BOFs with bottom as well as top blowing equipment and to modify Q-BOP (a proprietary version of a bottom-blown BOF) furnaces to allow for the preheating cycle.[32] This system, invented by a West German company and known as the OBM-S (advanced basic oxygen process with scrap preheating), is being adopted by the National Steel Corp. Increases of 27 to 42 percent in the amount of scrap used have been reported, as well as reductions in processing time. The capital cost of this retrofitting option is relatively high (about $10 million per furnace), so companies taking this route are likely to optimize scrap use in order to reduce total production costs.

Quality of Scrap.— While the need for increasingly higher quality scrap to make higher performance steels is mounting, the quality of the available scrap is declining. The increased use of alloy steels and recycled scrap, as well as the greater use of nonferrous materials in automobiles, has resulted in scrap containing more nonferrous elements such as zinc, copper, nickel, chromium, and molybdenum. These impurities, called "tramp," generally cannot be removed in the steelmaking process. Steel made from a 100-percent-scrap charge is only as "clean" as the scrap it is made from. Steel made with pig iron or DRI, along with scrap, does not have this cleanliness problem if the scrap percentage is sufficiently low.

The problem that the domestic steel industry may face in the future because of poor-quality scrap is spelled out in the results of a recent industry survey:

> The consensus of the returns was that the quality of ferrous scrap, as judged by tramp alloy contaminants, is generally declining, and that it could become a serious problem by 1985. The majority of the respondents stated that their customers will be seeking performance characteristics in steels by 1985 which are significantly to substantially higher than those which can be commercially achieved today. Further, this requirement is felt to be closely linked to scrap quality, Most of the respondents consider the tramp alloy content of their scrap to be a high-priority concern in this connection.
>
> The survey yielded considerable detail in regard to the tramp element which the responding mills routinely monitor, The implications of the rapidly-increasing usage of high-strength, low-alloy steels by scrap consumers turned out to be a controversial and uncertain matter to steelmen, Regarding the possibilities of consuming a significant volume of scrap recovered from municipal solid waste, a minor percentage replied "yes" and a minor fraction said "no,'" while the majority hedged with the answer "possibly."
>
> The consensus seemed to be one of doubt that technological developments in scrap processing and in steelmaking will compensate for the build-up of tramp elements in scrap, Closely related to this, the majority seemed to feel that direct reduced iron might become essential, in order to dilute the rising contaminant levels.

*Assuming an average yield of 0.92.

[31]W. F. Kemner, "The Operating Economic and Quality Consideration of Scrap Preheating in the Basic Oxygen Process, " Proceedings of American Iron and Steel Institute technical meeting, Philadelphia, 1969.

[32]33 Metal Producing, June 1979, p. 56; November 1979, p. 67-71.

All-in-all, the attitudes expressed regarding a long-range build-up of tramp alloy contaminants in ferrous scrap represents a stiff challenge to the scrap industry and its supporting sectors. It would seem to be crucial to lose no time in mounting an intelligent, well-coordinated campaign, nationwide, to attack this problem. The best results will doubtlessly require close cooperation between scrap suppliers and steelmakers. [33]

To reduce the tramp-element problem, low-grade purchased scrap ideally should be used in BOFs, and home scrap mixed with high-quality purchased scrap should be used in electric furnaces. However, industry structure does not permit such optimization; for example, electric furnaces are not always close to the sources of home scrap, Theoretically, there are three additional points of attack on the tramp-element problem:

- Product design. —Even though materials in products are becoming more sophisticated, products could be designed with recycling in mind. These products by their very design would facilitate identification and separation of various usable materials upon recycling.
- Improved scrap processing techniques, —This refers to better (more reliable, faster, more discriminating, and more economical) techniques of separating and identifying usable materials at the processing plant.
- New steelmaking techniques. —This refers to techniques of operation that would allow some impurities to be removed in the steelmaking process.

