ECONOMIC AND TECHNOLOGICAL IMPEDIMENTS TO RECYCLING OBSOLETE FERROUS SOLID WASTE

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ECONOMIC AND TECHNOLOGICAL IMPEDIMENTS TO RECYCLING OBSOLETE FERROUS SOLID WASTE

by

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Current technological impediments to recycling ferrous solid waste resulted to a large extent from earlier economic decisions concerning steel-making processes and plant locations. These prior long-run investment decisions are now contributing factors in the increasing accumulation of ferrous solid waste. The amount of obsolete ferrous scrap not recycled averaged nearly 22 million tons annually during the first half of the 1960 decade. During the late 1960's the amount not recycled increased to 29 million tons per year. Indications are that this trend will continue and possibly accelerate unless substantial changes in economic and technological conditions occur. The study suggests that even if public programs are implemented, the recycling of ferrous solid waste will be constrained until the late 1970's by existing technological impediments in the steel industry.

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

> studies on the effects of environmental contaminants on man and the biosphere, and
>
> a search for ways to prevent contamination and to recycle valuable resources.

This in-house study was part of a comprehensive effort at the National Environmental Research Center, Cincinnati, to examine the feasibility for reclaiming and recycling selected noncombustible materials from the solid waste stream. The particular emphasis in this report is on the non-recycled obsolete ferrous solid wastes, and their potential as substitutes for virgin materials in the production of raw steel. The results contained herein will be of interest to everyone concerned with the mounting solid waste problem and the rapid depletion of our natural resources.

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Director
National Environmental
Research Center, Cincinnati

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ABSTRACT

Ferrous solid waste is one component of the total problem relating to solid waste management. In addition to the costs of collecting and transporting, these wastes will occupy landfill space for a long time as they are extremely slow to degrade. Also, from a conservation viewpoint, ferrous wastes are the residuals of a scarce nonrenewable natural resource. And aesthetically, the piles of scrap are considered by many to be a blight on the landscape.

The study reported here focused attention primarily on the problems associated with recycling of obsolete ferrous scrap. The major steel companies use large quantities of in-house and prompt industrial scrap in the production of raw steel. But difficulties are being encountered in recycling obsolete ferrous scrap, particularly from certain discarded industrial and consumer type products. The emphasis was on the factors influencing the recycling of can scrap, automobile scrap, obsolete consumer durables, and incinerator residue.

The total amount of obsolete ferrous scrap not utilized continues to increase annually. Annual amounts of obsolete ferrous scrap not recycled averaged nearly 22 million tons during the first half of the 1960's. During the last half, about 29 million tons per year were not recycled. The indications are that this trend will continue and possibly accelerate during the decade of the 1970's unless significant changes in economic or technical conditions occur. And even if public programs with incentives are implemented, the analysis suggests that recycling of ferrous solid waste would not increase markedly until the latter half of the present decade.

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SUMMARY

The Solid Waste Problem

Public concern over environmental degradation and exhaustion of natural resources is reflected in the enactment of the Resource Recovery Act of 1970. The national objective of reclaiming valuable components from solid waste is made explicit in the Act.[1]

Although ferrous solid waste comprises only a small fraction of the total, the problem it presents to waste management are its slow rate of degradation in landfills and its accumulation on landscapes. It is also the residual of a non-renewable natural resource.

A portion of ferrous solid waste is readily recycled. This is the waste generated in-house by the steelmaking processes (revert scrap) and by fabricating operations (purchased prompt industrial scrap). It is the obsolete ferrous solid waste, especially the worn-out and discarded types from consumer use, that presents an increasing problem in solid waste management.

Utilization of Ferrous Solid Waste

The steel industry has been a basic industry in the U.S. economy for a long time. Five of the major steel corporations are among the 100 largest U.S. industrial corporations in terms of volume of sales and number of employees.[2] Steel shipments of primary products by the industry amounted to nearly $18 billion in 1967, or about two percent of the $793.5 billion gross national product that year.[3,4]

In recent years, the basic steel industry has been increasingly subjected to rising labor costs and competition from foreign imports of raw steel. Importations of steel mill products have also had an adverse effect. Domestic raw steel companies have had difficulty competing with foreign steel, perhaps because technological research and innovation by the domestic steel companies have not been as rapid as that of the foreign companies.[5]

The annual amount of obsolete scrap not recycled (that accumulating in open areas, landfills, backyards, etc.) has averaged over 34 million tons for the past five years. It increased from 23 million at the start of the 1960 decade to over 37 million in 1970. The proportion not recycled increased from 48 percent during the first half to nearly 52 percent in the last half of the past decade (Table 1).

The volume of obsolete scrap recycled has remained relatively constant over the past 20 years while the percentage of obsolete ferrous scrap recycled actually decreased (Figure 1). This trend is expected to continue. The projections of obsolete ferrous scrap indicate that by 1985 more than 90 million tons will be available each year for recycling as compared with about 60 million in 1972. The projections are based on steel shipments in preceding years and market uses of it.

The total amount of non-recycled scrap is expected to increase each year until about 1973. There may then be a leveling off or slight reversal in the trend for several years. By 1980 or before, the obsolete ferrous scrap not recycled is expected to accumulate at an increasing rate. These projections assume that net exports of obsolete ferrous scrap will hold at about the mid-1960 level.

Impediments to Increased Utilization of Ferrous Scrap

It has been suggested that the technical limits of using ferrous solid waste (scrap) in proportion to total metallics in steelmaking could be as high as 80 to 100 percent.[6] A distinction must be made, however, between the short-run and long-run time periods in comparing the practical limits with the theoretical possibilities. In the long-run perspective, impediments that appear to be technologically related are often really economic considerations. In the short-run, existing capital investments in natural resources and facilities, including iron ore and coal mines, blast and steelmaking furnaces, commit the industry to certain technological processes of steelmaking. These commitments define the technical range of substitution of scrap iron for iron ore. In the long-run time period, however, steel companies are able to modify their processes and plant facilities to reflect trends in costs of inputs, including scrap iron.

Transportation costs are influential in decisions on the recycling of ferrous scrap. Consumer types of obsolete (discarded) ferrous scrap are particularly vulnerable to transportation costs since they are relatively more dispersed than virgin raw materials. Steelmaking firms are mostly located near the sources of natural materials and along strategic transportation routes.

Conclusions and Implications for Public Policy

It appears likely that there will be very little increase in the proportion of ferrous solid waste recovered during the decade of the 1970's under existing economic and technological conditions. Rather, it is likely that even smaller proportions of the total available scrap will be utilized in the near future. From a strictly technological viewpoint, percentages are not likely to shaw much increase before the mid 1970's under any conditions. By the latter part of the current decade, steelmaking processes could be sufficiently modified to utilize more ferrous scrap if economic conditions are favorable.

The implication for public policy is that there is apparently a need to create a more favorable economic climate if there is to be greater utilization of ferrous solid waste. Public action could take several forms. Government could enact legislation to discourage the use of virgin materials, such as iron ore, and the use of contaminants that lower the utility of discarded ferrous products for recycling. There could be increased restrictions on imports to reduce competition with domestic steel products. Every ton of steel mill products imported into the country reduces the net utilization of ferrous scrap by about 0.3 ton.

The Federal Government could require specific percentages of obsolete post consumer scrap in finished steel products; legislation could be enacted to force manufacturers to reclaim the product after the consumer is finished with it. This might have the effect of encouraging producers to design their products for longer life and high recycling value.

Other measures available to the government include taxes on the use of virgin material and excise taxes on products containing less than minimum percentages of obsolete ferrous scrap. Elimination of the current tax privileges to owners and developers of natural raw materials is another strategy.

Economic incentives to accomplish national objectives are generally more socially acceptable than direct government controls or punitive legislation. Incentives can take a variety of forms. Purchased scrap can be subsidized through rebates or by outright government purchases and resale to firms at less than market cost. Incentives can be in the form of investment tax credits or accelerated depreciation allowances for capital equipment used in processes related to scrap utilization, similar to the credits allowed for pollution abatement equipment. Funds could be provided or interest rates subsidized to promote expansion of capital investments in recycling equipment.

Exports are an important outlet for domestic ferrous scrap. Exports of ferrous scrap have been averaging 5 to 6 million tons annually, although some decrease appears likely as foreign steelmakers become committed to processes that favor the use of iron ore rather than scrap. The expansion of exports could be encouraged, however, through export subsidies and trade agreements. It should be noted, however, that exports do nothing towards conserving the nonrenewable iron ore reserves.

