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# IRON AND STEEL RECYCLING IN THE UNITED STATES IN 1998

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# Iron and Steel Recycling in the United States in 1998

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## ABSTRACT

Consumption of iron and steel scrap and the health of the scrap industry depend directly on the health of the steelmaking industry. The United States, as well as most of the world, is expected to consume increasing amounts of scrap as a steadily increasing population demands more steel products. World resources of scrap should be sufficient for the foreseeable future. An estimated 75 million metric tons (Mt) of scrap was generated during 1998 in the United States, and 35 Mt of old scrap and 18 Mt of new scrap was consumed. The recycling efficiency was calculated to be 52%, and the recycling rate was found to be 41%. (See appendix for definitions.)

## INTRODUCTION

Iron, which includes its refined product steel, is the most widely used of all the metals. Iron and steel products are used in many construction and industrial applications, such as appliances, bridges, buildings, containers, highways, machinery, tools, and vehicles. The recycling of iron and steel scrap (ferrous scrap) is an important activity worldwide, especially in the United States, where 73 Mt of new, old, and home scrap was consumed in the making of new steel during 1998. Obsolete iron and steel products and the ferrous scrap generated in steel mills and steel-product manufacturing plants are collected because it is economically advantageous to recycle iron and steel products by melting and recasting them into semifinished forms for use in the manufacture of new steel products. The steel scrap market is mature and highly efficient. The recycling rate for steel scrap, which was defined by the Steel Recycling Institute as total scrap recovered versus total raw steel produced, has exceeded 50% every year since World War II and has been more than 60% for about two decades.

Iron and steel scrap is more than just economically beneficial to steelmakers; ferrous scrap recycling is part of wise management of iron resources. Recovery of 1 metric ton (t) of steel from scrap conserves an estimated 1,030 kilograms (kg) of iron ore, 580 kg of coal, and 50 kg of limestone. Each year, steel recycling saves the energy equivalent required to electrically power about one-fifth of the households in the United States (about 18 million homes) for 1 year (Steel Recycling Institute, A few facts about steel—North America's #1 recycled material, Fact Sheet, accessed July 13, 1999, at URL http://www.recycle-steel.org/fact/mail.html.) In the production of steel, 99.9% of scrap melted is consumed in the new steel while producing negligible environmentally undesirable waste. This materials flow study, as summarized in figure 1, describes the materials cycle of pig iron, direct reduced iron (DRI), and scrap used in the manufacture of iron and steel products; the recycling of scrap; and the losses of iron and steel during the steelmaking and product fabrication processes during 1998. The flow diagram shows the quantities of iron present at stages of steel product manufacture, shipping, and recycling.

In a free-market economy, scrap prices react quickly to changes in supply and, especially, demand. When demand for steel mill and foundry products is low, demand for scrap is low, and prices fall. Dealers cannot influence sales of scrap if mills and foundries do not need it to charge their furnaces. Although prices of scrap depend upon the market conditions for new products, the scrap industry uses inventory to absorb price differentials; that is, inventories increase as scrap prices decrease. Prices are also influenced by technological changes in mills, processing of scrap, the use of scrap substitutes, environmental controls and other Government regulations, and export demand. During the decade prior to 1998, the average annual composite price of No. 1 Heavy Melting Steel scrap, which was an industry standard, fluctuated between $84.67 and $135.03 per metric ton. Ferrous scrap prices declined significantly during 1991 and 1992 as domestic and world demand for scrap decreased. The period from 1993 to 1995 was one of strengthening demand and rising prices to a peak average price of $130.60 in 1995. Prices then declined to an average of $108.30 in 1998.

In 1998, an estimated old scrap supply of more than 78 Mt was available for recycling and about 35 Mt valued at nearly $3.8 billion was recycled in the United States. About 18 Mt of new scrap was consumed, and about 38 Mt was unrecovered. The old scrap recycling efficiency was 52%, and the recycling rate was 41% (table 1).

