The U.S. Copper-base Scrap Industry And Its By-products

An Overview

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PREFACE

The purpose of this report is to provide a brief background on the U.S. copper and copper alloy secondary processing industry. It is felt that policy and decision-makers can use a ready reference on an industry that is generally so little understood. The industry has undergone many changes over the past few decades and has been in decline over much of the last ten years. . While the coverage is not comprehensive, a brief mention is made of the many problems impacting the health of the industry. The secondary industry and the Government agencies most concerned with legislation affecting the collection, processing and markets for scrap are both working to overcome some of the current difficulties. Nevertheless, for some sectors of the secondary copper industry, the past ten years have been particularly difficult, given the restrictions within which they have operated, the potential for new restrictions, and the current copper market.

The author would particularly like to thank those in the industry who were kind enough to host informative visits to their plants and to provide much of the information contained in this report. In particular, Alan Silber of RECAP, who was of tremendous help in outlining the original report. Daniel Edelstein, Copper Specialist with the U.S. Geological Survey, also provided substantial help and advice. The International Copper Study Group, was of great assistance in providing world copper industry statistics. The research for this report was supported by the Copper Development Association. This tenth edition presents updated data tables and observations made since the first report was written in 1999.

ABOUT THE AUTHOR

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EXECUTIVE SUMMARY

The worldwide industrial recession, which began suddenly in 2008, continued through late 2009. The economy was somewhat improved through much of 2010. While metal prices and the stock market recovered gradually from late 2009 onward, U.S. industrial activity generally lagged over much of the period. Meanwhile, electrolytic refineries. Of the four secondary smelting and two electrolytic refining firms operating in 1996, none remained after 2001. Fire refining, which requires a better grade of scrap, held its own through much of the period, but was also affected by occasional cutbacks and closings. Plant closings also occurred in the ingot-making and foundry sectors of the industry. Without a basic domestic secondary-processing infrastructure, more valuable metals likely will reach the landfill as the most reasonable remaining choice. Export is always possible for the higher grades of scrap, but the lower-grade copper by-products, which might be traded domestically, could become less marketable.

The significant competition by foreign nations for quality domestic scrap over the past 10 years negatively impacted U.S. scrap dealers, scrap processors and users alike. A temporary drop in U.S. scrap exports in 2005 probably was partially owing to the threat from a short supply petition made to the U.S. Government in early 2004 as well as a move by the Chinese Government to tighten control on certain metal imports. Although the U.S. Government turned down the industry petition for control and monitoring of scrap exports, the U.S. scrap availability situation had improved by year's end 2004 for a short period. Some U.S. wire choppers reported significant pickup in activity and a return to profitability. However, by 2006, U.S. scrap exports continued at a high pace through 2007 and most of 2008, and were more than double the export rate of 1999. A record of about 965,000 tons of copper and copper alloy scrap was exported from the United States in 2010.

U.S. scrap processors and their U.S. customers (brass mills, ingot makers and foundries) remained at a critical point through 2010. Scrap supplies through 2006 - 2009 remained tight and some qualities (such as auto radiators) were difficult to obtain. Price spreads varied, but owing to higher processing costs (labor, environmental, energy and taxes), and high competitive scrap exports, domestic markets remained difficult. Tight scrap supplies were driving prices over much of this period. China, South Korea and India continued to be large importers of U.S. and European scrap.

During the U.S. industrial recovery of the 1988 to 1999 period, refined copper consumption in the United States increased to nearly 3 million tons. Copper industrial consumption increased by about 10.4% between 1994 and 2000. The reader is referred to **Figure** 14, in **Appendix A** of this report for a graphic illustration of U.S. copper consumption over time. By 2003, U.S. refined consumption decreased to around 2.3 million tons, recovering modestly to around 2.4 million tons in 2004. By 2007, copper consumption was down again to nearly 2.1 million tons. It is also worth noting that in 2006, the United States imported record amounts of refined copper, reaching nearly 1.1 million tons. These record imports were a continuing sign of a growing and higher U.S. import reliance. The U.S. import reliance reached nearly 40% in 2006, compared with only 2% in 1993.

The decrease in domestic copper consumption was the result of a struggling brass and wire mill industry. Semi fabricate (tube, sheet, strip, rod etc) production suffered as facilities closed. U.S. production of semi fabricates at brass and tube mills decreased from 3.9 million tons in 1999 to around 2.9 million tons in 2007. Two main factors contributed to tubing company demise: increasing use of plastic pipes for construction applications and increased imports of copper and aluminum tubing from China, Mexico and other countries. Further evidence of the industry contraction is illustrated by the fact that an estimated 16 brass mill plants and facilities closed in the United States over this period. This contraction occurred despite the fact that the United States since 2001 was undergoing a tremendous housing boom and supporting a foreign war, both large consuming activities for copper products. A total of 695,000 manufacturing jobs have been lost from the primary metals and fabricated metal products sectors since 2000 (Bureau of Labor Statistics).

While the United States copper industry was shrinking, world refined copper consumption increased by over 26% to more than 18 million tons by 2008, a growth rate of about 2.6% per year owing to increased growth in other countries. Despite higher secondary (scrap) exports and lower copper consumption, the United States remained a leading consumer of copper from copper-based scrap with 11% of the world's total in 2010. In 2010, the United States consumed about 2.4 million tons of copper from scrap and primary sources, including about 814,000 tons from refined and direct melt scrap.

While copper recovered from new, manufacturing scrap sources has been increasing in the United States, copper recovered and consumed by industry from *old*, used product scrap sources has been decreasing. Copper recovered, and consumed by the U.S. industry from old scrap was as high as 613,000 tons in 1980, but was only 143,000 tons in 2008. However, if net scrap exports (646,000 tons in 2008) are classified as old scrap and are included in an estimate for all *old* scrap recovered, the potential amount of copper in old scrap collected in 2008 was about 790,000 tons (old scrap plus net exports). This much higher value implies that the rate of old scrap copper recovered from the U. S. end-use reservoir has not really diminished, as otherwise might be indicated by reported domestic U.S. scrap consumption data.

World trade (imports) in copper-base scrap nearly tripled between 1989 and 2009, largely in response to the increased industrial growth in the Far East and Europe. Asia and Middle Eastern countries received about 75% of world copper scrap imports in 2009. The United States continued to be the largest exporter of copper scrap in the world, exporting 20% of the world's total copper-base scrap exports in 2010. Exports of scrap from the United States were over 900,000 tons per year in 2007, 2008 and 2010. The Middle East and Asia region used an estimated 54% of world copper recovered from scrap in 2010. China has become the largest copper scrap-consuming nation in the world.

In 2005, China's economy expanded by 9.9% over that of 2004, and this rapid growth continued through early 2008. To support its rapidly expanding economy, copper and copper alloy scrap imports by China reached a record peak of 5.6 million tons in 2008. China was the largest importer of copper-base scrap in 2008, with an estimated 68% of world copper scrap imports of 8.2 million tons.

In response to environmental concerns, China implemented import controls for scrapped electronics and the lower grades of copper scrap in 2002. Even so, China reduced its import duty on copper scrap in 2006 to promote the development of the metal recycling industry and to help shortages in the nonferrous metals sector, in general. China, a member of the World Trade Organization (WTO), has been accused by the European scrap processors of assisting its domestic companies through tax subsidies, credit facilities and other protectionist benefits that cause harm to the European scrap metal recycling industry.

Trade restraints on scrap, such as import quotas, export licenses, price controls and other mechanisms have been used many times over the past 30 to 40 years in the United States and other countries. These have been applied mainly during times of national emergency and supply shortage. The entire U.S. secondary copper processing industry was treated as a critical and strategic industry during these tight supply periods, such as during WWII and the Vietnam War. However, the United States has had no trade restrictions on copper-base scrap since 1970. All of the remaining copper in the National Defense Stockpile was sold in 1993. In April 7, 2004, the U.S. copper consuming industries filed a short supply petition under the Export Administration Act, requesting imposition of monitors and controls on the export of copper-based scrap. The U.S. Government turned down the petition later in the year.

The U.S. secondary copper processing industry currently consists of 5 fire-refiners, 23 ingot makers, 44 primary brass mills, 12 wire-rod mills and about 500 foundries, chemical plants and other manufacturers. Wire rod mills do not consume much scrap directly. Most of the chemical plants are hydrometallurgical plants that have created businesses based on using secondary by-products produced by other metal production and metal finishing. Many copper chemicals, such as cupric oxide, copper sulfate and others are produced from scrap in the United States. Some chemicals are also produced from the fluid streams of primary copper refiners. While one chemical plant closed in Texas during 2005, another opened in Arizona, associated with a primary producer. Two ingot makers have closed since 2003, as have an estimated 16 brass and tube mills. One wire rod mill closed in 2008.

The EU-15 as a group of countries is the largest ingot-producing entity in the world. However, the United States (28%), followed by Italy, Japan, and Germany, is the world's leading ingot-making country, providing the domestic foundry and brass mill industries with special alloys for casting and milling. Ingot-making, in particular, is a very scrap intensive industry, using mostly scrap as its raw material. Even so, the brass mill industry (76% of 2008 copper-base scrap consumption) consumes most of the copper-base scrap recycled in the United States. Some copper tube and wire rod mills have had secondary smelters or refineries associated with them because of their requirement for high-purity copper. Unfortunately, most of these secondary smelting and refining facilities have closed, owing to a poor economic environment for processing scrap and, at times, the easy availability of low-priced primary refined copper.

In 2008, recycled copper consumed in the United States was derived 82% from purchased new scrap generated in the process of manufacture and 18% from old scrap derived from used products. According to the U.S. Geological Survey, purchased new copper-base scrap yielded about 697,000 tons of contained copper in 2008, 84% of which was consumed at primary brass, tube, and wire rod mills. A manufacturer may generate up to 60% scrap in the form of slippings, trimmings, stampings, borings and turnings during the manufacture of finished articles. This new, or mill-return, scrap is readily used by the industry in making new semi fabricated products. A secondary material becomes "purchased" scrap when it is traded or otherwise sent to market. Home scrap, or runaround scrap, is used in-house, not marketed and not counted in consumption statistics.