The social benefits to be gained from promoting the growth of electric furnaces need to be evaluated. These furnaces are the major users of obsolete ferrous scrap. Increased use of these furnaces could substantially increase the volume of obsolete ferrous solid waste recycled each year. Growth of electric furnaces may depend heavily on nuclear energy since this source has lower market costs; but here the tradeoffs from increased recycling of obsolete ferrous scrap need to be compared with the social costs of managing increased amounts of nuclear wastes.

Environmental Implications

As the total solid waste problem becomes more visible, the need for utilizing the ferrous scrap fraction will become even more apparent. But the economic and technological merits of recycling must be viewed in terms of the total environmental system. Demands on the environment from activities related to recycling obsolete ferrous scrap must be compared with those using natural iron ore. The total environmental tradeoffs resulting from industry decisions about steelmaking processes, choice of fuels, and levels of recycling need to be fully examined. If, as a result of pollution abatement requirements, costs for one source of energy increase relative to costs of another, the result could be a substantial shift to the source having lower costs but greater pollution. It, therefore, becomes necessary to assess the various alternatives in resource use and associated environmental impacts within the framework of a total environmental impact model before recommendations can be made for policy decisions.

Need for Further Research

Very little is known about the sensitivity of the steel industry to various kinds of action available to the Federal Government. The steel industry is typical of most industries in the private sector in adhering to a well-known tradition of secrecy about their production costs.

The possibility of adverse effects on existing industries is frequently cited as the reason why the Federal Government should refrain from public programs designed to encourage recycling. Undoubtedly, some adjustments in existing industries would be required. But, the short-run adverse impacts need to be compared to the potential for long-run benefits society might gain from public programs designed to encourage recycling. On the other hand, increased recycling of obsolete ferrous solid waste may displace other ferrous scrap presently being recycled. Thus, total tradeoff effects need to be evaluated.

Research is needed to determine more precisely the role of transportation in recycling. It has been suggested that current transportation rates discourage the recycling of obsolete ferrous scrap, particularly the lower grades of scrap. The extent to which restructuring of rates would encourage recycling needs to be investigated.

Any proposal for reallocation of the Nation's resources, either through the price mechanism or through direct government regulation and control, requires an examination of costs and benefits stemming from the reallocation. Proposed programs need to be examined for their net benefits, including the distributive effects--that is, who benefits from the result of adopting proposed public programs.

Further technological research is also needed in areas of collection, processing, and utilization of ferrous solid waste. Improved methods of collecting and processing ferrous scrap for utilization might increase its value to steelmakers. More research is needed on techniques for detecting and separating out contaminants. The potential for contaminant buildup in furnaces resulting from continuous recycling also requires further investigation. Standardization and redesign of products are other opportune areas for further study.

A new process, direct ore-reduction (metallized, pre-reduced pellets), reduces iron ore to an intermediate iron stage (sponge iron) for subsequent melting and refining into steel in the steelmaking furnaces. The likely impact of this process needs to be investigated. It could have a significant effect on the future use of scrap. Its importance is especially significant because the metallized pellets are applicable to the electric furnace, currently a heavy user of scrap.

The trend towards continuous casting by the steel industry has further implications. Continuous casting has grown significantly in the last five years (from 1 million to 17 million tons). Opinions in the industry vary as to how rapidly the conversion to continuous casting capacity will occur, but there is general agreement that the trend will continue.[7]

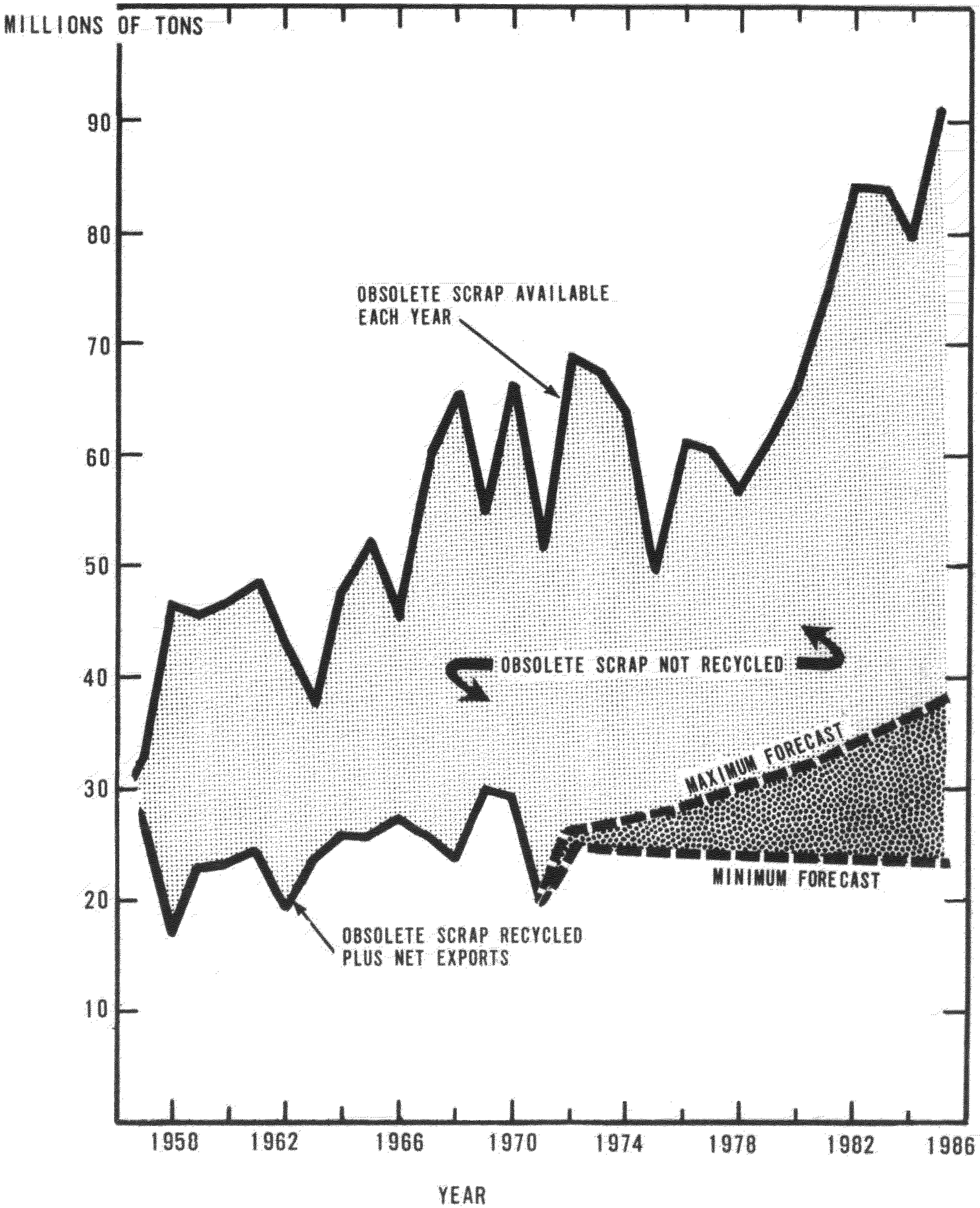

Figure 1. Comparison of obsolete ferrous scrap available with obsolete ferrous scrap recycled.

TABLE 1

TOTAL OBSOLETE SCRAP AVAILABLE

	Amount (thousand tons)			
Year	Total scrap available*	Recycled scrap plus net exports†	Nonrecycled obsolete scrap‡	Percent nonrecycled scrap
1956	27,687	30,780	(3,093)	---
1957	32,285	26,181	6,104	18.9
1958	46,156	16,999	29,157	63.2
1959	45,336	22,726	22,610	49.9
1960	46,752	23,087	23,665	50.6
1961	48,613	24,256	24,357	50.1
1962	43,814	19,182	24,632	56.2
1963	37,214	23,671	13,543	36.4
1964	47,728	25,881	21,847	45.8
1965	52,172	25,887	26,285	50.4
1966	45,325	27,023	18,302	40.4
1967	59,603	25,664	33,939	56.9
1968	65,930	23,470	42,460	64.4
1969	54,975	29,978	24,997	45.5
1970	66,658	29,300	37,358	56.0
1971	51,665§	19,965¶	31,700	61.4

*Based on estimating techniques developed by Battelle Memorial Laboratories as revised by the Business and Defense Service Administration using data from the annual issues of American Iron & Steel Institute's Annual Statistical Yearbook.

†Derived by substracting prompt industrial scrap from total purchased scrap and adding net exports. Total purchased scrap and net exports taken from the Institute of Scrap Iron and Steel's Facts 1970.

‡Derived as the difference between total available scrap and recycled scrap.

§Preliminary data by Battelle.

¶Estimated.