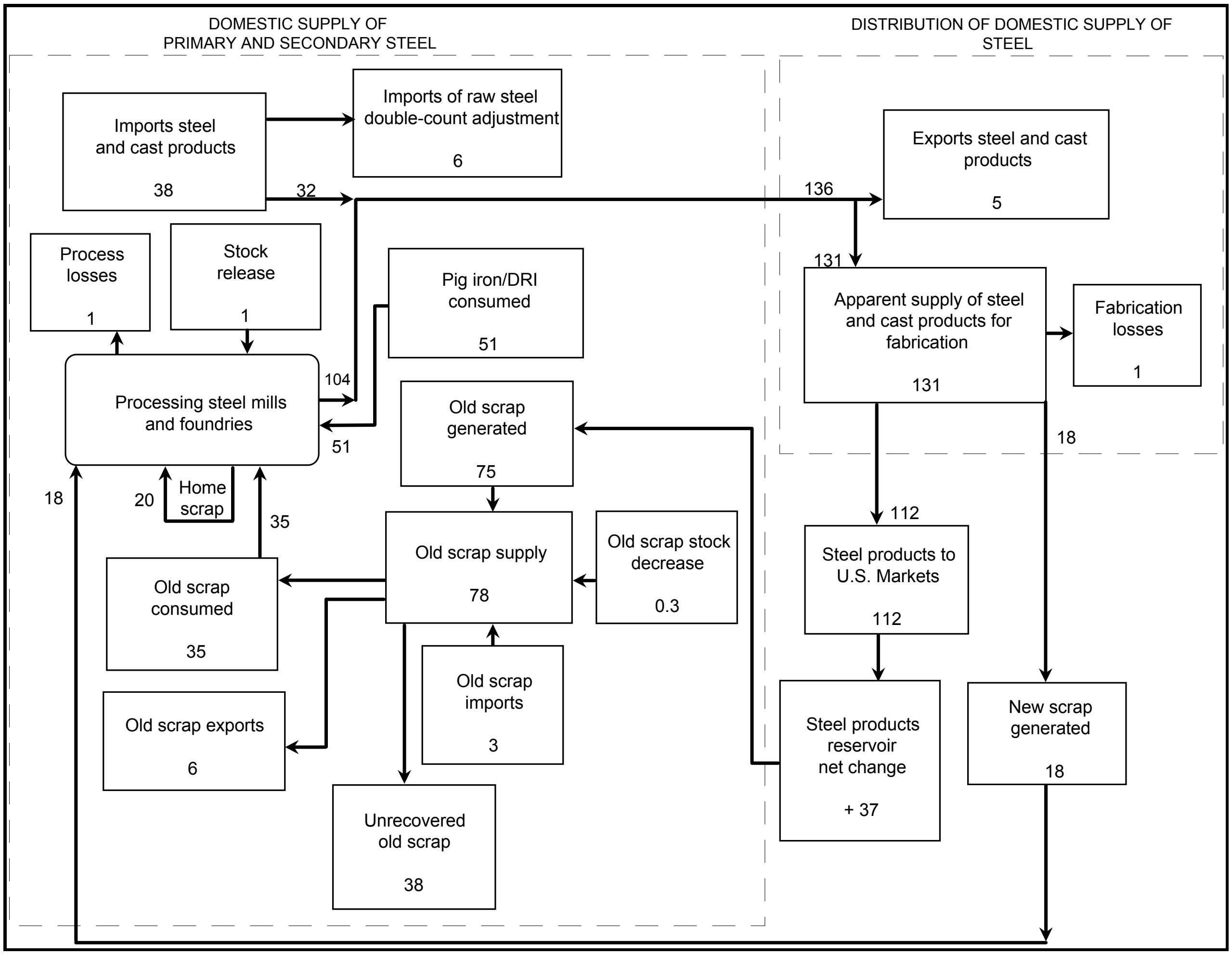


Figure 1. U.S. steel scrap material flow, 1998. (Numbers are in million metric tons; DRI, direct reduced iron.)