In addition to the better known classes of purchased scrap, there is a smaller group of lower-grade, copper-base scrap known generally as *low-grade ashes and residues*, or as *secondary by-products*. By current definition, these materials are comprised of copper-bearing ashes, residues, drosses, skimmings, dusts, slags and other materials containing less than 65% copper, and are derived as by-products of other copper-base metal processing. According to the U.S. Geological Survey, which has long tracked the purchased scrap market for this material, only 23,300 tons of low-grade ashes and residues was purchased and consumed domestically for its metal content in 2008. This is down considerably from the 300,000 tons to 500,000 tons that was marketed in the 1970s. The downturn in domestic consumption of this material coincides with cutbacks in the domestic smelter industry, the decrease in use of reverberatory furnaces by the copper industry, and the closure of secondary smelters and ingot makers.

Though most firms prefer to ship high-grade slags and skimmings (up to 65% copper) to other domestic or foreign firms for further processing, about 28% of the slag and skimming by-products produced are processed in the plant of origin. In addition, pickling solutions may also be reprocessed in house to produce copper cathode. A significant proportion of these higher-grade products is exported to Canada or Mexico as a result of decreased U.S. processing capacity.

In addition to the copper-bearing ashes and residues, the copper-base secondary industry also produces significant quantities of zinc oxide as a by-product of its metal processing. The USGS estimates that about 30% of the world's zinc is produced from secondary materials, some of which is from the flue dust collected during copper alloy processing. While some of the production is suitable for direct use as animal feed and agricultural products, most is sent to zinc smelters and processors for treatment and zinc recovery. Only the poorest grades are landfilled.

Spent furnace linings used in pyrometallurgical copper and copper alloy processing are also by-products that sometimes have further value. The type of lining used varies from chrome-magnesite brick to various types of ceramic-like materials that are applied like cement. While some spent linings are recycled for their metal content or used for concrete and other construction material, some end up in the landfill. Spent furnace brick containing appreciable cadmium or lead are shipped as hazardous material. All products sent to landfill must pass the USEPA hazardous material test, the Toxicity Characteristic Leaching Procedure (TCLP).

The TCLP has been challenged in court in recent years for its inherent difficulties in predicting all disposal situations. The TCLP was not intended to be representative of in situ field conditions, but rather of a generic municipal solid waste (MSW) landfill worst-case scenario. In February 1999, the Science Advisory Board's Environmental Engineering Committee (EEC) called for the need to review and improve EPA's current leach ability testing procedure. The U.S. mining industry and others have also challenged the applicability of the TCLP based on the physical and chemical differences between municipal waste sites and those used for large volume mine wastes, among other uses.

Many problems have been derived from the application of CERCLA (the Superfund Law), passed in 1980; and, RCRA (the Resource Conservation and Recovery Act), passed in 1976. Most problems stem from the reporting, permitting, and other paperwork requirements, as well as from the legal liabilities stemming from application of these laws. For example, liability concerns have been enormous barriers to *brownfield* cleanup technologies. A brownfield is a site, or portion thereof, that has actual or perceived contamination and an active potential for redevelopment or reuse. Because financial institutions can be liable for cleanup costs when they acquire the properties through default, they are unwilling to provide loans for development. Problems also emanate from the potential responsible party (PRP) aspects of CERCLA. The potential here is to be named liable for expensive cleanup solely because you may have done business with a firm named as a Superfund site. This approach to Superfund financing has caused businesses to think twice about shipping materials to certain firms.

In addition, restrictions on shipping products have increased. Once a product is classified as hazardous and/or is controlled as to market, handling and shipping, costs rise. Higher costs have resulted from rulings that dictate how much can be stored in one place or another, what must be classified as hazardous, who may receive the material, and what procedures must be followed through the entire production and marketing process. The permitting procedures and handling restrictions have not only added to the costs of shipping, but have also reduced the potential for by-product sale to other processors. Further tightening of regulations through reclassification of secondary products currently traded will result in higher costs and more products sent directly to the landfill.

Those firms that can have opted to invest money in becoming more internalized with increased in-house treatment of products. Many have adopted unique cost-saving devices and policies. Some also are instituting formalized, self-policing management systems to improve their processes and products, via the ISO 9000 and ISO 14000 standards. Some parts of the government are also taking a harder look at the regulations that affect the smooth marketing of products and, in particular, the development of brownfield sites. Nevertheless, the current economic situation continues to look more difficult for some parts of the secondary copper industry. This segment of the economy seems to be laboring under significant stress, caused in part by changing and more stringent government regulations.

Problems on the horizon include the safe collection and processing of junked electronics equipment and the potential for renewed recycling of radioactive metal from dismantled U.S. nuclear plants. U.S. scrap handlers and processors have been adapting rapidly to handle the increased recycling of electronics scrap. At the same time, however, adequate provision for facilities to handle the relatively small amount of radioactive copper scrap expected from dismantled nuclear facilities remains a problem to be solved in the future. More recently, additional charges to be levied through the carbon capture program associated with the so-called Global Warming efforts by the U.S. Government could deal a severe blow to the industry.

How much copper has been recovered for reuse in the United States over time? Recent calculations indicate that since 1864, more than 64% of all primary copper consumed in the United States has been returned and reused as scrap. Since 1864, based on reported U.S. data, cumulative primary refined copper consumed in the United States amounted to 129 million tons by 2009. From this source, a cumulative 44.4 million tons (52%) of copper from old end-use scrap has been returned for consumption by the industry through 2009. This leaves an estimated 48% remaining in use or recirculating as new manufacturing scrap. The latter percentage includes a very small amount known to have been dissipated through use as copper chemicals. It is not known how much may have been irretrievably dispensed with or thrown away, but it is suspected that this is small and may be only about 5% and no more than 15% of the total measured consumption.

The domestic copper scrap industry faces some difficult times in 2010. Not only can a continuing difficult economic environment be expected as a result of a potentially prolonged recession, but the underlying negative factors impacting the industry's competitiveness also will continue. The sharp drop in copper demand that occurred after September 2008 continued through mid-2009. While copper prices and Chinese demand have recovered, domestic copper demand has been slower to respond. As a result of the lower price in early 2009 and the slowing industrial economy, scrap supplies also were lower. Though lower energy costs may exist temporarily, higher taxes, labor costs, unfair trade rules and new environmental costs can be expected to be onerous. Under the misguided notion of changing the planet's climate, the U.S. government, through either the Clean Air Act, or new legislation, has the potential to levy onerous regulations on the industry for the control of carbon and carbon gas emissions. This might be viewed as the "nail" in the coffin. Without a considerable change in Government attitude toward industry and the economic environment, the outlook will continue to be poor. Foreign competition for the scarce scrap supplies also can be expected to continue.

CHAPTER 1: Industry Perspectives

Global Industry Perspective

World Copper Consumption and Production. Copper ranks third in the world consumption of metals, after iron and aluminum. According to the International Copper Study Group (ICSG), refined copper consumption was 18.8 million tons in 2010, up from 16.7 million tons achieved in 2005. Following the abrupt financial adjustments that rippled through the world beginning in August, 2008, industrial copper consumption was curtailed significantly during 2008 and most of 2009. Compared with the previous year, copper consumption was down by around 200,000 tons during 2008 alone. World copper consumption remained at near the 2008 level (18 million tons) during 2009, but showed significant improvement in 2010. China, in particular, continued to show robust growth in copper consumption while most of the rest of the world languished, despite widespread efforts by various governments to jump start their economies. U.S. consumption of industrial copper remained less than stellar over all of the period 2008-2010.

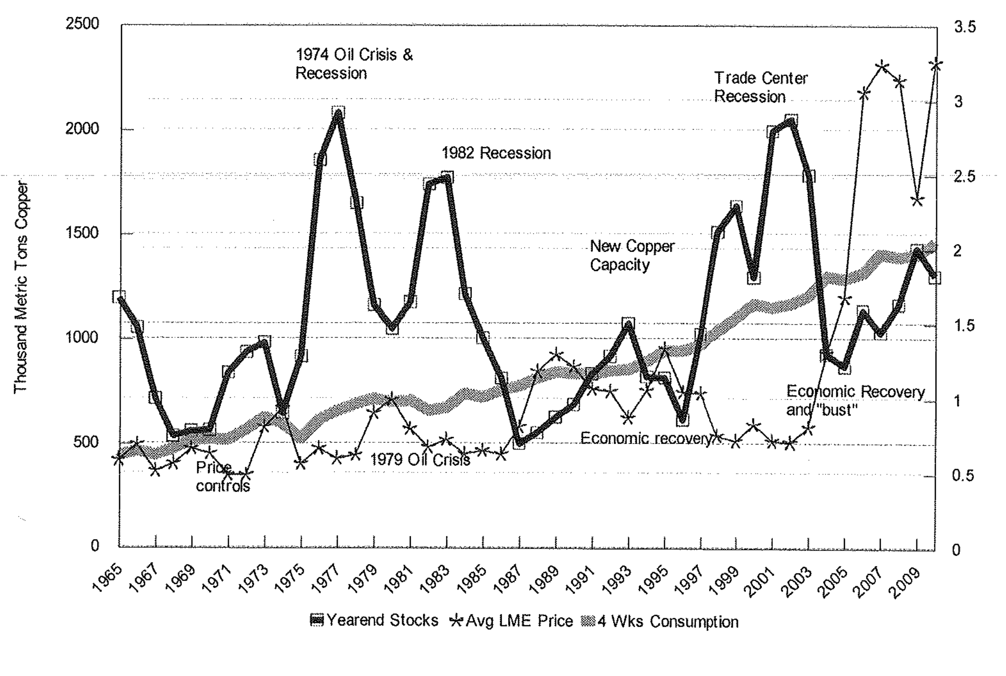
The major refined copper consuming nations of the world in 2009, were: China with 7.2 million tons (39%), United States 1.6 million tons (8.9%), Japan, 875 thousand tons (4.8%), Germany, 1.1 million tons (6.2%) and South Korea, 901,000 tons (5%). Copper usage in China for 2009 was 45% higher than that of 2007. China consumed 27% of total world copper in 2007. The increased Chinese growth in industrial copper was reportedly owing to stockpiling as well as to new domestic growth, and largely supported by government policy. In 2009, substantial parts of China's stimulus package were targeted at infrastructure. Metal intensive products were also helped by policy measures. The end result was that China's demand since 2008 has helped to pick up the "slack" for reduced demand in most of the rest of the world.