INTRODUCTION

The problem facing society today is how to cope with degradation of the environmental media--air, land, and water. Our earth is being subjected to ever-increasing environmental stress from wastes. It has been estimated that each year in the United States more than 250 million tons of solid wastes result from residential, commercial, and institutional sources. Additional wastes are generated by agricultural, industrial, and mining activities. The total solid wastes from all economic activities in 1969 has been estimated at over 4 billion tons.[8]

Solutions to the total waste problem are extremely complicated. Frequently, control techniques merely shift the problem from one medium of the environment to another. Much of it eventually accumulates as solid waste. Furthermore, the capacity of the environment to assimilate waste residuals is not infinite.

Opinions differ as to the seriousness of the solid waste problem. People in densely populated areas tend to view the situation differently from those in less concentrated areas. Variations in cultural and income levels also affect an individual's concern for the environment.[9]

Our knowledge of public attitudes toward environmental quality is quite inadequate. Even though individual preferences for environmental quality can be characterized and measured to a degree, we still have the problem of not knowing how to aggregate them, and market indicators of these preferences are practically non-existent. Despite some differences of opinion as to the seriousness of the problem, it is quite apparent that many people believe the solid waste problem is of sufficient magnitude to warrant national efforts for solution.

FERROUS SOLID WASTE

Solid wastes in the municipal waste stream consist of a number of components. The relative importance of these in the total solid waste management problem can vary in localities according to the nature of economic activities. Climate can also be a factor. The proportions also depend on whether they are in terms of a collected (wet), dry, or volume basis.

The metals component of municipal solid waste has been estimated to range between 6.85 and 9.1 percent.[10, 11] The exact percentage of ferrous solid waste has not been determined. It consists mainly of tin cans and discarded consumer durables such as appliances, lawnmowers, vacuum sweepers, steel furniture, and many other worn out post-consumer items (Table 2).

The generation of ferrous scrap actually begins with the steel and iron-making processes, including the finishing and fabrication operations. The in-house scrap from these activities, however, does not constitute a problem compared to the worn out and obsolete ferrous products discarded by consumers.

INDUSTRIAL USE OF FERROUS SCRAP*

There are three major industrial users of domestic ferrous scrap: 1) the domestic raw steel industry, 2) the domestic iron and steel foundry industry, and 3) the export market.+ There are also a few minor

*Scrap in the steelmaking industry refers to iron and steel scrap.

+An industry may be defined in several ways. It may describe a group of products that are close substitutes for each other and relatively distant substitutes for all products not included in the industry. An industry from the selling side of the market refers to the sellers of a particular product.

TABLE 2

COMPOSITION OF SOLID WASTES IN 21 U. S. CITIES*

Component	Percent of total†
Food waste	18
Garden waste	8
Paper products	44
Plastics, rubber, and leather	3
Textiles	3
Wood	2
Metals	9
Glass and ceramics	9
Rock, dirt, wash, etc.	4

*SOURCE: US Department of Health, Education, and Welfare, Incinerator Guidelines 1969 Washington, U.S., Government Printing Office, 1969, p. 6.

†Percent of composition is based on wet (as collected) weight.

uses, such as for copper precipitating. In this study, the industrial utilization of ferrous scrap refers principally to the raw steelmaking companies and the iron and steel foundries. Raw steelmaking companies account for about 80 percent of the total domestic utilization of ferrous scrap and therefore received the major attention in this study (Table 3).

The Basic Steel Industry

There are 107 producers of basic steel in the United States. These include the large, fully-integrated producers that operate coke ovens, blast furnaces, and steelmaking furnaces. The small specialized producers have only steelmaking (usually electric) furnaces.[12] The top three producers account for nearly half of the industry's shipments and the 10 largest producers account for 80 percent of the total output (Table 4).

Integration by the major raw steel producers has been mostly backward to sources of raw material, with very little forward vertical integration.* The major companies are fully integrated backward to the point where they own or have equity in basic raw material supplies including coal mines, limestone quarries, and iron ore deposits. They also own their own intermediate iron-making processes, including blast furnaces and coke ovens. For the purpose of expediting the study, it was assumed that raw steel products from the three different production processes (basic oxygen, open hearth, electric furnace) were all

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*A vertically integrated firm is one that performs more than one production process in the chain of processes beginning with extraction of raw materials to production of finished goods.

TABLE 3

FERROUS SCRAP UTILIZATION IN DOMESTIC STEELMAKING FURNACES, STEEL CASTING, AND IRON FOUNDRIES*
[In Millions of Tons]

Process	1965	1967	1969	1970
Raw steel industry				
Open hearth furnace	43.0	32.4	30.3	21.9
Basic oxygen furnace	7.8	13.9	19.8	21.2
Electric arc furnace	14.0	15.0	19.6	18.8
Blast furnace	5.1	4.7	4.8	5.3
Cupola	1.5	1.0	1.8	1.7
Other	0.0	0.1	0.4	0.4
Total	71.4	67.2	76.7	69.3
Foundaries				
Electric	2.7	3.1	4.2	4.1
Cupola	13.2	12.8	13.1	11.3
Air	1.5	1.1	0.2	0.2
Open hearth	0.7	0.6	0.5	0.1
Other	0.6	0.6	0.2	0.1
Miscellaneous	19.0	18.2	18.1	15.9
Total† scrap utilization	90.4	85.4	94.8	85.2

*SOURCE: American Iron and Steel Institute, Annual Statistical Report and American Iron and Steel Institute and US Bureau of Mines, Mineral Yearbook.

†Figures have been rounded.

TABLE 4

RAW STEEL PRODUCTION IN THE UNITED STATES IN 1967*
(TEN LARGEST STEEL PRODUCING COMPANIES AND U. S. TOTAL)

Company	Production†	Percent of total
Top 10 steel producing companies:		
U.S. Steel	30,900.0	24.3
Bethlehem	20,525.0	16.1
Republic	9,303.0	7.3
National	8,496.4	6.7
Armco	7,455.0	5.9
Jones & Laughlin	6,892.0	5.4
Inland	6,778.0	5.3
Youngstown	5,633.5	4.4
Wheeling-Pittsburgh	3,151.0	2.5
Kaiser	2,864.8	2.3
Total	101,998.7	80.2
Total Industry	127,213.0	

*Source: Annual Reports of the companies. Industry total was taken from American Iron and Steel Institute's <u>Annual Statistical Report 1970</u>, p.40.

†In thousands of tons.

identical, recognizing though that some variation in composition does exist because of the different processes.*

Technology

In the iron ore - scrap route, iron ore is converted to pig iron in the blast furnace and then refined to raw steel in the basic oxygen or the open hearth furnace. The modern blast furnace consists of an elongated pear-shaped vertical shaft rising about 100 ft high, lined throughout with special refractory brick. The hearth diameter is about 28 ft wide. Iron-bearing materials (iron ore, sinter, pellets, mill scale, scrap, etc.), fuel (coke), and flux (limestone and/or dolomite) are charged in at the top of the furnace.† Blasts of heated air and some fuel are blown in at the bottom. The flow of air is countercurrent to the descending burden (iron ore, coke and limestone). The blast burns part of the fuel to produce heat for the chemical reactions involved and for melting the iron. The balance of the fuel and part of the gas from the combustion are used to reduce the oxide of iron.†† Molten pig iron and molten slag are tapped near the bottom levels below points where air is blown into the blast furnace. The off-gases collecting at the top of the furnace are either burned or recycled for fuel.

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*For a detailed discussion on the various processes of steelmaking, see <u>The Making, Shaping, and Treating of Steel</u>, U.S. Steel Corporation, Pittsburgh, Pennsylvania, 1964, 1300p.

†Coke is produced in coke ovens by the distillation of coal in closed retort ovens. The volatile matter is collected and processed to gas and coal chemicals, and the remaining material (coke) is quenched (cooled) and sized for use as fuel for the blast furnace.

††Much of the iron ore is beneficiated before charging to the blast furnace. Beneficiation is a charge process whereby the concentration of iron is increased. Two commonly-used processes for beneficiation are sintering and pelletizing.

The last step in raw steelmaking by the iron -- scrap route takes place in the steelmaking furnaces, usually the open hearth or the basic oxygen furnace. Higher operational costs normally exclude charging the electric furnace with molten metal.

Open Hearth Process

The open hearth furnace resembles a large, enclosed bath-type container. Up to 12 furnaces may be housed under one roof. Fuel input ports are located on both sides of the furnace, with the regenerative chambers located beneath the furnace. Scrap and hot metal are charged through doors in the front. Fuel is burned over the bath, alternating from one side to the other. After 6 to 8 hours, the molten steel is tapped out the back side of the furnace.