## SOURCES OF IRON

Approximately three-quarters of the iron ore used by domestic integrated steel mills to make iron and steel originated in the United States in 1998. Brazil, Canada, and Venezuela accounted for more than 90% of iron ore imports, which average about 15 million metric tons per year. Domestic consumption of iron ore was about 78 Mt in 1998. Almost all ore is produced in Michigan and Minnesota from taconite, which is a low-grade ore and almost all of which is in the form of pellets. In 1998, the quantity of iron ore by type consumed at U.S. iron and steel plants was: pellets, 63 Mt, 11 Mt sinter, and direct shipping ore, 900,000 t. Integrated steel mills consumed about 16 Mt of iron and steel scrap and 400,000 t of DRI in blast and basic oxygen furnaces during 1998. Minimills that use electric arc furnaces consumed about 3.4 Mt of pig iron and about 42 Mt of scrap during 1998. Thus, steel scrap comprised about 43% of iron units supplied for steelmaking. During 1998, minimills also consumed about 1 Mt of DRI to improve steel quality; more than in previous years. About 87% of DRI imports, or 900,000 t, came from Venezuela.

## SOURCES OF IRON AND STEEL SCRAP

Sources of different types of scrap are key features of the flow diagram (figure 1). Ferrous scrap available for recycling comprises home, new, and old scrap. Home, or mill, scrap is generated within the steel mill during production of iron and steel. Trimmings of mill products and defective products are collected and quickly recycled back into the steel furnace because their chemical compositions are known. The availability of home scrap has been declining as new and more-efficient methods of casting have been adopted by the

Table 1. Salient statistics for U.S. iron and steel scrap, in 1998
[Thousand metric tons, unless otherwise specified]

| | |
|---|---|
| Old scrap: | |
| Generated[1] | 75,000 |
| Consumed[2] | 35,000 |
| Value consumed | $3.79 billion |
| Recycling efficiency[3] | 52% |
| Supply[4] | 78,000 |
| Unrecovered[5] | 38,000 |
| New scrap consumed[6] | 18,000 |
| New-to-old scrap ratio[7] | 34:66 |
| Recycling rate[8] | 41% |
| U.S. net exports of scrap[9] | 2,510 |
| Value: U.S. net exports of scrap | $272 million |

[1] Old scrap that will theoretically become obsolete in the United States in 1998. Net U.S. imports of semifinished products containing iron in 1998 are included. Dissipative uses are excluded.

[2] Old scrap recycled in 1998.

[3] (Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imports plus old scrap stock decrease).

[4] Old scrap generated plus old scrap imports.

[5] Old scrap supply minus old scrap consumed minus old scrap exports.

[6] Includes prompt industrial scrap but excluding home scrap.

[7] Ratio of quantities consumed, each measured in weight and expressed as a percentage of old plus new scrap consumed.

[8] Fraction of supply that is scrap on an annual basis. Old plus new scrap consumed divided by apparent supply (primary plus secondary production (old plus new scrap) plus imports minus exports plus adjustment for industry stock changes), in percent.

[9] Trade in scrap is assumed to be principally in old scrap

industry. Old scrap includes metal articles that have been discarded after serving a useful purpose. Because of the wide variety of chemical and physical characteristics, old scrap often requires significant preparation, such as sorting, de-tinning, and de-zincing, prior to consumption in mills. Statistical data for domestic consumption of home and old scrap were collected by the U.S. Geological Survey (USGS). The amount of new scrap is an estimated 15% of apparent consumption of steel mill products.

The domestic supplies of primary and secondary iron as portrayed in the diagram consists of inputs from domestic steel mills and DRI producers, imports, and the supply of old scrap available for recycling. Statistical data were collected by the USGS, the American Iron and Steel Institute, and the U.S. Census Bureau.