The steel industry's ability to influence product design as a means of reducing the tramp-element problem is limited, at best. The scrap-processing and steelmaking industries could pursue the second and third options, and they have incentive to do so because they are directly affected by the tramp-element problem. Scrap-processing improvement may have more potential than changing steelmaking techniques, but there is some chance for innovations in the latter area.

Direct Reduction. * —Of all current technological changes affecting the demand and price for scrap, DR is the only one that can reduce demand for scrap and thus reduce its price. Thus, a way to alleviate growing demand pressures on scrap and to moderate scrap price increases may be to produce or import DRI. This "clean" material can substitute for ferrous scrap in electric furnace steelmaking, and it also offers certain technical advantages.

Recent technological advances in DR suggest that it could become economically viable and could supplement ferrous scrap supply at a price competitive with that of scrap. The use of DRI can also help avoid some of the anticipated problems of tramp alloy contaminants in scrap. At the present time, DR facilities are limited in the United States (accounting for less than 1 percent of steel made), but this is not so in other countries. In the past, scrap availability and low scrap prices in the United States have acted as a disincentive to development of DR. As scrap prices rise, DRI will become more competitive. **

Targets for Increased Use of Ferrous Scrap

It is in the national interest to maximize the use of recovered materials, in part to save energy. It has been generally accepted that scrap embodies the energy (18.7 million Btu/tonne) that was originally used to convert the iron ore to iron. Two statutory provisions have been enacted that deal with maximizing the use of scrap and other waste sources of iron generated in steel plants. These provisions do not adequately consider the long-range consequences of attempting to maximize the use of scrap and other recovered materials. The relevant provisions are:

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[33] R. D. Burlingame, "Trends in Scrap Quality for the 1980s,'" *Iron and Steelmaking*, February 1979, p. 18.

*DR is described and discussed in ch. 6, and its role in the growth of nonintegrated steelmaker in ch. 8.

**The price of DRI, whether imported or manufactured domestically, will in the long run be a decisive determinant of increased electric furnace use.

- Section **461** of the National Energy Conservation Policy Act (Public Law 95-619) of 1978, which mandates that the Department of Energy (DOE) set voluntary targets for use of recovered materials to be observed by the entire ferrous industry—ironmakers and steelmaker, foundries, and ferroalloy producers.
- Section 6002 of the Resource Conservation and Recovery Act (Public Law 94-580) of 1976 amending the Solid Waste Disposal Act, which requires that Government procuring agencies procure items composed of the highest practicable percentages of recovered materials and instructs the EPA Administrator to promulgate guidelines for the use of procuring agencies in carrying out this requirement, it also requires suppliers to the Government to certify the percentage of recovered materials in the total material used.

The setting of targets or guidelines presents a number of problems. It may not be technically or economically feasible in all **cases to use** recovered materials to the extent suggested or indicated by the Government. The methodology and assumptions used to calculate targets can be tenuous and highly controversial. Steel producers are especially worried about infeasible voluntary targets that could become mandatory,

One problem with legislative attempts to maximize the use of ferrous scrap is that they apply indiscriminately to all segments of the steel industry and to all types of production processes. Moreover, many types of companies would find targets relatively easy to circumvent. For example, targets for purchased scrap could be circumvented if companies sell their home scrap to others and purchase other firms' home scrap. * In addition, set goals could in fact be counterproductive to the original objective of maximizing recovered materials use and saving energy. Should targets and guidelines effectively increase demand for purchased scrap, this would raise scrap prices. The impact of higher scrap prices on nonintegrated companies would be much worse than on integrated steelmaker. This could lead to a decrease in steel made by nonintegrated producers and less total scrap used. Additionally, integrated producers using more scrap in BOFs must also use more natural gas and electricity for necessary process modifications, thereby increasing energy use at least on a temporary basis.