The importance of the open hearth furnace has been steadily declining and is expected to continue to decline, and very little is being done to improve the process (Table 5). The open hearth requires a larger capital outlay and a longer production interval than the basic oxygen furnace. There do not appear to be any technical breakthroughs on the horizon that would bring about new growth in the use of open hearth furnaces.

The open hearth furnaces accounted for slightly more than a third of the total domestic raw steel production in 1970. By 1975 they will probably produce 21 percent, and by 1980, only 9 percent of the total. Production capacity of open hearth furnaces has been largely replaced by the basic oxygen furnaces. The consensus is that the use of open hearths for steelmaking will become less important. There is some disagreement as to how rapidly their importance will decline. A middle-of-the-road projection would suggest their output at 30 million tons of raw steel in 1975 and about half that amount in 1980 (Table 5).* Comparing these forecasts to current production, the 1975 level would be two-thirds the 1970 production and the 1980 production about one-third.

Basic Oxygen Process

The basic oxygen furnace is relatively new. In 1960, only 3 percent of the total raw steel production was refined in the basic oxygen furnace. By 1970, the percentage had increased to 48 percent and 63 million tons, compared with 48 million tons in the open hearth.

The basic oxygen process is more efficient in terms of cost per unit of output. It also requires a substantial capital outlay, however, as these furnaces are sizable units. The furnaces are also likely to be integrated with blast furnace operations since they are dependent upon them for the molten metal.

The basic oxygen furnace resembles a large bottle-type vessel with a closed bottom and open top. The cylinder is lined with refractory material. Hot metal (pig iron), scrap, and flux are charged in at the top. An oxygen lance in the furnace directs a jet of high purity oxygen at high speed onto the molten iron to oxidize the impurities. The vessel can be turned 180 degrees from vertical, in both directions, to facilitate charging and pouring. Modern basic oxygen furnaces can produce from 200 to 300 tons of raw steel per cycle in about 1 hr, thus, its process takes only about one-sixth as long as that on the open hearth. Two

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*A maximum forecast of raw steel from the hearth in 1980 would probably be the 25 million tons estimated by Battelle.[13] There are some in the industry who predict no production rather than the 25 million tons.

TABLE 5

PROJECTIONS OF RAW STEEL PRODUCTION
FOUNDRY SHIPMENTS, AND FERROUS SCRAP UTILIZATION

(In thousands of tons)

Item	1969	1970*	1975	1980
Electric furnaces:				
Production, raw steel	20,132	20,162	32,000	45,000
Inputs, pig iron and scrap	19,788	21,300	33,000	46,500
Yield (production as percent of inputs)	101.7	94.7	97.0	96.7
Pig iron inputs	213	2,466	700	900
Scrap input (total)	19,575	18,834	32,300	45,600
Home	6,630	6,702	11,400	16,600
Purchased	12,945	12,132	20,900	29,000
Basic oxygen furnace:				
Production, raw steel	60,236	63,330	82,000	105,000
Pig iron and scrap inputs	66,236	69,977	90,500	116,000
Pig iron inputs	46,408	48,853	63,200	81,200
Scrap input (total)	19,828	21,124	27,300	34,800
Home	20,350	21,627	28,300	36,100
Purchased	-522	-503	-1,000	-1,300
Yield (production as percent of inputs)	90.0	90.5	90.6	90.5

Source: American Iron and Steel Institute, Annual Statistical Report 1970; Battelle Columbus Laboratories, "Identification of Opportunities for Increased Recycling of Ferrous Solid Waste" (a report to the Institute of Scrap Iron and Steel); and Institute of Scrap Iron and Steel, Facts 1970.

*1970 scrap utilization data are preliminary estimates. Projections are based on historical trends.

†Because of changes in inventory, purchased scrap consumed does not necessarily equal scrap purchased, as shown in Table 6.

TABLE 5

PROJECTIONS OF RAW STEEL PRODUCTION
FOUNDRY SHIPMENTS, AND FERROUS SCRAP UTILIZATION
(Continued)

(In thousands of tons)

Item	1969	1970*	1975	1980
Open hearth furnace:				
Production, raw steel	60,894	48,022	30,000	15,000
Pig iron and scrap inputs	67,649	52,771	33,300	16,700
Pig iron inputs	37,397	30,836	18,300	9,200
Scrap inputs (total)	30,252	21,935	15,000	7,500
Home	21,340	17,144	10,700	5,800
Purchased	8,912	4,791	4,300	1,700
Yield (production as percent inputs)	90.0	91.0	90.1	89.8
Blast furnace:				
Production	95,017	91,435	- - -	- - -
Inputs				
Scrap (total)	4,779	5,302	4,800	5,500
Home	873	886	1,100	1,600
Purchased	3,906	4,416	3,700	3,900
Other types (cupola, air, etc.):				
Inputs				
Scrap (total)	2,207	2,128	2,600	2,800
Home	- - -	- - -	- - -	- - -
Purchased	2,207	2,128	2,600	2,800
Total raw steel production	141,262	131,514	144,000	165,000
Total scrap used by raw steel industry	76,641	69,323	82,000	96,149

TABLE 5

PROJECTIONS OF RAW STEEL PRODUCTION
FOUNDRY SHIPMENTS, AND FERROUS SCRAP UTILIZATION
(Continued)

(In thousands of tons)

Item	1969	1970*	1975	1980
Foundries:				
Shipments	18,984	16,529	19,000	21,000
Inputs	- - -	- - -	- - -	- - -
Pig iron	- - -	- - -	- - -	- - -
Scrap (total)	18,175	15,895	18,200	20,200
Home	7,030	6,105	7,100	8,000
Purchased	11,145	9,790	11,100	12,200
Total scrap usage	94,816	85,218	100,200	116,400
Home	56,223	52,464	58,600	68,100
Purchased	38,593	32,754	41,600	48,300
Prompt industrial	15,640	14,796	18,300	22,000
Obsolete	22,953	17,958	23,300	26,300

or three vessels are usually housed together in one shop, with supporting equipment such as cranes, rails, and ingot molds.

Various means of increasing the ferrous scrap charge to a basic oxygen furnace have been tried. Among these, the most important are: (1) scrap preheating in the vessel, (2) scrap preheating external to the vessel, (3) additions of chemicals to the steel bath, and (4) use of a bottom blown process (Q-BOP). The associated economics are such that considering fuel costs and scrap prices, it appears doubtful that any of the above will be readily adopted to increase the scrap charge in the near future.

Although adverse to scrap utilization, the basic oxygen furnace is forecasted to account for 105 million tons in 1980. This forecast may actually be conservative. The relative economics of the process assures the continued growth of the basic oxygen furnace.

Electric Furnace Process

In the scrap route, scrap is refined in an electric furnace, or to a minor extent in a cupola. In the early period before World War II, electric furnaces confined their production to mostly quality steels such as stainless, heat-resisting, or tool and die steels. The electric furnaces did not compete economically with open hearths in the production of carbon grade steels until about 1946.*

Production from electric furnaces has been steadily increasing. A part of the growth has been due to the "mini" mills that require lower

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*Ninety percent of all raw steel production is carbon steel. By 1970, about 70 percent of electric furnace production had shifted to carbon steel.

capital investment compared with the other processes. Not all electric furnaces are "mini" units, however. And while the electric furnace process incorporates certain advantages that are unique to steelmaking, its operating costs for auxiliary equipment, labor, power, electrodes, and refractories are relatively higher than for other processes.

The charge to an electric furnace is essentially scrap with electricity providing the heat to melt it. The circular steel shell furnace resembles a huge tea kettle. It is mounted on rockers so that it can be tilted to pour off the molten steel and slag. The side walls are lined with refractory brick and generally contain two openings. The clay-lined spout is used for tapping off the molten steel and slag. Modern electric furnaces have moveable roofs to facilitate charging. The atmosphere in the furnace can be controlled to reduce undesirable nonmetallic inclusions. An electric furnace can rapidly generate extremely high temperatures (up to 3500°C).

Electric furnace production can be expected to account for a greater proportion of the total domestic output during the 1970 decade. Of the 144 million tons of domestic raw steel production projected for the middle of the decade, electric furnaces are expected to account for about 22 percent. This compares with 15 percent of the total production in 1970. By 1980, the electric furnace proportion is expected to rise to 27 percent. An increase in production by electric furnaces would provide a stronger market outlet for ferrous scrap in general, and thus enhance the possibilities for recycling some of the obsolete ferrous scrap that is accumulating.