## OLD SCRAP GENERATED

Old, obsolete, or postconsumer scrap are available for recycling. The largest source is junked automobiles followed by appliances, machinery, worn out railroad cars and tracks, demolished steel structures, and other products. Old scrap estimated as available for recycling were products in circulation that became obsolete in the United States in 1998. On the basis of the estimated average useful life of products and on the amounts of iron and steel embodied in the various market classes in the appropriate prior years, the estimates of obsolescence developed by market class total 75 Mt. The weighted average product life was 19 years.

## NEW SCRAP

New, prompt, or industrial scrap is generated from manufacturing plants that make steel products. Scrap accumulates when steel is cut, drawn, extruded, or machined. The casting process also produces scrap as excess metal. Its chemical and physical characteristics are known, and it is usually transported quickly back to steel plants through scrap processors and dealers or directly back to the steel plant for remelting to avoid storage space and inventory control costs. The supply of new scrap is a function of industrial activity. When activity is high, more industrial scrap is generated. New scrap generated and recycled in 1998 was estimated to be 18 Mt. The new scrap-to-old scrap ratio during 1998 was 34:66.

### HOME SCRAP

Home, or revert, scrap consists of scrap that is produced in steel mills and foundries as a byproduct of their operations, as well as old plant scrap. This scrap has a known composition and is always recycled to the furnace for remelting. Home scrap generated and recycled in 1998 totaled about 20 Mt.

## DISPOSITION OF IRON AND STEEL SCRAP

The U.S. steel industry reports scrap receipts and consumption to the USGS. Also, the U.S. Census Bureau reports scrap imports and exports. In figure 1, the starting point for ferrous scrap flow through processing is old scrap generated, which is the estimated 75 MT of iron and steel that became obsolete in 1998. The old scrap supply available for recycling in the domestic steelmaking industry is 78 Mt—old scrap generated with 3 Mt old scrap imports added.

Some scrap is lost to the environment and is unrecoverable. Scrap that is discarded to scrap yards or abandoned in place is considered to be temporarily unrecoverable and may be recycled at some future date. In 1998, the steel industry used 35 Mt of old scrap and exported 6 Mt. Unrecovered old scrap, which is old scrap supply less old scrap consumed and old scrap exports, was estimated to be 37 Mt for 1998.

## RECYCLING EFFICIENCY FOR OLD SCRAP

The relation between the amount of scrap that is theoretically available for recycling and what is actually recovered and reused is called recycling efficiency. Old scrap recycling efficiency during 1998 was 52%. Recycling efficiency is not expected to increase significantly because ferrous scrap competes with direct reduced iron and pig iron as a raw material, both of which are readily available and tend to hold down scrap prices, thereby limiting scrap availability and recycling efficiency.

## INFRASTRUCTURE OF IRON AND STEEL SCRAP INDUSTRY

Steel mills and foundries require ferrous scrap provided by brokers and scrap collectors and processors. Brokers bring scrap buyers and sellers together on a scrap transaction and receive a fee for this service. Consumers use brokers to procure scrap; processors use their services to market their scrap. Brokers purchase scrap without having storage or processing facilities for a particular client buyer or with the hope of finding a future buyer offering a favorable price and profit. More than 16,000 automotive dismantlers and thousands of scrap processing facilities in the United States play an integral role in the steel industry by collecting and preparing scrap for transport to steel mills that need raw materials (Steel Recycling Institute, The inherent recycled content of today's steel, accessed August 21, 2000, at URL http://recycle-steel/org/buy/BuyInherent.html). The greatest concentration of these facilities is in the northeastern, north-central, and middle Atlantic regions because the large population uses more steel products and generates more scrap. The scrap recycling infrastructure causes the recycling rate of steel in the United States to be equal to and, in most cases, exceed other industrialized countries. The rate is much higher than that of lesser developed countries.