China's refined production was 4.1 million tons in 2009 up about 8.3% from 3.8 million tons of copper produced in 2008. China maintained a position of leading refined copper producer, exceeding that of Chile (3.3 million tons). However, about 34% of China's refined production is from scrap, whereas all of Chile's refined production is from primary sources. China continued to be the leading world importer of copper concentrates and scrap. About one-third of China's domestic scrap consumption is derived domestically, the rest is imported.

In this report, 2010 production and trade estimates on the data tables were made for the convenience of the interested reader. These current year estimates, for

Figure 1. World Copper Inventory Trends

Copper Consumption Rates and Prices



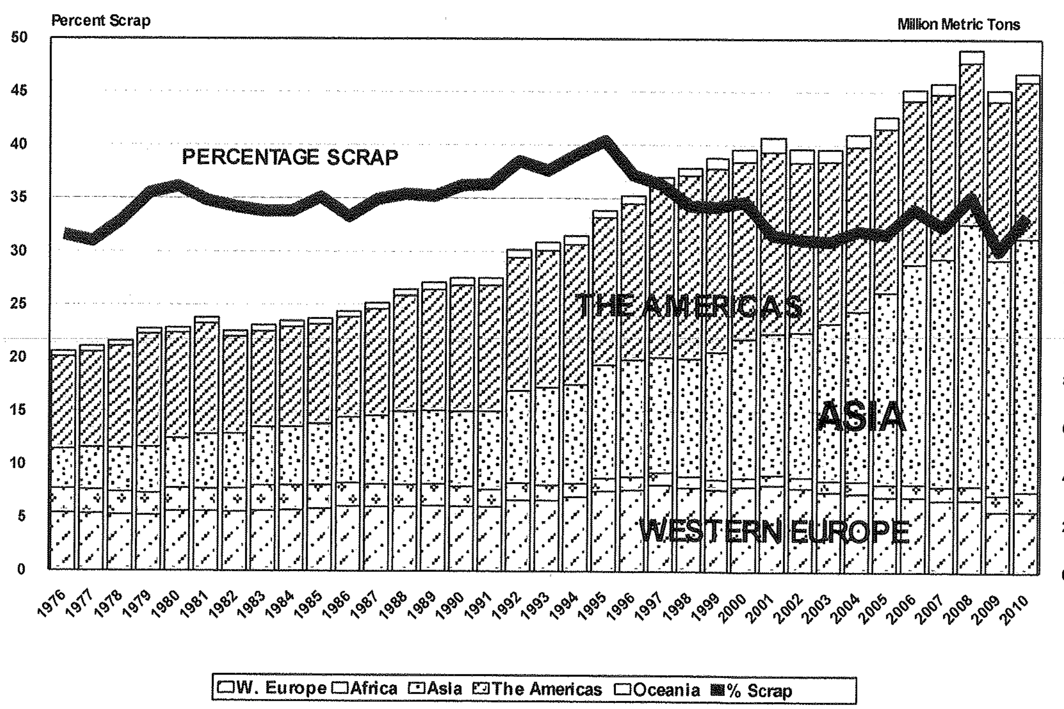
the most part, were based on 8 to 10 months of reported data. The previous (2009) year's estimates are revised to a provisional status based on published data now available by the reporting agencies. In recent years, mineral and secondary industries data from the critical Minerals Information group of the U.S. Geological Survey has been severely impacted by a lack of government funding and contraction of available staff. As a consequence, public data delivery has continued to suffer. Not many in the public realize that this organization (previously part of the Bureau of Mines) is the backbone to U.S. scrap data collection, which it has been collecting for over 100 years. The minerals information community would otherwise be much more concerned. As a consequence, the data presented in this report contains more estimates than would otherwise be the case. The 2008 scrap data reported was the data found in the 2008 Minerals Yearbook, which still contained significant estimates. No final yearbook tables for 2009 and no detailed scrap data for 2010 were available at the time of this report writing since some significant scrap tables have been removed from the monthly Mineral Industry Survey reports.

Following several years of soft demand and high inventories on the LME , Comex and SHME, copper inventories reached new lows by late 2004 (see trends on **Figure 1**). At the end of 2005, world inventories, according to the ICSG were only 867,000 tons and about 32% less than that required for one month's world consumption. Despite efforts by the major copper producers to bring mines back on stream during 2005 and to increase production, shortages persisted through much of 2006-2008. Copper prices exhibited marked increases during this period. Labor strikes, lower ore grades and other production problems seemed to plague the industry. Production and consumption appeared to be more in balance by year-end 2006, and inventories decreased slightly through mid- 2008. Except for the last 4 months of 2008, prices remained mostly above $3 per pound, averaging $3.15 for the year. While copper hit its LME price bottom in December 2008, it steadily gained from February 2009 to average $ 2.34 per pound for 2009. Copper prices were significantly higher during 2010, exceeding $4 per pound for brief episodes, and averaging about $3.35 per pound for the year.

By January 2009. the LME price had retreated to a low of $1.46 per pound. Inventories had increased to a world total of about 1.161 million tons on the exchanges at yearend 2008 (ICSG, Oct. 2010). By July 2010, total inventories held by the exchanges, producers and consumers had increased only slightly

Figure 2: World Copper Recovery from All Sources[1/]

And Percent Copper from Scrap, 1976-2010



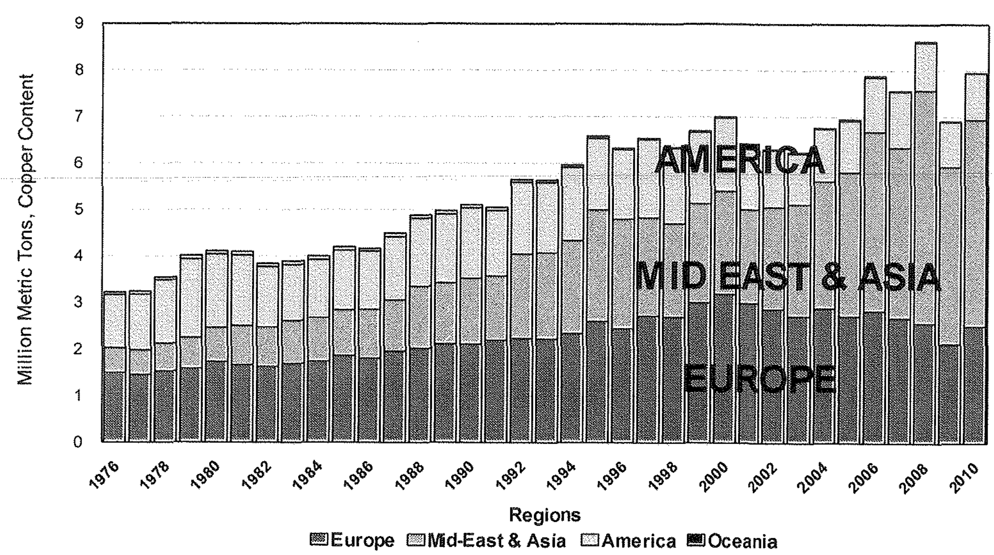
1/ Includes copper in primary and secondary refined production and estimates for direct melt scrap consumption.
Data Sources: ICSG and USGS reports. See Table 2A, this report.

to about 1.297million tons. To put this in perspective, this inventory level is less than the 1.6 million tons that is estimated to represent one month's copper consumption for the world. As a result of the continued pressure on supplies, the average LME price for refined copper continued to be in the mid-$3 range through most of 2010, reaching a lofty peak of $4.45 per pound by yearend. The weaker dollar and the pressure of Chinese buying were largely responsible for the rise in prices. However, it was revealed late in 2010 that a brokerage firm, JP Morgan, had purchased nearly 90% of the copper inventories on the LME, ostensibly to establish a new copper exchanged-traded-fund (ETF). No doubt, this speculative activity also influenced the late 2010 price spike.

Scrap collection and use tends to be very price dependent. World copper prices steadily decreased 1997 through 2003, as a result of the more than adequate world supply of copper (see **Table 1**). During this period, copper prices reached low levels not seen since the recession years of the early 1980's. Since lower prices tend to prompt a decrease in the supply of copper scrap, the use of copper scrap as a component of world refined copper also decreased from 16% in 1996 to about 12% in 2003. World production of refined copper from scrap increased along with the higher prices that dominated the period 2004-2008. According to the ICSG, refined copper from scrap comprised about 15% of total world refined copper production 2004 through 2008, reaching 18% in 2009 and 20% in mid-2010.