ECONOMIC AND TECHNOLOGICAL IMPEDIMENTS

The domestic raw steel producers normally use home-generated (revert) scrap before purchasing scrap. The decrease in scrap utilization resulting from less open hearth production would be offset by increased production from electric furnaces, if it were not for the lower scrap input required by basic oxygen furnaces. The open hearth furnace uses about 45 percent scrap and 55 percent pig iron in the production process, while the basic oxygen furnace consumes only about 30 percent scrap in its charge. The electric furnace consumes about 98 percent scrap in its metallic input. If the operating costs of electric furnaces could be reduced, this process would very likely expand at the expense of the basic oxygen process, thereby increasing total scrap consumption. For every additional ton of steel refined in the electric furnace instead of the basic oxygen furnace, 0.7 ton more of scrap is consumed.

Electric furnaces are more likely to be situated where ferrous scrap accumulates; consequently transportation costs are lower. Additional advantages of the electric furnaces include: (1) flexibility in product output and operation, (2) production economics favorable for relatively low volume output, and (3) independence from heavy capital investment in blast furnace facilities.

The electric furnace has definite advantages for producers who want to install additional facilities in small incremental amounts beyond the capacity of the blast furnace to provide hot metal. If, however, there is a need to expand an existing steelmaking facility and sufficient or excess blast furnace capacity is available (i.e., capacity is greater than necessary for the present), it is usually not economical to add increments in the form of an electric furnace because of its higher operating costs. It appears that the domestic steel producers have the necessary blast furnace capacity to meet their production needs at least until 1980. Thus, it is unlikely that they will be installing many electric furnaces unless it is to meet air quality standards.

Another major factor influencing the decision to add an electric furnace is the cost of electricity as compared with coal. If electricity costs are relatively low, the electric furnace enjoys a cost advantage, perhaps even with some excess blast furnace capacity. Electricity costs, however, are also related to the price of coal; and it is quite possible that costs for electricity will increase as additional costs for air pollution control equipment are incurred. Depending upon the extent to which this happens, the forecast of 125 percent increase in output by electric furnaces in the current decade (from 20 million tons in 1970 to 45 million in 1980) may possibly be overly optimistic.

Management also looks at the relative prices involved for pig iron and scrap. The major steel companies have heavy commitments in the natural resources and they have the facilities for making pig iron; therefore this limits the economic feasibility of their substituting purchased scrap for pig iron in the short-run. The capital invested in such facilities constitutes "sunk costs" that are mostly overlooked when comparing costs for pig iron with scrap. From an economic viewpoint, therefore, the elasticity of substitution of scrap for pig iron is limited in the short-run. In the long-run, however, considerations involving capital costs and associated furnace processes are also variable.

From an operational standpoint, the competition for metallic input to the furnace is between ferrous scrap and the molten metal (pig iron). The economic advantage of one over the other is difficult to ascertain, however, as the published prices for pig iron prices are not considered representative of actual conditions. The published prices for pig iron reflect unusual stability as compared to scrap prices. Actually, relatively small amounts of pig iron move through the market channels. It is quite likely that costs for pig iron are substantially below the published prices. A study by Midwest Research Institute estimated production costs for pig iron production were \$37.50 per ton.[16]

There are perhaps three major factors influencing management to select either the basic oxygen or the electric steelmaking process: (1) existing investments or commitments related to the basic oxygen process; (2) expectations of future prices for ferrous raw materials (iron ore and ferrous scrap); and (3) projections of costs for alternative fuels (coal or electricity). A fourth factor that can be included is the individual steel producer's tendency to prefer one steelmaking process over another because of personal choice.

As mentioned earlier, the process selected by a company for increasing production capacity depends heavily on the current and foreseeable capacity of blast furnaces. If excess blast furnace capacity already exists, the economic advantage favors adding new basic oxygen units rather than new electric units by a ratio of 2 to 3. If excess blast furnace capacity

TABLE 6

STEEL INGOT PRODUCTION AND SELECTED GRADES OF FERROUS SCRAP UTILIZED

BY STEEL PRODUCERS AND STEEL FOUNDRIES

Year	Amount (in millions of tons)				Percent change from previous year			
	Steel ingot production*	Purchased scrap receipts†	Purchased prompt industrial‡	Purchased obsolete scrap§	Steel Ingot	Total receipts	Prompt industrial	Obsolete Scrap
1960	99,281	26,095	10,868	15,227	------	------	---------	---------
1961	98,015	25,305	10,217	15,088	98.7	97.0	94.0	99.1
1962	98,328	25,284	11,033	14,251	100.3	99.9	108.0	94.5
1963	109,261	29,432	11,912	17,520	111.1	116.4	108.0	122.9
1964	127,075	31,831	13,540	18,291	116.3	108.2	113.7	104.4
1965	131,185	35,804	15,879	19,925	103.2	112.5	117.3	108.9
1966	134,072	36.671	15,068	21,603	102.2	102.4	94.9	108.4
1967	127,213	32,654	14,265	18,389	94.9	89.0	94.7	85.1
1968	131,098	33,587	16,388	17,199	103.1	102.9	114.9	93.5
1969	141,069	36,929	15,640	21,289	107.6	110.0	95.4	123.8
1970	131,514	33,889	14,796	19,093	93.2	91.8	94.6	89.7

*Source: Institute of Scrap Iron and Steel, Facts 1970, p. 34, and American Iron and Steel Institute, Annual Statistical Report, 1970, p. 40.

†Battelle Memorial Institute, Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, August 1971, p. 77.

‡Calculated as a percent of total steel shipments (raw steel production plus imports minus exports). Based on historical trends shown by U.S. Department of Commerce, Business and Defense Service Administration, Iron and Steel Scrap Consumption Problems, 1966, p. 48.

§Calculated as the residuals of purchased scrap receipts after deducting prompt industrial scrap from total purchased scrap receipts.

TABLE 7

ANNUAL AVERAGE PRICES FOR SELECTED GRADES OF FERROUS SCRAP AND PIG IRON, 1960 TO 1970*

	Annual average price				Pig iron composite price ($/ton)	Scrap prices as percent of pig iron composite price	
	No. 1. heavy melting		No. 2. bundle			No. 1 heavy melting	No. 2 bundle
	$/ton	Percent change from previous year	$/ton	Percent change from previous year			
1960	33.20	-----	22.15	-----	65.95	50.3	33.6
1961	36.37	109.5	24.72	111.6	65.95	55.1	37.5
1962	28.34	77.9	20.44	82.7	65.46	43.3	31.2
1963	26.89	94.9	19.85	97.1	62.87	42.8	31.6
1964	36.50	135.7	22.69	114.3	62.75	58.2	36.2
1965	34.27	93.9	22.83	100.6	62.75	54.6	36.4
1966	30.66	89.5	21.80	95.5	62.75	48.9	34.7
1967	27.63	90.1	20.42	93.7	62.70	44.1	32.6
1968	25.94	93.9	20.11	98.5	62.70	41.4	32.1
1969	30.54	117.7	24.09	119.8	63.78	47.9	37.8
1970	41.15	134.7	28.65	118.9	---	--	--
Ave.	---	---	---	---	---	48.7	34.4

*Source: Institute of Scrap Iron and Steel, Facts 1970, pp. 52-53.
Scrap prices for 1970 by telephone communication with the Institute of Scrap Iron and Steel. Pig Iron prices from Midwest Research Institute, "Economic and Environmental Analysis of Steel Recycling," draft report, 1971, p. 13

is not available, the economics favor adding incremental units of the electric furnace by a ratio of about 1 to 14.[14]

Investment decisions are ordinarily made 4 to 5 years ahead of actual installation. Thus, usage of scrap has already been largely determined up to 1976 or 1977, except as actual utilization is affected by variations in the levels of demand for steel.

Ferrous Scrap Prices

The relationship between production of raw steel and scrap utilization is shown in Table 6. In 6 of the 7 years when steel ingot production increased, the receipts of purchased ferrous scrap also increased. This suggests that the use of ferrous scrap is mainly a function of steel production. The steel industry's demand for purchased scrap could be expected to shift with changes in raw steel production. Scrap prices would also normally be expected to reflect these shifts. Price changes, however, do not clearly reflect this relationship. Prices of No. 1 heavy melting scrap (a prompt industrial scrap when sold) actually move in opposite directions to quantities utilized in 7 of the last 10 years (Tables 6 and 7). This suggests more accurately movement on the same demand curve. In 6 years of the 10-year period, however, No. 2 bundle price changes coincided with the changes in direction for obsolete scrap. The No. 2 bundle grade consists to a considerable extent of discarded automobiles.[15]

Yearly price averages show considerable fluctuations. Variations of as much as one-third occurred for No. 1 heavy melting scrap and prices sometimes varied nearly 20 percent from preceding years for No. 2 bundle scrap. These large variations underscore the degree of instability and uncertainty in scrap prices in the industry.