## PROCESSING OF IRON AND STEEL SCRAP

Using a variety of equipment, scrap dealers collect and process scrap into a physical form and chemical composition that steel mill furnaces can consume. The type and size of equipment they use depends on the types and volume of scrap available in the area and the requirements of their customers. The largest and most expensive piece of equipment is the shredder. The shredder can fragment vehicles and other discarded steel objects into fist-size pieces of various metals, glass, rubber, and plastic. These materials are segregated before shipment by using fans, magnets, air ducts, hand pickers, and flotation equipment. Hydraulic shears, which have cutting knives of chromium-nickel-molybdenum alloy steel for hardness, slice heavy pieces of ship plate, railroad car sides, and structural steel into chargeable pieces. Baling presses are used to compact scrap into manageable bundles thereby reducing scrap volume and shipping costs. Scrap dealers must carefully sort the scrap they sell, and steelmakers must be careful to purchase scrap that does not contain unacceptable levels of undesirable elements. Total scrap processing capability in the United States is estimated to be 118 Mt (Robert Garino, Institute of Scrap Recycling Industries, Inc., written commun., January 2, 2001).

Old and new scrap consumed or recycled during 1998 was about 53 Mt. Recycled automobiles accounted for about one-sixth of the ferrous scrap recycled by the U.S. steel industry in 1998. About 16,000 automobile dismantlers and 202 shredders in the United States disassembled and shredded automobiles in 1998 (Recycling Today, 1998); appliances, bicycles, and other steel products are also shredded for recycling. More than 1,500 scrap yards process steel from construction and demolition sites by shearing, shredding, and baling. By comparing the annual tonnage of steel used to produce the new product with the tonnage of recycled product, steel recycling rates during 1998 were determined for the following: automobiles, 92%; construction plate and beams, 88%; appliances, 72%; steel cans, 56%; and all products, 64% (Institute of Scrap Recycling Industries—Scrap facts, Fact Sheet, accessed October 15, 1999, at URL http://www.isri.org/viewpage.cfm?pgname=2.0).

Steel mills melt scrap in basic oxygen furnaces (BOF), electric arc furnaces (EAF), and, to a minor extent, blast furnaces. The proportion of scrap in the charge in a BOF is limited to less than 30%, whereas that in an EAF can be as much as 100%. Steel and iron foundries use scrap in EAF's and cupola furnaces. In 1998, BOF's were used to produce 55% of total steel in the United States while using only 19% of total scrap consumed (American Iron and Steel Institute, 1998, p. 75). During the same period, EAF's produced 45% of total steel while using 62% of total scrap consumed. Scrap was also melted in blast furnaces and other types of furnaces.

Fabrication of new steel products produces new steel scrap that is relatively clean, chemically and physically, and of known chemical composition. For this reason, most scrap consumers prefer new scrap to old scrap. Preparation of new scrap is usually limited to cutting, cleaning, and baling prior to rapid transport back to the steelmaker for recycling.

## SUMMARY AND OUTLOOK FOR FERROUS SCRAP RECYCLING FLOW

Consumption of ferrous scrap and the growth or decline of the scrap industry depends directly on the health of the steelmaking industry. Most regions of the world will see a marked increase in steel consumption during the next 5 years, according to the International Iron and Steel Institute (American Metal Market, 2000). In the United States, a steadily increasing population and a growing economy in the long term should assure that demand for steel products, and the scrap used to make them, will also increase. Steel and scrap consumption will continue to be in strong demand in the automotive and consumer appliance sectors. New highway and bridge projects supported by increased Federal funding will require structural and reinforcement bar products. The use of steel framing is increasing in the construction of multifamily developments, retirement homes, and single-family residences. Steel demand in can production, which includes aerosol cans, food, and paint, should remain strong in the long term. A thriving steel industry is dependant on plentiful inexpensive energy. As energy costs increase, the demand for steel pipe and tubular goods used in oil and gas industry will increase for new drilling projects. Foundries are an important market for tin-bearing scrap from recycled cans.

Relative consumption of iron and steel scrap in four major markets from 1979 through 1998 may be inferred from shipments of steel mill products by the end-use sector (figure 2). Total shipments and inferred scrap consumption in all sectors shown declined during the early 1980's, but by 1998, they regained the levels of the late 1970's. During the 20-year period, the proportion of steel containers to the total decreased from 7% to 4%, that of transportation decreased to 16% from 24%, and that of construction materials increased only slightly to 15% from 13%.