A reasonable spread in price also must be present between the current refined copper price and that for purchased scrap in order for processing to be profitable. The price spreads between No. 2 scrap and refined copper are lower or higher in coincidence to the decreasing or increasing refined copper price in recent years. For example, the price spread (between COMEX High Grade, first position and Refiners buying price for number 2 scrap) in the United States was as high as 31 cents in 1995, but ranged between 11 and 22 cents per pound over the 1996-2004 period. The price spread for these years was lower than the 12-17 cent spread experienced during the recession years of 1983-1987. The price spreads increased again between 2004 to 2007 in tandem with the higher copper price. With increasingly stringent environmental regulations and requirements, the costs to process scrap at all levels, from low-grade scrap to pure metal scrap have escalated. The drastic cost squeeze during the poor pricing period (1998-2002) prompted U.S. secondary processors to rethink business methods and in fact, some opted to get out of the business. It is encouraging to note that the estimated average price spreads were 21 cents in 2004 , more than 31 cents in 2005, 48 cents in 2006, and as high as 34 cents in 2008.

Figure 3: World Consumption of Copper from Direct Melt and Refined Scrap, by Region, 1976-2010



Note: Europe includes Eastern Europe and Russia. America represents both North and South America countries.
Sources: International Copper Study Group and USGS. See Table 2D, this report.

When the producers price is used in calculating the spreads, it adds an extra 4 cents to 5 cents per pound for shipping and insurance. This is the delivered price. If the COMEX price is used for the comparisons, the spreads are more narrow. Refer to the scrap and refined prices shown in **Table 1** for a complete series and comparisons. During 2009, variability in scrap prices were generally credited to Chinese buying and lower U.S. scrap generation, and not to increased domestic demand.

World copper recovered from all forms of scrap (refined and direct melt, **Table 2D**) decreased slightly to about 6.7 million tons in 2009, but was up sharply to an estimated 7.7 million in 2010. In a word of caution, the actual amount of copper from direct melt scrap may be underestimated, since these data (with a only a few exceptions) are based largely on known (and estimated) semi fabricate production in a particular country. No amount of scrap that might be properly classified as "home scrap", or that is lost in the production process, is added to the direct melt scrap presumed to be part of the end product. The general formula is comprised of total semi fabricate production less amount of refined copper consumed. The copper content of direct melt scrap is based on percentages ranging between 75% and 90% of the total, dependent upon type of products produced (i.e., brass mill or copper rod mill etc). The average copper content is about 80% of total gross weight direct melt scrap estimated. The United States reports actual numbers for types of scrap consumed, but is unusual among nations reporting scrap data. The U.S. Geological Survey is currently the scrap data collection and reporting agency for the U.S. Government. Prior to 1995, this was done by the U.S. Bureau of Mines for over 100 years. Funding and staffing problems have plagued the Minerals Information group since the transfer.

In 2010, the ICSG published its first edition of Global Recyclables Survey. The data covered by this report extends through 2008. The survey indicated a decrease in global copper scrap use in 2008, owing to a decrease in use of direct melt scrap. The fall off in direct melt usage in 2008 reflected, in part, falling overall semis production in the major semis producing countries, including the United States, Japan, Germany, Italy, Taiwan, the Korea Republic, France and others. (ICSG, 2010 Annual Global Recyclables Survey, 9 p.)

Copper recovered from all scrap, as a percent of total world copper produced, has ranged between the low of 30% in 2009 to as high as 40% during 1995, as shown on **Table 2A** and in **Figure 2**. The current rate of recovery (2006 and 2008) is estimated to be 34% and 35%, respectively. The percentage of scrap used by the world, relative to primary copper, was noticeably lower after 1996. This trend shows a striking parallel to a downward trend in prices between 1996 and 2003 (see **Table 1**). This was also a period of surplus primary copper production. Periods of low scrap recovery, such as those in 1975-1978, 1983-1984, and again in 2001-2003, coincide with low copper prices and surplus copper supplies. Scrap supplies also slowed in late 2008 when copper prices dropped precipitously, and continued well into 2010.

Scrap consumption in Asia has seen a remarkable increase since the early 1980's. As a group, the Middle East and Asian countries account for about 58% of world copper recovered from scrap in 2010(see **Table 2D**). Consumption of copper from scrap in Asia grew from about 723,000 tons in 1980 to 2.4 million tons in 1995-1996. Following a short industrial contraction in 1997-1998, the region experienced an 8% drop to about 2 million tons of copper in scrap. However, by 2008, Asia and the Middle East scrap consumption had recovered to 5 million tons of copper per year, largely through the continued insatiable growth of Mainland China. China, with an estimated 45% of world copper recovered from all scrap in 2008, has become the largest copper scrap-consuming nation in the world.

The Chinese Government in its 11th Five-Year Plan (2006-2010) was encouraging the greater use of scrap metals to help alleviate a shortfall in supplies. The target consumption of secondary copper was 35% of the total national copper consumption, an increase of about 14% (Peoples Daily Online, 2007). China's 12th Five-Year Plan, beginning in 2011 was to target an increased electrical grid, calling for more copper. China has steadily increased copper in scrap consumed from around 100,000 tons in 1980 to over 3 million tons per year in 2008. Chinese copper scrap imports (gross weight) reached 5.6 million tons in 2008 (see Table 4), but dropped down to 4 million tons per year in 2009 and 2010. Other major copper scrap consuming nations for 2008 in the Middle East and Asian country group (as a percent of total world scrap) include Japan (7%), South Korea (4%)and India (1%). The Western European countries account for 21% and **(See Table 2D)** and the countries of North and South America accounted for 12% of world copper recovered from all scrap in 2008. Germany, Italy, France and the United Kingdom are the leading consumers of copper scrap in Western Europe. The United States (10% of world total) is the major copper scrap consuming country of the America group shown in **Table 2D** and **Figure 3**. The Americas (12%) are the third largest copper scrap-consuming region, after Western Europe and Asia. The Oceania and Africa countries are minor scrap consumers.

World Trade in Copper Scrap. The United States (17% of world copper-base scrap exports in 2009) is the largest exporter of copper scrap in the world. U.S. exports of scrap have increased by 93% since 2000. Access to raw materials such as scrap remains critically important for all U.S. manufacturing industries. Since 1999, export trade barriers have increased around the world and have been enacted by countries such as China, Russia, Ukraine and India. These include export bans, export taxes and quotas, export licensing restrictions and currency valuations. Many of these trade barriers are in violation to World Trade Organization agreements, and all of them adversely impact U.S. manufacturers as well as the general global economy (2008, Wiley Rein LLP, Wash. D. C.). In a move contrary to U.S. government efforts in recent years, the U.S. International Trade Commission (ITC) voted unanimously that the U.S. steel industry had been materially injured or threatened with injury by imports of certain tubular (steel pipe) goods from China (Recycling Today, 12/30/2009). Some in other similarly impacted industries viewed this action as hope for a change in US government attitude.

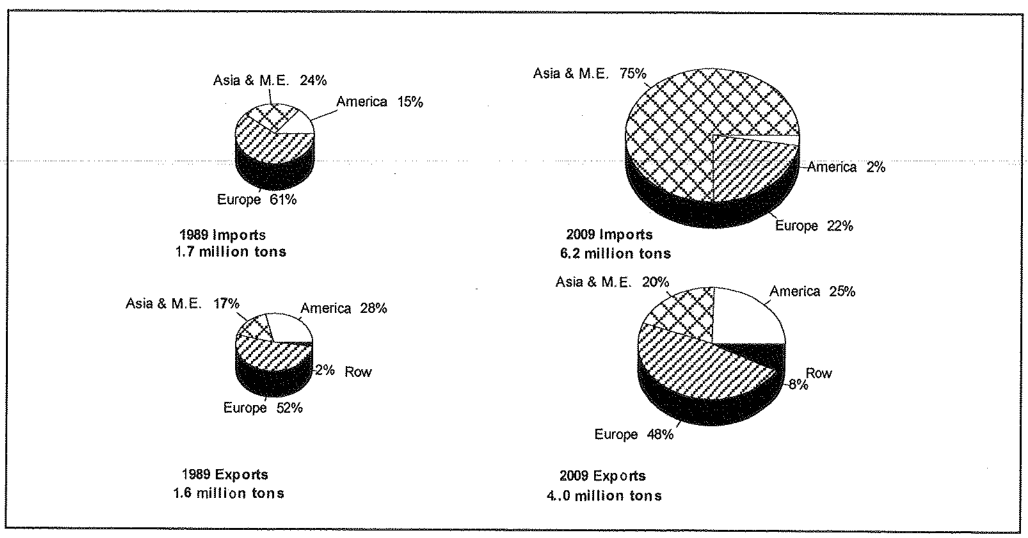
Export duties caused Russia's export of copper scrap to slow to a trickle after 1999. Since that time, Russia restricted the export of raw materials from its territory by maintaining onerous export duties and an unpredictable customs service. Such barriers serve to protect Russia's manufacturers by artificially inflating supply and depressing domestic prices for raw materials and other inputs. Russia's exports of copper base scrap increased 3-fold between 1993 and 1998 to around 357,000 tons, but since 1999 have dropped sharply to about 1,300 tons per year in 2009.

Japan (7.3%), Germany (9%), United Kingdom (8.7%), France (4.6%), Belgium (2.2%), Canada (3%), and Hong Kong (1.4%), are also major exporters of copper-base scrap, as shown in **Table 3**. Since 1999, exports of copper-based scrap increased significantly from Japan, from around 84,000 tons in 1999 to about 425,000 tons for 2007, but have decreased since then to at an estimated 288,000 tons in 2010. World imports of copper-base scrap, as shown in **Figure 4**, in increased by 265% between the years 1989-2009, in response to the significant industrial growth of the Far East and Europe. The Asia & Middle East region is the largest recipient for both the United States and World scrap exports. This region received some 75% of total world imports in 2009 and In 1989, Asia accounted for only a 24% share. Europe (61%), had a higher share of the world's imports of scrap in 1989. In 2009, as shown in **Figure 4**, Europe (West and East Europe) accounted for only 22% of global scrap imports. The countries in the Americas (North and South America) have seen their share of world scrap imports diminish from 15% (1989) to around 2% (2009) over this period.