TABLE 8

EXPORTS OF FERROUS SCRAP BY SELECTED GRADES, 1960 TO 1970*

(In thousands of tons)

Year	No. 1 and 2 heavy melting	No. 1 heavy melting	No. 2 bundles	Total exported
1960	3,623	2,376	1,082	8,040
1961	4,989	3,439	1,498	9,714
1962	2,683	1,715	1,105	5,112
1963	4,386	3,137	1,642	6,364
1964	3,639	2,470	1,248	7,886
1965	3,091	2,148	1,450	6,249
1966	3,175	2,210	1,283	6,356
1967	3,913	2,762	1,509	7,669
1968	3,265	2,482	969	6,692
1969	4,461	3,452	1,038	9,036†
1970	-----	3,657†	-----	-----

*Source: Iron and Steel Institute, Facts 1970, p. 46.

†Preliminary

To some extent, in-house scrap data from intra-company shipments are included in the purchased scrap data. This reduces the validity of the prices, since the in-house scrap does not move through market channels. It has been estimated that this inclusion may involve up to five million tons annually.[16]

Price fluctuations for No. 1 heavy melting scrap and No. 2 bundles rather closely resemble the yearly changes in quantities exported (Table 8). These two grades constituted about half of the total scrap exported in the past decade. Total exports of ferrous scrap ranged between 5 and 10 million tons during the 1960's.

There is much that has to be learned about the supply industry in ferrous scrap. Both the role of the processors and the role of the scavengers in the supply chain is not fully understood. A general, although somewhat outdated, overview of the iron scrap industry is presented in Barringer's The Story of Scrap.[17] A more recent discussion on the salvage industry for materials from solid waste is provided by Midwest Research Institute.[18]

The scrap supply is probably inelastic in the short-run. The immediate supply, is, of course, influenced by the scrap supply industry's expectations about forthcoming demand and price conditions. These speculations contribute to the short-run inventory and price changes. In the long-run, the supply function is more responsive to changes in technology and production costs.

OBSOLETE FERROUS SCRAP

Scrap prices must be differentiated with respect to the qualities of scrap. The more desirable scrap, such as No. 1 heavy melting, is readily consumed by the raw steel industry. The less desirable grades, on the other hand, such as machine shop borings, burnings, shovelings, and punchings, sometimes accumulate in dealers' yards or at shops when overall demand for scrap is slack. During slack demand, the less desirable grades of prompt industrial scrap may transfer to the processor without compensation to the shop owner. In extreme instances, he even has to pay to have the scrap removed from his premises.

With the exception of automobiles, utilization or recycling of obsolete consumer type ferrous scrap is less frequently compared with the prompt industrial scrap. For one reason, chemical elements such as chrome, nickel, copper, aluminum, and tin are often added in the making of steel products. The use of obsolete scrap presents the risk that these elements may be included in undesirable proportions. For example, an excess of tin and copper in raw steel can cause brittleness and bad surface conditions in steel. Detinners have more difficulty detinning can scrap when aluminum is present.* The amount and kind of contaminant that can be tolerated depends to a large extent on the end products for the raw steel. Structural steel, for example, can tolerate higher proportions of contaminants then deep-drawing steels.

Can Scrap

The recent introduction of tin-free steel (TFS) will eventually reduce the problem of tin in can scrap. The use of TFS in can steel is progressing rather slowly, however. A complete shift to TFS will

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*Some steel companies send their in-house tin scrap to the detinners who retain the tin for the service of detinning. The incremental value of the detinned scrap then equals the value of the tin recycled.

probably never occur, because some food products are too corrosive for the chrome plating in tin-free steel. The changeover requires additional capital that will only be invested when a steel company believes there is sufficient demand to make it economically feasible.

In recent years, about 8 percent (7 million tons) of the total raw steel product shipments consisted of tin plate and tin-free steels for can making.[19] About 85 percent of this tonnage, or 6 million tons, is used for the manufacture of cans. The average life of a steel can is about 1 year, thus about 6 million tons of can scrap becomes available each year.[20] Another source estimates 7 million tons a year.[21]

The recycling of tin cans attracts considerable publicity. A recent newspaper article quotes the American Iron and Steel Institute as saying that steelmakers are taking back all the discarded cans they can get and turning them into new steel. Moreover, it suggests that steelmakers can use up to 60 billion cans.[22] This is equivalent to about 3 million tons or 50 percent of the can scrap available annually.* It is interesting to note that only about 5 percent of all metal cans produced annually are presently being recycled.[23]

Recent discussions with representatives of the steel industry indicate that the major steel companies differ in their attitudes towards recycling of can scrap. An individual steel company may accept only bundled or baled can scrap, or it may not actually use the tin cans it purchases. In most cases the price is for can scrap delivered to the steel plant. If the scrap has to be moved a considerable distance,

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*There was no indication as to the time period required for this.

freight charges are more than the price received for the scrap.

The optimum use for can scrap has apparently not yet been determined. In discussions with metallurgists and other personnel at the major raw steel companies, some ranked tin can scrap as the least desirable of the market categories of obsolete steel products. One company had just begun to accept tin can scrap but was undecided on how it was going to use it. A recent study by the National Steel Corporation suggests that the steel industry's use of can scrap will be in "quantities limited to meet process and product chemistry requirements."[24]

It should be pointed out that increased recycling of tin can scrap by the raw steel industry may mean that less ferrous scrap of other kinds will be recycled. If this occurs, the emphasis on tin can recycling will only change the ferrous scrap mix. It will not reverse the total scrap utilization.

Automobile Scrap

It may be a popular misconception that the discarded automobile is difficult to recycle. In actuality, it is one of the more readily-recycled consumer types of obsolete ferrous scrap. About 85 percent of the automobiles going out of service each year are eventually scrapped and recycled. The number of vehicles scrapped has been estimated at about 8 million units annually. These vehicles furnish about 10 million tons of ferrous scrap to the raw steel industry annually.[25]

Automobile recycling has been enhanced by the development of improved auto shredders. Mobile car crushers (bashers) are facilitating the collection of discarded autos, particularly in the less populated areas of the country.

Automobile scrap is preferred to most other kinds of obsolete ferrous scrap by the steel producers. It is the only consumer type of obsolete ferrous scrap utilized to any extent by the companies. This scrap makes up a substantial proportion of the No. 2 bundle.[26] Although usually purchased as a No. 2 bundle, shredded auto scrap by itself is actually preferred to the composite No. 2 bundle because it contains less contaminants. As such, it commands a somewhat higher price that discourages its use by steel producers.

In the salvage industry, the trend is toward greater use of shredders. This facilitates the removal of ferrous metals by magnetic separation and a reduction in the proportions of contaminating copper, tin, and nickel. The price of shredded auto scrap may become more competitive with the No. 2 bundle as more shredders become available and the competition for material inputs intensifies.

The usual practice in the salvage industry is to remove certain parts from discarded automobiles before sending them to the shredder. These parts include the radiator, gas tank, seats, battery, transmission, generator, starter, ignition harness, and sometimes the engine. The overriding incentive for removing most of these is the salvage market value for the individual parts rather than the contaminants they contain. Copper is a contaminant in steelmaking and steelmakers are eager to have it removed. The parts with a high copper content (such as the generator, starter, and radiator) also have a high salvage value and are removed for that reason. The copper may be reclaimed or the entire component resold as a used part if it is still in operational condition. As much as 80 to 90 percent of the recoverable copper is being reclaimed according to one source.[27] Some copper in body wirings and motor windings is still escaping separation and recovery, however.

The maximum copper content that is technically allowable in raw steel, based on the quality level for specific end products, it shown below.[28]

Quality of steel	Maximum copper content (%)
Low	0.5
Average	0.3
High	0.1
Deep Drawing	0.05

The copper contained in the average No. 2 bundle scrap averages 0.48 percent.[29] This is close to the product category for low quality steels. Thus, the amount of copper contaminant severely limits the economic value for much of the ferrous scrap.

Consumer Durables

Among the consumer durables, the so-called "white goods" make up one of the more difficult types of scrap to recycle. "White goods" are household appliances with a porcelain coating. It has been estimated that discards of the nine major appliances add 1.7 million tons annually to ferrous solid waste stream (Table 9). In addition to these, many other kinds of consumer durables containing ferrous material are discarded annually. The total ferrous scrap from all discarded consumer durables has been estimated to amount to 4 million tons annually.[30]

The total residential solid waste includes the bulky consumer durables listed in Table 9. The larger items, such as refrigerators, hot water heaters, and the like are not always included in the routine pickups. In some areas, a special charge is made for these items.