The EAF contribution to the total production of steel has risen dramatically, and the proportion of EAF steel produced should continue to increase, perhaps at a rate of 4% per year during the next 10 years (Steel Times International, March 2000). The EAF may be the primary steel production method in the world by 2010 (Forster, 1999). The EAF has evolved in minimills from the small unit limited in use for specialty steel production to the large-capacity unit used to produce a wide range of steels, which includes flat product sheet and plate, long product bars, structural shapes, tubulars, and wire.

The availability of scrap and operating and capital cost advantages have made EAF growth possible. Locations of new minimills in areas of increasing population growth and manufacturing activity in the Southern and Western States, and away from the traditional "rust belt" States have, to a large extent, satisfied demand for construction steel products and products used by the oil and gas industry. The EAF process is flexible in its raw material requirements and sources and can operate with considerable flexibility in making products depending on market requirements. Steelmaking by the EAF will continue to grow because of the capital and operating cost advantages relative to those of the BOF, an increasingly wide range of steel products that it makes, and its environmental cleanliness. The use of the EAF is the most effective way of reducing carbon dioxide emissions because of the lower energy needed to melt scrap than to smelt ore. Use of EAF's will increase as new minimills are built and EAF's may replace operating BOF's. Ispat Inland Inc. is considering replacing one of its two BOF's with an EAF, which would create new demand for large amounts of ferrous scrap, as much as 900,000 metric tons per year (Worden, 2000). As the expansion of the EAF in the United States continues, ferrous scrap will continue to be available in sufficient quantities worldwide, but the role of the United States as the world's largest scrap supplier may diminish in importance (Katrak and others, 1999; Michael Marley, 2000, Role as 'largest scrapyard' changing, Special Report, accessed March 17, 2000, at URL http://www.amm.com/subscrib/2000/mar/special/0314-1.htm).

Ferrous scrap will remain the most important raw material used, but reduced iron in the form of DRI and hot briquetted iron (HBI) will become a larger component in the raw materials mix for EAF steel production. Increasing availability from domestic producers of DRI and HBI will be a factor in this trend as will the increasing need for low-residual feedstock for the production of high-quality flat steel and special-bar quality steels required to compete in the higher end markets.