Of all countries, China has had the most significant growth in scrap imports over the period 2001 through 2010, as shown in **Table 4.** Although Mainland China apparently suffered a marked collapse in amount of scrap imported in 1996 and 1997 owing to import

Figure 4. Trade in Copper and Copper Alloy Scrap

by World Region, 1989 and 2009



Source: International Copper Study Group restrictions, copper base scrap imports were again higher by 1998. By 2001, China's imports of copper-based scrap was 4-times that of 1996. By 2007, Chinese imports were 67% higher than that of 2001. South Korea, Taiwan, Hong Kong, Japan and India also have been significant importers of copper base scrap in recent years.

By early 2001, the availability of copper scrap was reported as especially tight in the United States, owing to low prices and the higher exports to the Far East. Birch/cliff and berry/candy grades were in particular demand. This difficult situation coincided with the closure of the last secondary copper smelter in the United States in 2001. Since that time, China has emerged as the major outlet for U. S. exports of No. 2 scrap and mixed grades of alloyed scrap, in particular. Supplies of scrap in 2009 and 2010 continued to be very tight in the United States as a result of lower prices in 2009 and a drop-off in manufacturing-based new return scrap.. With the precipitous drop in copper prices in 2008-2009, a cutback of copper demand from China and equally abrupt cancellation of several contracts, U.S. copper scrap exports slowed to a trickle through early 2009. Supplies to U.S. metal traders essentially dried up while the prices were trying to stabilize. In late 2008 and early 2009, some dealers were stuck suddenly with supplies for which they had paid much higher prices than the current buying market. By yearend 2009, however, owing to higher prices, dealers reported that orders had picked up, but there still wasn't much excess material available, but China was again active in the market.. Along with a shortage of scrap generation during 2009, container availability also was a problem for some overseas shippers. By the spring of 2010, higher prices prompted more scrap to come out of the system. Copper rose to about $3.50 in April. Domestic brass and bronze ingot makers were buying on a more limited basis from regular suppliers. Even so, mid-2010 saw another slowdown as Europe entered its slow season and margins were being squeezed with difficult pricing.

In Europe, exports of copper scrap to the Far East also increased dramatically between 1999 and 2008. This occurred at a time of lower local scrap availability in the European Union (EU), creating problems for European refiners. Some in Europe, as well as in the United States, felt that unfair customs regulations, and lower labor and environmental costs had enabled the Asian countries to pay higher prices for scrap over this period.

Owing to decreased manufacturing levels and other problems, scrap exports from Europe dropped off during 2009. The brass and copper industry in Italy was reported as operating at 60% of capacity (Recycling Today, Dec. 2009). Italy, normally a large importer of copper scrap, in 2009 imported only 54% of the 167,000 tons of scrap imported in 2008 (see **Table 4**). Some recovery was indicated by preliminary 2010 data, but Italian imports were still low. By September 2010, half the brass industry in Italy had been closed and half were sitting idly by (Recycling Today, Sept/Oct 2010).

In recent years, the United States has increased its domestic collection and processing of electronic scrap, but U.S. export of low-grade copper scrap derived from electronic products such as computers remained an issue of concern. Even though China was tightening its rules for importing electronics scrap, other poor countries may still be willing to accept these materials. According to some reports (Recycling Today, Feb. 2002), Pakistan had become a bigger market for electronic scrap and used computers. China reportedly applied import restrictions on electronic scrap and in May 2002 instituted a substantial tariff on class 7 scrap. This class includes lower grades of copper scrap such as unprocessed wire and die cast alloyed parts. The tariff may have also been enacted to force the domestic smelting industry to use higher grades of scrap as a pollution reduction measure. China continued to tighten regulations and began in November 2004 to ban all used television sets and other electronic scrap imports in a bid to clean up its environment.

China reportedly reduced the import duty on copper scrap in 2006 and 2007 to promote growth in the metal recycling industry and assist the nonferrous metal sector in its need for raw materials. China reduced the import tariff for copper scrap from 1.5% to 0% in mid-July 2007 (ISRI Friday Report, July 20, 2007). In late 2007, China announced that it would remove import duties on refined copper. The 3% import tax for refined copper was cut on Jan. 1, 2008 (12/28/07, www.recycleinme.com). In mid-November 2005, China also signed the first East Asian trade agreement with Chile (an major source of primary copper) as an important bilateral trading partner.

To maintain adequate supply for the home market, the Chinese Government applied strict controls on the export of copper-based products. In November 2006, the export tax rebate on copper products was cut to 5% from 13% and the export tariff on copper concentrates increased to 10%. Meanwhile, export tariffs on copper scrap, blister copper and electrolytic (refined) copper were also raised. The Chinese Government levied an export tax on nonferrous scrap at 10% from June 1, 2007 (Recycling Today, May, 2007). In September 2007, a huge back up of containers filled with scrap was reported, caused by a crackdown on importers trying to avoid complying with the new duties for scrap. Two months previously, Chinese customs officers launched a major offensive against importers, who had been trying to avoid complying with new duties. There also had been a widespread practice among many Chinese importers of mixing lower content scrap with higher purity material to avoid paying higher taxes. Duties are applied to the copper content, so a reduced copper content means lower duty. Another problem area is "mixed" loads of scrap where the high value copper is loaded in front of the container and lower grade scrap is loaded in back.

In mid-summer, 2009, a slowdown in customs clearance in Guangzhou, China was reported as having a big effect on domestic importers of copper scrap. A large number of containers were stranded at the ports. The number of containers were reported as exceeding 2,000 at each port (Recycling Today, Aug. 2009). The government was introducing new procedures to standardize and improve imports of metal scrap. Inspection was intensified to prevent violations of price deception, lower bidding and omission of proper reporting. In October, 2010, China for the first time in 3 years raised interest rates, reducing loan volume by an estimated 22$. China felt a strong economy was becoming inflationary. This caused a slight correction in metal prices, but the upward trend was still in tact.

In 2010, China published Notice 32, which required separate packaging of different materials. In addition, China's General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) registration process was defined for overseas suppliers on July 1, 2010. Certification to ISO 9001, Recycling Industry Operating Standard (RIOS) or an equivalent quality assurance standard would be required for first time applicants for an AQSIQ license. (Recycling Today 7/30/2010).

Export controls on scrap (such as those imposed in China, Russia and Ukraine) have been commonly applied in the world during periods of scarce supply. Historically, copper base scrap has been a highly prized raw material, especially in those nations with scarce natural raw material sources for copper. European scrap export controls during the 1980's were seen as affecting the U.S. copper industry unfairly. As a result, the U.S. Copper and Brass Fabricators Council (CBFC), representing domestic brass mills submitted a 301 petition concerning the trade of copper and zinc scrap to the U.S. Trade Representative on Nov. 14, 1988. The application was not successful in developing U.S. controls. Domestic semifabricators asserted that European (EEC) and Brazilian brass mills had been able to maintain materials cost and product price advantages since the middle 1970's, largely through export controls on the flow of copper and zinc scrap. However, in 1992, the EC terminated the export controls on copper and copper alloy scrap. Several Asian nations and Russia have maintained scrap market controls in recent years. The Bureau of International Recycling (BIR), a European recycling organization, recently assisted Romanian companies in opposing a Romanian governmental decree to impose 20% to 30% export taxes on nonferrous and ferrous scrap.

In April 7, 2004, the CBFC and Non-Ferrous Founders Society filed a short supply petition under the Export Administration Act, requesting imposition of monitors and controls on the export of copper-based scrap. ISRI and its members were opposed to the petition as they did not want exports restricted. The Commerce Department issued its decision in August 2004 citing no need for controls or monitoring of copper-based scrap exports. See Appendix A for a more complete discussion.

The voluminous paperwork requirement the Chinese government implemented for the importation of scrap also was viewed as an impediment in early 2004. Some scrap recyclers and brokers labored to comply with export regulations being put in place by the Chinese Government's Administration of Quality Supervision Inspection and Quarantine (ASQIQ) (Recycling Today, August 2004). The significant load of paperwork required had an initial deadline set at July 1, 2004 in order to be registered or permitted to ship scrap to China. Not only the information requirement was tedious, but some information such as floor plans and other operational details of the exporting company, required to qualify for the CCC mark system, was objectionable. The suspicion existed that the Chinese importers were determined to help themselves to efficient production facility know - how through this information.

Another problem with copper scrap exports to China revolved around China's handling of its VAT (Value-added Tax). The VAT tax on copper waste and scrap was 17% in 1999 (www.chinavista.com). The same tax applied to refined copper imports. Chinese copper scrap importers and Chinese customs officials were accused of manipulating the VAT to the detriment of U.S. industries. Chinese importers received a rebate on VAT and then further manipulated import documents to gain greater VAT refunds. These actions caused global copper scrap prices to rise because Chinese importers could pay more for scrap, but still make a profit. U.S. manufacturers that use scrap were faced with higher prices for raw materials, thus increasing their production costs. Finished products from China were subsequently undersold in U.S. markets (US Info.State.Gov. 10/7/2003).

In December, 2008 (Recycling Today, Dec.2008), China's Nonferrous Metal Industry Association (CNMIA) announced that the government was considering canceling the 17% VAT tax on scrap imports. The CNMIA hoped the move would help companies cut costs as the economy slowed.