Technically and economically, it is extremely difficult for integrated steelmaker to increase their use of recovered materials substantially. They would most likely incur costs that do not improve productivity. An important exception is an integrated company that increases its steel production, without increasing blast furnace capacity, by investing in technology to increase scrap use in BOFs or in electric furnaces that use purchased scrap almost exclusively. Even then, these investments must be sound economically in themselves on a plant-by-plant basis; targets based on industry averages maybe inapplicable.

Scrap targets or guidelines are not relevant for electric furnace steelmaking because at present that process uses only scrap. With the advent of DR and the availability of DRI, however, electric furnace steelmaker could use less scrap, so targets or guidelines could act as disincentives to the introduction of DR. Though the proportion of scrap used in any one electric furnace shop would decrease if it also used DRI, an expansion in electric furnace steelmaking, even using both scrap and DRI, could increase the total amount of purchased scrap used. The new average amount of scrap used in nonintegrated companies or electric furnace shops of integrated producers would likely be greater than the average for conventional integrated operations using BOFs.

It appears that EPA, for some of the reasons given above, will not actively pursue the setting of guidelines for ferrous scrap use. The Department of Energy has already set targets, but they appear to be quite low. For

*Such an activity might only occur on paper through intermediaries, Actual transportation costs could be prohibitive.

the entire ferrous industry, the target for 1987 is that 41 percent of steel shipments be made from purchased prompt industrial and obsolete scrap. The actual value for 1978 was 40 percent, and for 1979 it appears to have reached 41 percent. OTA analysis indicates that if the use of continuous casting were increased to 50 percent on the 1978 base, scrap use would be 44 percent. If a 2-percent annual increase in steel production is added to a 50-percent continuous casting scenario, scrap use would be 48 percent by 1987. Changes in BOFs would increase the scrap-use rate still further.

Future Scrap Shortages

There can be no unequivocal answer to the question: will there be a shortage of ferrous scrap in the United States? A shortage is defined as a market situation in which there is a rapid and substantial rise in the price of scrap at the quality level required by a substantial fraction of users, but shortages can vary with geographic or cyclical aspects of ferrous scrap supply and demand. It is apparent that a number of major factors will influence the average supply and demand of ferrous scrap in the United States, and thereby either promote or reduce the likelihood of a general domestic shortage.

Physical Supply.—Although more and more steel scrap will exist in some form within the United States, steel consumption is growing at a relatively low rate and, hence, so is the magnitude of the scrap supply. The portion of the supply that is readily and economically retrievable will decline as: less scrap is produced in manufacturing, less steel is used in automobiles, less scrap is concentrated in a relatively small number of geographical areas, the cost of transporting scrap by any means increases, more and more nonferrous materials become intimately part of and mixed with ferrous materials, and product lifecycle considerations lead to longer lifetimes for steel products. Thus, these factors favor a future shortage of usable scrap.

Exports to Foreign Electric Furnace Steelmakers.—As the domestic and foreign trends toward more electric furnace steelmaking continue, foreign steelmaker will put greater demand pressure on U.S. scrap, and this will increase the likelihood of a scrap shortage. Should the current shortage of domestic coke continue, it would likely result in even greater use of scrap-based electric furnace steelmaking, although inadequate electricity generation could reverse this trend.

From an international point of view, the general shift of steelmaking capacity (especially from Europe) to the Third World will tend to reduce foreign demand for U.S. scrap, because steelmaking in those countries will be based on DRI. On the other hand, the relatively high level of foreign steel production costs, particularly in Europe, will make high-priced U.S. scrap competitive with alternate overseas sources while raising costs for domestic steel producers. And finally, an important factor that is often overlooked is the effect of currency exchange rates. As the dollar weakens against other currencies, U.S. scrap becomes more attractive to foreign buyers. Thus, foreign steel producers can bid up domestic scrap prices and still have an attractively priced raw material, but domestic raw materials costs will be adversely affected. Conversely, strengthening of the dollar could reduce foreign demand.