TABLE 9

CONSUMER TYPE OBSOLETE FERROUS WASTE FROM MAJOR APPLIANCES DISCARDED DURING 1971*

Appliance	Number of units (in millions)	Ferrous material (pounds per unit)	Total ferrous scrap (mil. of pounds)
Refrigerators	4.08	260	1,060.80
Washers	3.99	207	825.93
Ranges	3.76	178	669.28
Freezers	1.05	195†	204.75
Hot water heaters	3.52	68‡	239.36
Dryers	1.61	132	212.52
Room air conditioners	1.50	62	93.00
Dishwashers	0.62	120	74.40
Disposals	0.80	12†	9.60
Total weight			3,389.64§

*Source: National Industrial Pollution Control Council, "The Disposal of Major Appliances," a report to Department of Commerce (Washington, D.C.: Government Printing Office, 1971), p. 10.

†Personal communication with Mr. Samuel Jordon, National Industrial Pollution Control Council.

‡Based on inquiries to local appliance repair shops.

§Equivalent to 1.7 million tons.

Having essentially a negative value then, they tend to accumulate in household basements or backyards. Eventually, however, most of the consumer durables (with the exception of automobiles) are finally deposited at the public dumps or landfills, as the major steel producers make little use of consumer durables such as refrigerators, freezers, and ranges. In addition to the risk of contamination by tin, nickel, chrome, and copper, the insulation in refrigerators, freezers, and ranges present problems. The "white goods" are not desirable at all as ferrous scrap unless they have first gone through a shredder. Shredder operators, however are not overly eager to accept this material as it takes about 10 refrigerators to equal one automobile. The productivity of the shredder is substantially lower when refrigerators or similar household items constitute the input.[31] There is also some variation in the efficiency with which shredders can handle these wastes.

Incinerator Scrap

Incinerator scrap should be distinguished from "incinerator bundles"- an industry term for a specific grade of ferrous scrap.[32] The Bureau of Mines has developed a process for separating incinerator residue into definable metallic iron concentrates, nonferrous composites, glass fractions, and carbonaceous ash. The National Steel Corporation has conducted tests on the chemical composition of incinerator residue to determine its usefulness for steelmaking. It found that the residue is relatively high in certain critical contaminating elements. The conclusion was that the ferrous scrap in incinerator residue could be recycled into useable products. However, the residuals included contaminants such as copper, tin, and nickel; and this would limit the usefulness of this type scrap in steelmaking.[33]

Contaminant Buildup

Contaminant buildup is likely to occur with repeated recycling, unless diluted by iron ore. Whether this is a potentially serious problem has not been determined. Ostrowski makes reference to an increase in tin residual from the use of tin can scrap.[33] Whether there will be lead accumulation on blast furnace linings also seems uncertain. Midwest Research Institute projected tin contaminant buildup to the 19th year of recycling and concluded that at that time it would still be well below the maximum tolerance of 0.06 percent.[34] Their projection, however, erroneously assumed that tin can scrap was uniformly distributed among the steel and iron producing companies. It should also be noted that recycled tin can scrap is generally used in the manufacture of products having a service life of more than 19 years. Thus, any substantial contaminant buildup would very likely appear after that time.

Transportation Costs

Scrap is heavily dependent upon railroads for transportation. About 75 percent of all ferrous scrap moves by rail as compared with 58 percent of the iron ore.[35] Rail transportation costs therefore influence market values and the utilization of ferrous scrap. Freight rates are essentially the same regardless of grade or quality, thus the lower quality and low-volume grades are less economical to ship to distant steelmaking plants or foundries.

The railroads have been charged with discrimination in the transporting of ferrous scrap. The Institute of Scrap Iron and Steel believes that rail transportation rates should reflect the metallurgical comparison between scrap and pig iron components, and on that basis ferrous scrap would be able to compete more favorably with pig iron. The Interstate Commerce Commission (ICC), on the other hand, asserts that decisions on freight rates must conform to the national transportation policy that requires a sound and economically viable transportation system.[36]

A comparison of rail freight charges for virgin and secondary materials was recently made by the Resource Planning Institute, Cambridge, Massachusetts.[37] Their comparison was based on actual revenues and ton miles hauled by a major carrier of secondary and virgin materials in the Eastern United States. The study showed that on a cent-per-ton-mile basis, the argument that secondary materials are penalized in terms of transportation costs is unfounded. In the case of iron scrap, however, they found that the virgin material (components of pig iron) was being hauled at a lower charge than the secondary material.

The goals of society influenced the freight rates in this country in the past. In the early period of freight rates, the Nation was intent upon settling and developing the country's vast natural resources. Favorable rates for this purpose were therefore reflected in ICC decisions. In a later period of history, there was concern for the plight of agriculture. A restructuring of rates was then considered desirable to promote the movement of the agricultural products.[38] It remains to be seen whether the current national concern for the environment will bring about a restructuring of transportation rates to promote the recycling of waste materials.

THE ROLE OF FOUNDRIES IN RECYCLING FERROUS SCRAP

Foundries account for about one-fifth of the total domestic utilization of ferrous scrap (Table 3). There are three general types of foundries: (1) those that produce castings (these account for 84 percent of the total casting shipments); (2) those that produce steel castings (accounting for 11 percent of the total); and (3) foundries producing malleable iron castings (these account for 5 percent of the total).[39]

The foundry industry uses mainly three types of furnaces: the cupola, the electric furnace, and the open hearth. There are very few basic oxygen furnaces in the foundry industry.

There are approximately 2,000 foundries in the United States. Of these, the captive foundries (those owned by automotive firms, farm machinery companies, heating and plumbing fixture companies, and steel producers) comprise about 20 percent of the total number and account for over 40 percent of the tonnage. The pattern of growth in the foundry industry has been similar to that in the steel industry during the past decade. In 1970, foundry industry shipments totaled 16.5 million tons. The industry purchased 9.9 million tons of ferrous scrap.*

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*The estimate is based on total receipts of purchased scrap of 33,889,000 tons. The raw steel industry had net receipts of 24,012 tons, leaving 9,877,000 tons for foundries. (Battelle Columbus Laboratories, Recycling of Ferrous Solid Waste, August 1971, p. 77, and American Iron and Steel Institute, Annual Statistical Report 1970, p. 53).

Since foundries are not dependent upon either the ingot or roll process, it would appear they may provide a potential for utilizing the more contaminated types of obsolete ferrous scrap that cause problems in the raw steel industry. This study was limited mainly to the raw steel industry. However, the opportunities for increasing the recycling of ferrous scrap in the foundry industry should not be overlooked. Time and resources precluded a fuller evaluation of their potential in this study.

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APPENDIX TABLE I

DOMESTIC AND EXPORT PURCHASES OF FERROUS SCRAP, 1946 TO 1970*

(In thousands of tons)

Year	Domestic scrap purchases: Prompt industrial†	Obsolete‡	Total purchased scrap§	Net scrap exports	Total domestic scrap plus net exports
1946	6,671	16,679	23,350	84	23,434
1947	8,555	20,731	29,286	100	29,386
1948	9,351	23,193	32,544	(268)	32,276
1949	8,124	17,048	25,172	(853)	24,319
1950	10,684	22,246	32,930	(568)	32,362
1951	11,817	26,064	37,881	(171)	37,710
1952	9,858	24,326	34,184	198	34,382
1953	11,948	23,491	35,439	136	35,575
1954	9,261	14,133	23,394	1,440	24,834
1955	12,368	23,367	35,735	4,901	40,636
1956	12,150	24,695	36,845	6,085	42,930
1957	11,432	19,654	31,086	6,527	37,613
1958	8,887	14,404	23,291	2,595	25,886
1959	10,947	18,096	29,043	4,630	33,673
1960	10,868	15,227	26,095	7,860	33,955
1961	10,217	15,088	25,305	9,168	34,473
1962	11,033	14,251	25,284	4,931	30,215
1963	11,912	17,520	29,432	6,161	35,583
1964	13,540	18,291	31,831	7,590	39,421
1965	15,879	19,925	35,804	5,962	41,766
1966	15,068	21,603	36,671	5,420	42,091
1967	14,265	18,389	32,654	7,275	39,929
1968	16,388	17,199	33,587	6,271	39,858
1969	15,640	21,289	36,929	8,689	45,618
1970	14,796	19,093	33,889		

*Source: Institute of Scrap Iron and Steel, Facts 1970, p. 33.

†Based on estimating techniques developed by Battelle Columbus Laboratories (see Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, 1971, p.2). [Obsolete scrap is that ferrous solid waste material resulting from discarded industrial and consumer products.]

‡Derived by substracting prompt industrial scrap from purchased scrap.

§Purchased scrap is that scrap sold by scrap dealers and purchased by the consuming industries from outside the basic steel and the iron and steel foundry industries. Purchased scrap consumed does not necessarily equal scrap purchased because of changes in inventory.