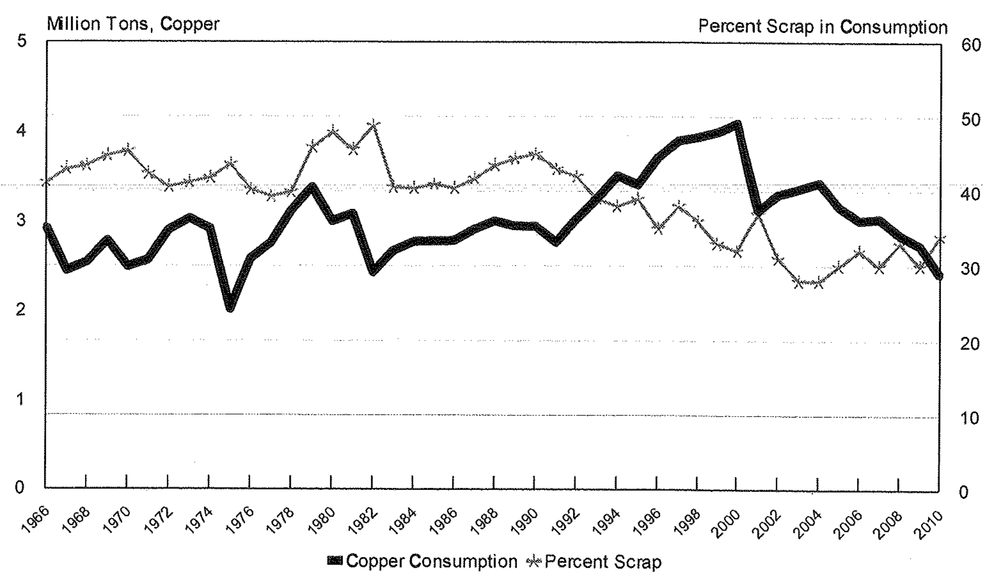
Pegging the yuan to the dollar was also reported as a deliberate strategy to support Chinese industry and boost exports. China's undervalued currency was acting as an additional trade barrier to U.S. exports and an unfair subsidy for all Chinese exports (Congressional-Executive Commission on China, Sept 24, 2003).

Some observers have used problems in Chinese trade regulations to explain the tremendous differences between reported world statistics for copper scrap imports and exports. (See **Tables 3 and 4** in this report for differences.) Among importing countries, the import statistics for China seem to be the most suspect. Copper scrap imports are over reported because some other industrial recycle material has been claimed at customs as copper or copper alloy scrap. Some believe this may be the result of the lower copper scrap import duty relative to other industrial wastes. Some traders may be trying to avoid the higher import duty by importing non-copper industrial waste as copper scrap. Imports of scrapped electrical domestic and office goods also may have been imported as copper scrap, since these have been prohibited since Aug. 15, 2002.

Ukraine's parliament gave approval to a bill in late 2006 that would lift the ban on exports of scrap nonferrous metals. An export duty of 30 Euros per metric ton would apply the first year the bill is in effect and would be gradually reduced to 15 Euros per metric ton over the next 5 years. The duties would start when Ukraine joined the World Trade Organization. (Recycling Today, 11/30/06). Export taxes are not the only trade barrier that Ukraine maintains. Ukraine does not allow the export of scrap metal products unless exporters are properly registered with the Ministry of Economy and are issued an export license. Export registration fees also obstruct trade in scrap metals. Until recently, the fee for export licenses for ferrous and non-ferrous scrap was five times higher than the ordinary customs clearance fee of 0.1 percent of the value of the export contract. Despite Ukraine's pledge to reduce its high export taxes in 2006, political divisions leading up to the 2010 presidential election, coupled with the substantial influence of industry leaders, have slowed progress towards trade liberalization and deregulation. In the face of its commitments to eliminate or reduce export and import bans and tariffs across a wide variety of industries, and just days after Ukraine became a working member of the WTO, the Ukrainian parliament passed a major bill containing export and import duties that were in direct violation of WTO agreements (Wiley Rein, 2008).

In late 2009, the Bureau of International Recycling (BIR) was reported (Recycling Today, Aug. 2009) as pressing India to make changes to its requirements for the import of recyclables. Imports were being

Figure 5. U. S. Total Copper Consumption 1/
Including All Scrap, 1966 to 2010



Source: U.S. Bureau of Mines and U.S. Geol. Survey.
1/ Total Copper Consumption = Primary refined, secondary refined + copper in direct melt scrap.

impeded by the requirement of pre-shipment inspection certificates. The new Indian rules restricted imports to end users and thereby excluded traders. This was a major issue for trading companies and their business associates, who were seeking amended rules.

World Production and Trade in Copper Alloy Ingot. While copper and copper alloy ingot production and trade are not large in volume compared with other copper products; they form the foundation blocks for important specialty metal fabrication industries. Many nonferrous foundries, brass mills, steel mills and other parts of the world's manufacturing industry are dependent on the special alloys produced by these essential-processing plants. Because the ingot makers and associated foundries of the world are heavily reliant on scrap, especially old scrap from returned manufactured and used products, it is important to put this industry in world perspective.

The United States is a world leading producer of copper and copper alloy ingots and foundry products from scrap (see **Tables 5A, B and C** and **Table 10**). The United States produced 254,000 tons (23%) of world nonferrous foundry products in 2002 , but only 290,300 tons in 2008, about 11% of world total. In 2008, Italy (5.5%), Japan 5.5%) and Germany (5.2%) are also significant producers of nonferrous foundry products. China (33%) has increased foundry production significantly since 1999, producing more than 600,000 tons per year by 2008.

The United States produced 27% of the total world ingot production in 2008. Nearly 80% (349,000tons) of the world's alloy ingot production, of around 436,400 tons per year in 2008, was exported (see **Table 5C**) The ICSG Copper Bulletin reported world ingot imports at 304,000 tons and exports were 349,000 tons in 2008. During 2009, China (24%), Germany (17%), Italy (4%), Taiwan (4.4%), Canada (2.2%), and France (3.6%) were the largest importers of ingot. Since 1999, China has increased its imports of ingots by a factor of 6 to around 82,000 tons in 2003 and 72,000 in 2010. The United States (27,600 tons), Japan (31,800 tons), Germany (9,800 tons), the United Kingdom (11,300 tons), South Korea (15,200 tons), Spain (12,100 tons) and Belgium (9.500 tons) were the leading exporters of ingot in 2009.

Over the past 8 years, U.S. ingot exports were between 29,000 tons and 40,000 tons, reaching a peak in 2007. U.S. ingot imports decreased markedly from about 23,000 tons per year in 1999 to around 4,000 tons per year in 2003, but increased to around 10,000 tons in 2006, and 4,500 tons in 2009. Ingot imports have decreased generally in every region of the world with exception of the Middle East and Asia, which has tripled the amount of alloy ingot imports since 1999.

Domestic Industry Perspectives

Domestic uses for Copper. About 75% of the copper consumed in the United States is for electrical and electronic uses, finding widespread application in most end use sectors of the economy. According to the Copper Development Association (CDA), 4,676 million pounds (2.1 million metric tons) of copper and copper alloy mill products were shipped for domestic 2009 end-use markets. The products were distributed in sectors as follows (electrical is distributed through all end-use markets): Building Construction (49%), Electrical and Electronic Products (20%) Industrial Machinery and Equipment (9%), Transportation Equipment (12%) and Consumer and General Products (10%). In 2009, copper mill production of 4,676 million pounds and much below the high point of 9,379 million pounds for 1999. Though smaller in total tonnage than the electrical and electronics uses of copper, the copper powder and chemical industries also provide important products. Copper and copper alloy powders are used for brake linings and bands, bushings, instruments, and filters in the automotive and aerospace industries, for electrical and electronic applications, for anti-fouling paints and coatings, and for various chemical and medical purposes. Copper chemicals, principally copper sulfate and the cupric and cuprous oxides, are widely used as algaecides fungicides, wood preservatives, copper plating, pigments, electronic applications and numerous special applications. See **Tables 10, 10A** and **10B** in this report for production and trade in some of these products.

U.S. Consumption of Copper. In the United States, copper derived from both primary (mined) and secondary (recycled) sources is consumed at industrial production plants. U.S. industry import reliance for copper in the last 14 years has increased from less than 1% of domestic consumption in 1991 to over 48%, and 32% in 2003 and 2008, respectively. In 2006, a record level of refined copper, around 1.1 million tons, was imported into the United States. This compares with only 343,000 tons of refined imports as recently as 1993. Copper derived from domestic mines and as well as from domestic scrap sources has steadily decreased in recent years as imports of refined copper have increased. As copper consumption at U.S. plants dropped further in 2008, however, the rate of refined imports also declined. US refined imports for 2009 were 663,600 tons, and still well above that of 1993-1997. U.S. refined copper consumption for 2009 was estimated to be 1.6 million tons.

Recycled copper used to make semi fabricated products may be derived from (1) scrap that is first refined before use (*refined scrap*), or (2) from copper and copper alloy scrap that can be directly melted at the time of use (*direct melt scrap*). Total refined copper, from both primary and secondary sources, consumed by the U.S. industrial sector in 2009 was a about 1.6 million tons, according to the U.S. Geological Survey (see **Table 6**), and considerably lower than the high point of 3 million tons in 2000. Of the total refined copper consumed in 2009 only 46,000 tons (or 4%) was derived from scrap processed at a refinery (see **Table 7**). This is down considerably from 480,000 tons (25% of refined consumption) of copper from refined scrap in 1989. In addition, the United States industrial sector consumed about 758,000 tons of copper in 2009 derived from direct melt, copper-based scrap (See **Table 2C**). Total copper from scrap (refined plus direct melt copper base scrap and from other than copper-base scrap) amounted to about 804,000 tons in 2009. The range in annual average copper content for direct melt copper-based scrap in the United States has been 83% to 85% of the gross weight over the past 10 years, according to an analysis of data provided by the U.S. Geological Survey.