New Technologies.—Although the expected near-term increase in the use of continuous casting and scrap-use-enhancing changes in BOFs would increase the likelihood of a domestic scrap shortage, the development of coal-based DR would greatly reduce it. DRI clearly could be the most effective substitute for scrap and the most competitive means of limiting scrap price increases. However, until and unless scrap prices rise sufficiently to allow the lowest cost DR technology available to compete in the marketplace, DR is not likely to be adopted on a substantial scale in the United States. DRI imports seem to offer greater near-term potential than does domestic adoption of the technology. The increased development of DR in less developed countries with cheap natural gas could provide worldwide trade in DRI. It is distinctly possible that within the next decade DRI imports could obviate a domestic shortage of scrap. Farther in the future, more radical steelmaking technologies, such as nuclear steelmaking, magnetohydrodynamic steelmaking, plasma steelmaking, or direct (one-step) steelmaking, which could economically convert iron ore to steel, would greatly reduce the likelihood of scrap shortages.

Federal Policies.—A number of policy options could either increase or reduce the likelihood of ferrous scrap shortages. In particular, policies that would increase transportation costs, increase domestic demand for scrap, and facilitate scrap exports (including a declining dollar) could promote a domestic scrap shortage. Policies that could stimulate the development of new steelmaking technologies, such as DR and formcoking, could help prevent scrap shortages. In the absence of any policy changes, and without the influx of enough capital to construct major new blast furnaces, a scrap shortage is likely to occur if there is a continued steady growth of domestic demand for steel. An analysis by the president of a successful nonintegrated company appears valid:

> . . . scrap is going to be more valuable and in shorter supply.
>
> In how short supply? We have made an exhaustive study of this covering seventeen variables including such things as scrap generation, plant construction, market growth, the utilization yield and imports of coke, development of continuous casting, direct reduced iron production and imports, and many others. We've tried to evaluate all of these but manifestly with so many variables there can be many answers. Nevertheless, within what we believe to be reasonable parameters, a scrap surplus which has recently been allowing 10,000,000 tons a year to be exported will by the year 1985 allow only 5,000,000 tons which leads quickly to no surplus at all. I should emphasize that I see this drop in exports resulting from domestic price competition, not from government embargo.[34]

Of particular importance in the above statement is the viewpoint that increasing domestic demand, rather than Government export controls, will reduce exports. Even more interesting is a scrap supplier's expectation of a domestic scrap shortage under conditions of continuing exports:

> For the 18 months preceding August 1979 ,.. domestic scrap demand . . . equalled the scrap demand during 1973 and 1974. As a practical matter, we had reached the balance between supply and demand, . . . Three to four years from now, we will be hard pressed to find enough No. 1 (high quality) grades of scrap to meet the demand.

When such a shortage occurs, what will happen?

1. Scrap can be diverted from export, but who will pay the extraordinary freight charges to move this scrap to regions of domestic shortage? And, what will be the effect on our nation's friends who are the major consumers of our export scrap?
2. Direct reduced iron can be purchased in the United States or imported, But who will invest the hundreds of millions of dollars required to build these plants? Further, who will commit to pay $150 to $175 per gross ton for the product ?
3. Integrated steel production can be increased. But who will invest the billions required and take the environmental risks associated with this solution?
4. Finally, we can do nothing and our increased domestic demand for steel will be satisfied by importing 25 percent or more of our needs by the mid-1980s.[35]

Concluding that there will be a scrap shortage some time during the next decade is risky. The number of uncertainties on both the supply and demand sides of the issue are so great that any forecast must be equivocal. This very uncertainty about future domestic scrap supplies makes policy decisions affecting scrap use, supplies, and exports quite difficult (see ch. 2).

[34] W. W. Winspear, president, Chaparral Steel Co., speech to National Association of Recycling Industries, September 1979.

[35] Blauvelt, op. cit.