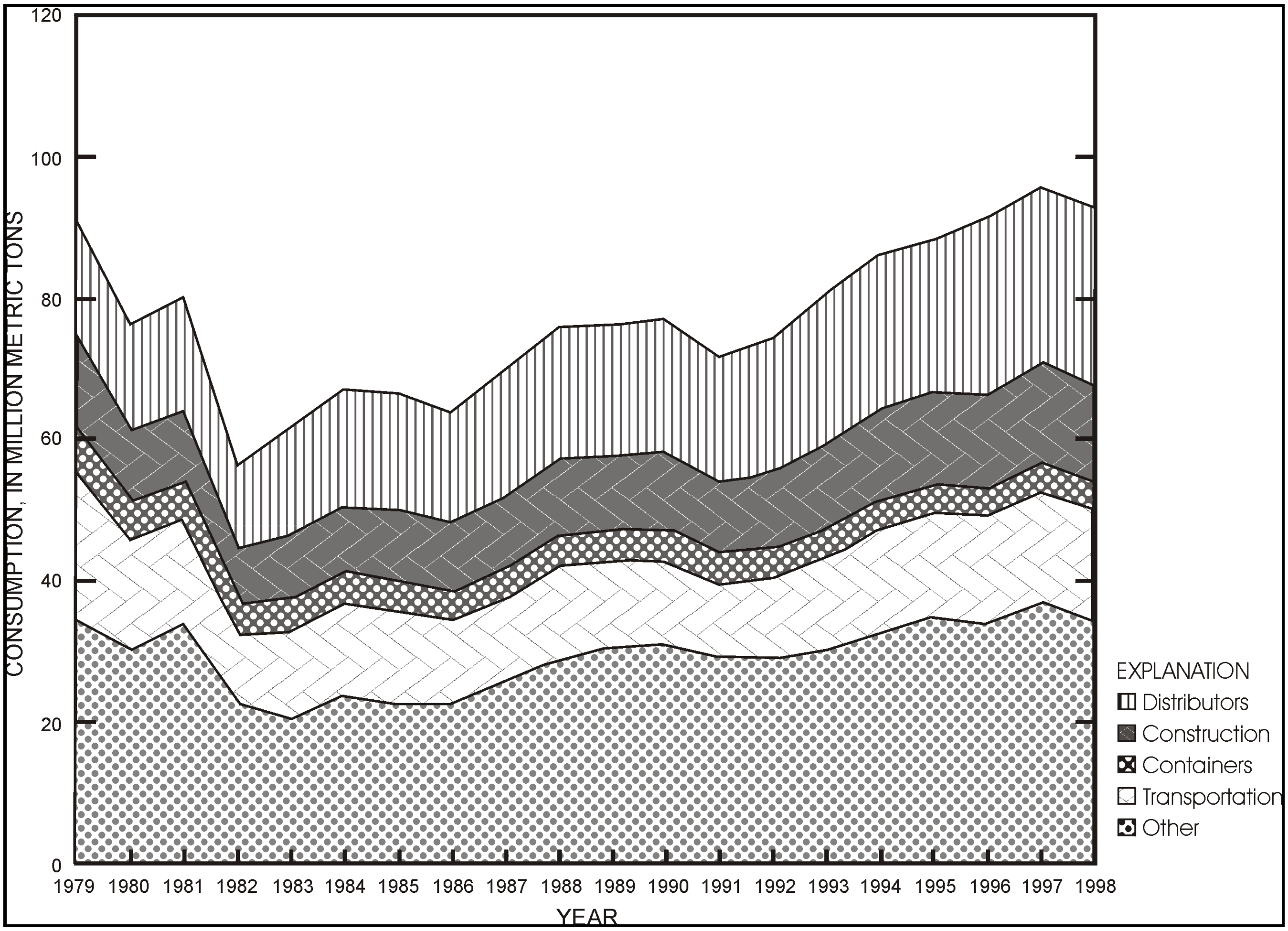


Figure 2. U.S. steel product shipments, by end-use sector, 1979-98.

E-commerce has been making progress at different rates in the steel industry, as well as many sectors of the economy. Selling scrap through e-commerce has potential but adoption of e-commerce marketing by the ferrous scrap industry will probably be a slow evolutionary process. For e-commerce to be adopted, scrap processors, dealers, and brokers must realize the value of this new Internet technology and see potential gains in profits and efficiency.

A major problem for world and U.S. steel industries is that the world is currently producing too much steel. Except for North America,world steelmaking capacity is excessive relative to demand–perhaps as much as 15% more than can be consumed (Matthews, 2000). Companies continue to expand production about 2% each year as profits decline. Excess steel production from major steelmaking nations is being imported into the United States because of its strong economy and open market system. The result has been declining domestic steel production, falling steel prices, and declining scrap demand and prices. Support seems to be increasing for consolidation among domestic steelmakers followed by the closing of inefficient plants and production reductions. Also, increased communications between scrap processors and consumers to resolve common issues of concern, such as quality control, the universality of specifications, and delivery services, will help maintain profitability for all concerned.

Recycling a large amount of scrap steel reduces the total energy needed to produce steel. Nevertheless, the steel industry uses about 3% of the energy consumed in the United States and more than 10% of that used by the industrial sector. Energy purchases represent nearly 20% of the total manufacturing cost of steel. Of particular concern is the recent trend toward declining availability of and higher prices for oil, gas, and electricity. To control these significant production costs, the industry will use and promote, as much as possible, new technologies to conserve energy, such as scrap preheating. Scrap preheating may increase threefold in new furnaces owing to energy conservation, shorter cycle times, and reduced operating costs (Steel Times, 2001). Another technology advance is the development of strip casting that reduces energy usage by as much as 50% by casting steel into its final thickness and shape with minimal further hot or cold rolling.