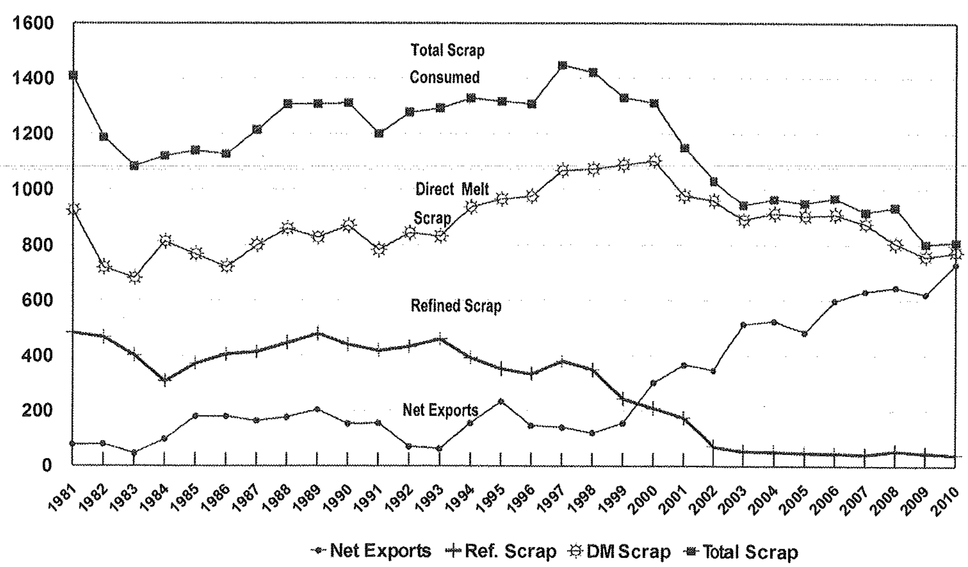
Traditionally, scrap used in refining and smelting has been made up mostly of "*old*" scrap, while the purchased direct melt scrap used by brass mills is mostly "*new*", customer-returned scrap. The rate of recovery for "*old*" scrap copper in the United States is related to the variability in the copper price, the domestic industry demand for this type of raw material, competition from exporters, and the availability of primary copper. The small amount of U.S. secondary refined copper in 2008 was 50% derived from old scrap sources and 50% from new scrap sources, according to the U.S. Geological survey (2008 MYB, Table 7). The amount of secondary copper in U.S. refinery production was only 53,800 tons out of a total 1.279 million tons refined copper. This was down considerably from around 480,000 tons of refined copper derived from scrap in 1989. The significant decrease observed since 2000 was the result of the gradual and complete closure of all of the secondary smelters in the United States. Refer also to **Figure 8** for complete statistical details on smelter capacity changes over this period.

Ingot making also uses large quantities of copper from "*old*" scrap (84% derived from old scrap in 2008). Copper from old scrap only made up 17% of total copper recovered from copper-base scrap in 2008. (USGS, 2008 MYB, Table 7). Some copper tube mills may use a higher proportion of old scrap when purchased from dealers as good clean, No. 1 copper scrap. It is many times impossible for a mill to determine whether the scrap is "*old*" or "*new*" in its origin after it has been chopped and processed by an intermediary.

U.S. scrap statistics shown in **Table 6,** represent consumption, or copper scrap usage, as reported at industrial plants, and thus, do not reflect the total amount of material collected at scrap dealers and

Figure 6. Trends in U.S. Net Exports and Consumption

of Copper in Scrap[1/], 1981 - 2010



Source: US Geological Survey .
1/ Revised to include copper from copper- base and other-base scrap.

traders. An increasing amount of U.S. scrap collected has been exported in recent years. Using an assumption that most internationally-traded copper scrap may be derived from used materials, the addition of U.S. scrap exports to *old scrap* reported as consumed by the industry will provide an estimate of total old scrap recovered in a particular year. This also assumes, of course, that most *new* scrap is returned to the domestic mill of material origin and is not also sold abroad.

Old scrap recycling and its contribution to U.S. total copper derived from scrap has fallen from 43% in 1992 to 19% in 2009 (see Table 6). U.S. recovery and consumption of "*old*" scrap was highest during WWII, the 1950's and 1960's, which were years of high copper demand and good prices. Old scrap recovery was also high during the Great Depression years, when mine production was severely curtailed. As a percent of total copper consumed, (see **Figure 5 and Table 6**) copper from scrap has declined from 49% since the early 1980's to around 30% in 2007. Despite the robust U.S economy over much of the period 1994-2007, domestic use of copper from old scrap and refined from scrap, in particular, experienced a significant decline (See **Tables 6 and 7**). For example, copper from old scrap recovery was as high as 613,000 tons in 1980, but was only about 143,000 tons in 2008. Exacerbating the decline in collection, processing and consumption of old and low-grade scrap in the United States has been the closure of essential U.S. smelting and refining plant capacity. All U.S. copper scrap smelting plants, most scrap refining plants and some ingot makers have closed owing to the higher costs associated with tight environmental regulations, increased worker safety standards, and the competitive pressures from increased export of scrap.

Scrap is a necessary raw material in the U.S. manufacturing cycle. Not only does the U.S. industry generate many tons of copper-base scrap, but it also needs and uses many thousands of tons each year during the process of new manufacture. Customer-returned new scrap tends to be recirculated to the plant of domestic origin. In 2008, about 98% of copper-based scrap consumed at brass and wire rod mills was new scrap, according to the U.S. Geological Survey (2008 MYB Table 11). The purchased scrap market gradually increased in the United States through 1997, as shown in **Table 6** and in **Figure 6.** This increase has been presumed to reflect the steadily increasing industrial base, from which more customer return scrap is generated. It was also the result of the gradual decrease in processing capacity for old scrap. Since 1997, however, total scrap use has declined, coincidental to the significant increase in U.S. scrap exports (**Table 3** and **Table 8**). Lower copper prices (see **Table 1),** associated with an increase in primary copper supplies until 2003, also contributed to decreased use of scrap Though higher copper prices generally have been the case since 2004, significant foreign competition for scarce domestic supplies continued to impact copper availability for domestic firms through 2010.

Even while the brass and wire mill sectors of the U.S. secondary-based industry were expanding capacity, mill consumption of scrap copper relative to primary copper was decreasing. Until 1982, copper from all scrap sources had grown each year in the United States, as a percent of total copper consumed, varying between 7% (in 1906) to 50% (in 1950). However, from a peak of around 49% in the early 1980's, the contribution of copper from scrap to domestic copper usage gradually has been decreasing to around 30% in 2007 (see **Table 6**). Copper prices have escalated since 2003, but a coincidental increase in US industry scrap consumption did not accompany the higher prices. Instead, U.S. scrap exports steadily increased over the period.

Copper consumption from scrap, as shown on **Table 6**, does not include the significant amount of *run-a-round* or *home scrap* that is generated at every plant. Between 15% and 40% of raw material consumed remains in the production cycle of brass and wire mills and is recycled again and again. To include this material in consumption statistics each year, however, would be to double count the material each time it passed through the production process and was scrapped. Yet, this material is available and forms an essential part of the semis production cycle. Unfortunately, few statistics are available to quantify run-a-round material.

U.S. Trade in copper and copper alloy scrap. Copper and copper alloy scrap of all types has significant intrinsic value for the manufacturing industries of both the United States and the World. Copper base scrap, including lower-graded copper materials with by-product metal value, are all commodity-like materials that are traded (bought and sold) and used just like other raw materials. As a consequence, recycled materials form a significant part of the U.S. copper exports and imports. This has been particularly significant in recent years since the manufacturing bases of the Asian countries have been growing and demanding more raw materials. The domestic market for scrap is still larger than exports though exports have been growing at a fast rate. U.S. industry consumption of scrap has decreased from around 1.77 million tons in 1997 to a 995,800 tons in 2008 (see **Table 17**). U.S. net exports of scrap in 2010 were 730,000 tons, up from a net export of around 63,000 tons in 1993, and

140,000 in 1997. Net exports of copper scrap for 2009 were estimated to be lower at 623,900 tons.

The United States is a significant exporter of copper and copper alloy scrap as shown on **Tables 3 and 8**, and has been the world's largest exporter of copper-based scrap since 1999. The most significant U.S. scrap export destinations are in Western Europe and Asia. Although the amounts have been declining since 1997, the United States also imports around 100,000 tons per year of scrap. The most important U.S. import sources of copper and copper alloy scrap in 2008 continued to be Canada (40%) and Mexico (35%). Scrap exports generally have been increasing since the early 1970's. Exports suddenly doubled between 1999 and 2000 (see Table 8), and have remained well over 500,000 tons annually since that time. Lower scrap imports and exports in 1996 through 1999, were the result of the worldwide depressed copper prices, the strong U.S. dollar and a temporary setback in Chinese imports during the early part of this period. The lower scrap price and stronger dollar also combined to make U.S. scrap scarce for domestic buyers, as well as expensive for foreign buyers over that short (1996-1999) period of time. Since 1999, however, foreign buyers (principally China) have managed to outstrip local mills in competition for scarce purchased scrap.