APPENDIX TABLE 2

PROJECTIONS OF TOTAL OBSOLETE SCRAP AVAILABLE

(In thousands of tons)

Year	Total scrap available*	Recycled obsolete scrap†		Nonrecycled obsolete scrap‡			
		Minimum forecast	Maximum forecast	Maximum forecast	As percent of total available	Minimum forecast	As percent of total available
1972	69,000	25,000	26,000	44,000	63.8	43,000	62.3
1973	67,800	24,900	26,600	42,900	63.3	41,200	60.8
1974	63,800	24,800	27,200	39,000	61.1	36,600	57.4
1975	49,600	24,700	27,900	24,900	50.2	21,700	43.8
1976	61,100	24,600	28,700	36,500	59.7	32,400	53.0
1977	60,600	24,500	29,500	36,100	59.6	31,100	51.3
1978	57,000	24,400	30,300	32,600	57.2	26.700	46.8
1979	61,600	24,300	31,100	37,300	60.6	30.500	49.5
1980	66,700	24,200	32,000	42,500	63.7	34.700	52.0
1981	74,600	24,100	33,100	50,500	67.7	41,500	55.6
1982	84,700	24,000	34,200	60,700	71.7	50,500	59.6
1983	84,100	23,900	35,400	60,200	71.6	48.700	57.9
1984	79.600	23,800	36.700	65,800	70.1	42,900	53.9
1985	91,400	23,700	38,000	67,700	74.1	53,400	58.4

Source:* Based on estimating techniques developed by Battelle Memorial Laboratories as revised by the Business and Defense Service Administration.

† Based on calculations of maximum and minimum purchased scrap requirements of the steel and foundry industries, assuming continuation of current trends (including net exports).

‡ Derived as the difference between total scrap available and recycled scrap.

APPENDIX TABLE 3

AMOUNTS OF OBSOLETE SCRAP RECYCLED AND NOT RECYCLED, BY FIVE YEAR PERIODS FROM 1956 TO 1985.
(In million of tons)

Period	Total available scrap*	Obsolete Scrap recycled†				Obsolete scrap not recycled‡			
		Minimum estimate	As percent of total available scrap	Maximum estimate	As percent of total available scrap	Maximum estimate	As percent of total available scrap	Minimum estimate	As percent of total available scrap
1956-60	198.2	119.8	60.4	119.8	60.4	78.4	39.6	78.4	39.6
1961-65	229.6	118.9	51.8	118.9	51.8	110.7	48.2	110.7	48.2
1966-70	292.5	35.4	46.3	35.4	46.3	157.1	53.7	167.1	53.7
1971-75§	301.9	119.4	39.6	127.7	42.3	182.5	60.4	174.2	57.7
1976-80§	307.0	122.0	39.7	151.6	49.4	185.0	60.3	155.4	50.6
1981-85§	414.3	119.5	28.8	177.4	42.8	294.8	71.2	236.9	57.2

*Source: Based on estimating techniques developed by Battelle Memorial Laboratories as revised by Business and Defense Service Administration using data from American Iron and Steel Institute's Annual Statistical Yearbook 1970. Data for the projected years are the authors.

†Derived by substracting prompt industrial scrap from total purchased scrap and adding net exports from the Institute of Scrap Iron and Steel's Facts 1970, p. 33. Data for prompt industrial scrap was estimated by the technique shown above.

‡Derived by taking the difference between total available and recycled scrap.

§Projected.

APPENDIX TABLE 4

IMPORTS AND EXPORTS OF STEEL MILL PRODUCTS AND FERROUS SCRAP

(In thousands of tons)

Year	Steel mill products		Ferrous scrap	
	Exports	Imports	Exports	Imports
1940	7,640	18	3,159	21
1945	4,354	54	96	66
1950	2,639	1,014	217	785
1951	3,137	2,177	231	417
1952	4,005	1,201	342	154
1953	2,991	1,703	304	174
1954	2,792	771	1,683	239
1955	4,061	973	5,155	229
1956	4,348	1,341	6,422	256
1957	5,348	1,155	6,744	239
1958	2,823	1,707	2,924	333
1959	1,677	4,396	4,937	309
1960	2,977	3,359	7,181	178
1961	1,990	3,163	9,714	268
1962	2,013	4,100	5,113	262
1963	2,224	5,446	6,364	222
1964	3,435	6,440	7,881	299
1965	2,496	10,383	6,170	235
1966	1,724	10,753	5,857	464
1967	1,685	11,455	7,504	229
1968	2,170	17,960	6,565	294
1969	5,229	14,034	9,036	345
1970	7,053	13,364	-----	---

* Source: Data for 1940-66 were taken from U.S. Department of Commerce, Business Statistics, 1967, p. 157. Data for 1967-70 were taken from the American Iron and Steel Institute's Annual Statistical Report, 1970; and from the Institute of Scrap Iron and Steel's Facts, 1970.

APPENDIX TABLE 5

GENERATION AND UTILIZATION OF SELECTED FERROUS SCRAP GRADES BY RAW STEEL PRODUCERS AND STEEL FOUNDRIES*

(In thousands of tons)

	Generation		Utilization		Purchased Scrap†	
Year	No. 1 heavy melting scrap	No. 2 bundle scrap	No. 1 heavy melting scrap	No. 2 & all other bundles scrap	No. 1 heavy melting	No. 2 & all other bundles scrap
1960	16,503	223	21,490	3,984	4,987	3,751
1961	15,383	546	20,517	3,569	5,134	3,023
1962	16,258	692	20,901	3,484	4,643	2,792
1963	------	---	25,181	5,897	5,950	4,708
1964	------	---	29,127	6,486	6,870	5,252
1965	------	---	30,355	5,735	7,763	5,128
1966	------	---	30,751	5,939	8,688	5,319
1967	------	---	28,049	5,354	7,167	4,694
1968	------	---	27,018‡	4,056‡	7,589§	3,770§
1969	20,442	384	27,195	4,270	6,753	3,886
1970	------	---	26,544	3,918	8,175	3,607

* Source: U.S. Bureau of Mines, Mineral Yearbooks, 1960-70.

†Derived. No. 2. and all other bundles are not strictly comparable with No. 2. Bundle but in-house generation of No. 2 Bundle is minor. Data are for total receipts and may contain some outshipments.

‡Battelle Memorial Laboratories, Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, August 1971, p. 204.

§Obtained from Bureau of Mines by telephone.

APPENDIX TABLE 6

CHANGES IN GROSS NATIONAL PRODUCT AND RAW STEEL PRODUCTION*

	Gross national product (in billions of dollars)†	Change from previous year (percent)‡	Raw steel production (in millions of tons)	Change from previous year (percent)‡
1960	487.7	----	99.3	----
1961	497.2	1.95	98.0	-1.31
1962	529.8	6.60	98.3	0.31
1963	551.0	4.00	109.3	11.19
1964	581.1	5.46	127.1	16.28
1965	617.8	6.32	131.5	3.46
1966	658.1	6.52	134.1	1.98
1967	675.2	2.60	127.2	-5.15
1968	706.6	4.65	131.5	3.38
1969	724.7	2.56	141.3	7.45
1970	720.0	-0.65	131.5	-6.94

*Source: Gross national product data are from Joint Economic Committee of U.S. Congress, "Economic Indicators"; November 1971. Steel production data are from the American Iron and Steel Institute's Annual Statistical Report 1970, p. 40.

†Based on 1958 prices.

‡The average change for the 10-year period 1961-70 was 4.00 percent for gross national product and 3.07 percent for raw steel production.

APPENDIX TABLE 7

AVAILABLE OBSOLETE SCRAP SUPPLY FROM STEEL MILL PRODUCTS, 1970[*]

	Production-scrap lag (years)	Production years	Current (1970) scrap supply (in millions of tons)	Percent of total
Market source				
Agriculture	15	1954-56	1.2	3.0
Automotive	10	1959-61	1.7	4.2[†]
Consumer Durables	15	1954-56	4.0	9.8
Containers	1	1969-70	6.3	15.5[‡]
Machinery	20	1949-51	5.2	12.8
All Others (excluding exports)[§]	20	1949-51	22.2	54.7
Total			40.6	100.0

[*]Source: Battelle Columbus Laboratories, Identification of Opportunities for Increased Recycling of Ferrous Solid Waste, August 1971, p. 114. (Unpublished Report)

[†]Assumes that about 88 percent of the automobiles are recycled.

[‡]Assumes that 15 percent are returned and reused.

[§]Consists of forgings, nuts and bolts, steel service centers, contractors' products, ordanance and military, and nonclassified.