Of immense concern to the scrap and steelmaking industries is the threat of accidental melting of radioactive scrap. Steel mills that receive ferrous scrap have been exposed to radioactive materials without warning. Such accidents can be extraordinarily expensive to steelmakers. The Federal Government recently proposed releasing very low-level radioactive scrap into the recycling stream, an action that is vigorously opposed by the scrap and steelmaking industries. The Metals Industry Recycling Coalition has been trying to persuade the U.S. Department of Energy, the Nuclear Regulatory Agency, and the U.S. Congress to keep any radioactively contaminated scrap out of the commerce stream.

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# APPENDIX—DEFINITIONS

**apparent consumption (AC).** Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

**apparent supply (AS).** Apparent consumption plus consumption of new scrap (CNS).

**dissipative use.** A use in which the metal is dispersed or scattered, such as paints or fertilizer, thus making it exceptionally difficult and costly to recycle.

**home scrap.** Scrap generated as process scrap and consumed in the same plant where generated.

**imports of raw steel double-count adjustment.** Apparent steel supply or consumption is the amount of steel products available within the United States. A unit of imported semifinished steel is reported by American Iron and Steel Institute-reporting companies in imports and shipments that are added together to calculate apparent supply. This unit must be removed from imports to avoid double counting and overestimating apparent consumption.

**new scrap.** Scrap produced during the manufacture of metals and articles for intermediate and ultimate consumption; this includes all defective finished or semifinished articles that must be reworked. Examples of new scrap are borings, castings, clippings, drosses, skims, and turnings. New scrap includes scrap generated at facilities that consume old scrap. Included as new scrap is prompt industrial scrap—scrap obtained form a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap that is generated as process scrap and used in the same plant.

**new-to-old scrap ratio.** New scrap consumption compared with old scrap consumption, measured in weight and expressed in percent of new plus old scrap consumed, for example, 40:60.

**old scrap.** Scrap that includes but is not limited to metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, metals from shredded cars and appliances, silver from photographic materials, spent catalysts, tool bits, and used aluminum beverage cans. This is also referred to as "postconsumer scrap" and may originate from industry or the general public. Expended or obsolete material used dissipatively, such as paints and fertilizer, is not included.

**old scrap generated.** Metal content of products theoretically becoming obsolete in the United States in the year of consideration; this excludes dissipative uses.

**old scrap recycling efficiency.** Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as [consumption of old scrap (COS) + exports of old scrap (OSE)] divided by [old scrap generated (OSG) plus imports of old scrap (OSI), plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks], measured in weight and expressed as a percentage; that is,

$$\frac{\text{COS} + \text{OSE}}{\text{OSG} + \text{OSI} + \text{decrease in OSS or - increase in OSS.}} \text{x100.}$$

**old scrap supply.** Old scrap generated plus old scrap imports plus old scrap stock decrease; that is,

OSG + OSI + OSS decrease.

**old scrap unrecovered.** Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase; that is,

OSS - COS - OSS increase.

**price.** Average 1998 three-city composite price (Chicago, Philadelphia, Pittsburgh) of $108.30, published by American Metal Market, used to calculated values of old scrap consumed and U.S. net scrap exports.

**process losses.** Includes slag, dust, and sludge.

**recycling.** Reclamation of a metal in useable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying (or other base metals) in steel; recovery of antimony in battery lead; recovery of copper in copper sulfate; and even the recovery of a metal where it is not desired, but can be tolerated—such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and/or tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

**recycling rate.** Fraction of the metal apparent supply that is scrap, on annual basis. It is defined as consumption of old scrap plus consumption of new scrap divided by apparent supply, measured in weight and expressed as a percentage; that is,

$$[(COS + CNS)/AS] \times 100.$$

**scrap consumption.** Scrap added to the production flow of a metal or metal product.