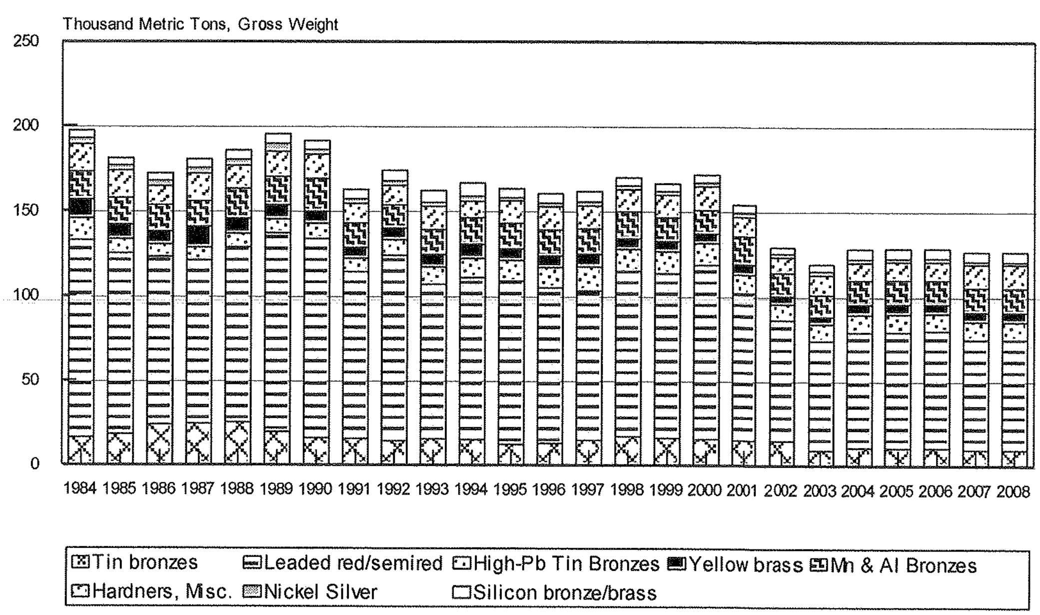
U. S. copper and copper alloy scrap exports set another record in 2010 estimated at 994,000 tons (see **Table 8A**). Since 2005, U.S. trade statistics have tracked the type of scrap in its export statistics, as shown on **Table 8A**. While unalloyed scrap exports have remained around 350,000 tons per year, alloyed and mixed scrap exports have escalated from around 300,000 tons in 2005 to 685,000 tons in 2010. The bulk (80%) of this mixed copper and copper alloy scrap has been destined for China (USGS, Dec 2008 MIS, Table 17).

In lieu of scrap, primary copper at bargain prices between 1998 and 2003 provided a ready substitute in the United States for those who could utilize it. However, owing to the types of furnaces used, size of charge needed, and chemical requirements for certain alloys, this was not possible for all secondary metal users, and the market became difficult for these industries. Those mills and ingot makers that were dependent upon direct melt alloy scrap were highly affected by the increased U.S. exports.

The trend in U.S. net scrap exports appears as a mirror image to the trend of copper recovered from refined scrap, as shown in **Figure 6**. When refining from scrap (largely "*old*" scrap) is high, net exports (exports less imports) are lower. Lower exports and

Figure 7: U.S. Copper Alloy Ingot Production

By Ingot Group, 1984-2008



Source: U.S. Bureau of Mines and Geological Survey Mineral Yearbooks higher imports of scrap in the early 1980's were in part owing to the stronger dollar of the period.

Trade in low-grade, copper-containing ash and residues has been recorded by the Bureau of the Census under HTS 262030 since 1989, when the harmonized code was instituted in the United States. Prior to this nomenclature, the TSUS standards and nomenclatures were used. For exports, the TSUS number is 6030010 and for imports, it is TSUS 6035040. Exports of "ashes and residues containing mainly copper" are reported in gross weight of material. The import data are in copper content, but it can be extrapolated to gross weight for comparison with the USGS reports for consumption of low-copper ashes and residues. Although the material may contain up to 65% copper, an average copper content of 35% was used in estimating the gross weight for exports and imports on **Table 9**.

The major trading partners receiving ashes, residues and slag from the United States for further processing are Belgium, Canada, Germany, Mexico, the United Kingdom and, more recently, China. Major import sources are the copper producers of Botswana, Chile, Mexico, Canada and Australia. Copper ashes and residues exports increased from the early 1980's to reach 28,110 tons in 1995, but then decreased to as low as 2,950 tons in 2002. Since 2004, copper ash and residue exports again began to increase and, in 2008, were 46,200 tons. Imports of copper-containing ashes and residues have been decreasing; from 5,400 tons of copper content in 1988 to less than 700 tons in 2002 (see **Table 9**.). Imports of ashes and residues increased slightly since 2003, reaching 8,700 tons in 2007, but were lower at 6,000 tons in 2008 (**Table 9**).

Because many of these materials are associated with the brass and bronze making process, trade in zinc dross, skimmings, ashes and residues are also shown in **Table 9**. As measured in zinc content of zinc ash and residues (HTS 26201960), exports reached a peak in 1992, but declined through 1999 to 4,500 tons. Exports of zinc ash and residues increased significantly since that time to reach 25,000 tons in 2002, and 13,200 tons in 2004, but were down again to 4,220 tons and 10,360 tons in 2006.and 2008, respectively. Zinc ash and residues imports steadily increased to around 24,300 tons, as measured in contained zinc through 1998, but then decreased to a range of between 14,000 and 17,000 tons until 2005. Zinc ash and dross imports were again higher at 33,750 tons in 2006 but have been lower for the past several years at nearly half that level.

U.S. Export Controls on Scrap. During periods of high military activity and/or difficult economic conditions, copper and copper-base scrap has been in such tight demand and scarce supply that U.S. export controls and other restrictions have been placed on its use. Tight supply periods occurred in the 1960's and early 1970's, occasioned not only by requirements of the Vietnam War, but also by the effects of long copper mine labor strikes during the late 1960's. To compensate for the severe shortages, more than 1 million tons of copper from the National Defense Stockpile were released. In addition, during the early 1970's, price controls were briefly implemented. A review of the historical events surrounding the use of export and price controls relative to the copper market and the need for copper scrap may be found in **Appendix A.** Given the propensity for military efforts to use large amounts of copper and its alloys, as well as to cut off major sources for copper around the world at times, it is highly possible that export controls and the pressure for increased use of secondary copper can occur again. All of the remaining copper in the National Defense Stockpile was sold in 1993.

Products and by-products from Scrap

Wrought copper and copper alloys. The making of brass and bronze wrought metal alloys by brass mills accounts for the largest share of copper recovery from scrap. Wrought copper and copper alloys are produced from purchased scrap, home scrap, refined copper, and other metal alloying additives. These alloys are fabricated into products such as sheets, tubes, rods and pipes. Wire rod mills produce continuous cast, pure copper rod for making wire that is drawn down to various types of coated and uncoated wire. Because of the stringent requirements for making copper wire, wire rod mills use mostly refined copper in making rod. The small amount of scrap that is used by wire rod mills must first be refined. Only one wire rod mill in the United States has a continuous system for fire refining, melting and rod casting from scrap. This mill uses the company's own customer-returned scrap from its wholly-owned wire mills in the fire-refining plant.

For 2008, the combined semi fabricate production of brass and wire mills amounted to 2.66 million tons of copper and copper alloy products. (**Table 10**). This was somewhat lower compared with 3.4 million tons of semi fabricate products produced in 2004 (**Table 10**), and considerably lower than the peak of 3.9 million tons reached in 1999-2000. The current lower production rate is a continuation of the U.S. industrial retraction that has been experienced since 2000. About 16 brass and tube mills have closed in the United States since 2000 (see **Table 13A**). Two main factors contributed to tubing company demise: increasing use of plastic pipes for construction applications and increased imports of copper and aluminum tubing from China, Canada, Mexico and other countries. More recently, a large wirerod mill closed in Illinois.

U.S. copper consumption statistics, as shown in **Table 6**, are reported from brass and wire mill activity. These statistics do not represent the entire U.S. population's consumption of copper. The statistics for the domestic population would include copper contained in finished and semi fabricate imported goods. To determine a complete U.S. societal copper consumption estimate, copper in imported finished goods also should be considered, such as copper in imported cars, refrigerators and other goods. These statistics are difficult to estimate, and is beyond the scope of this paper. Judging by the volumes of products scrapped, however, it is suspected that the U.S. society remains the largest consumer of copper in the world, regardless of where the product originated or how it was used.

Brass and Bronze Ingots. . Ingot making was a critical U.S. industry during World War II, comprising a basic support for the essential brass mill and foundry production needed for the war effort. This was so much the case, the Defense Production Act required that, among all other Government copper surveys, only the ingot maker, foundry and brass mill data surveys were mandatory under penalty of law. Special alloys and the special castings, fittings and parts made for military uses were dependent upon domestic production from ingot makers and foundries.

According to the U.S. Geological Survey, ingot production (including master alloys) in the United States was 128,000 tons (see **Table 10**) in 2006, but was down to 118,000 tons in 2008. Ingot production has been less than 200,000 tons in the United States since the 1980's. Ingot production ranged from 300,000 tons to 380,000 tons of ingot in the 1960's and 1970's. U.S. ingot exports have increased significantly in recent years to around 38,000 tons in 2008 (see **Table 5C**). U.S. ingot imports also increased to around 9,000 tons in 2008, but were significantly lower in 2009 and 2010

Ingot makers produce a wide range of cast copper alloys for the nonferrous foundries. Ingots weigh about 30 pounds each when cast, being of a small enough size to suit foundry furnaces. Production trends for several broad ingot groups are shown on Table 10 . The most important of these are the red brass, bronze, and yellow brass groups. **Figure 7** clearly shows the gradual decline in U.S. ingot production since the middle 1980's with another sharp drop since 2000. The leaded and semi-leaded red brass and the tin bronze categories of ingot seem to show the most volume decrease since the late 1980's. A decrease in hardeners and master alloys also has occurred since 2000. The general ranges in ingot compositions are shown on **Table 11**. There are actually hundreds of ingot metal compositions designed for special tasks. The groups shown in **Table 10** are very general.

Individual grades of copper and copper alloys have been designated in the past by a three-digit number series developed by the industry. More recently, however, this series has been incorporated into the Unified Numbering System (UNS) for metals and materials developed by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE). This system designates each alloy by 5 digits preceded by the letter C. The UNS system is administered by the Copper Development Association Inc.(CDA). There are about 370 types of copper and copper alloys divided into the broad categories of wrought and cast metals. Within these two categories, the metals are further subdivided into classes as follows:

Coppers: Metals containing at least 99.3% copper. There are 44 numbered coppers, including oxygen-free, tough-pitch, and deoxidized varieties.

High-copper alloys: Copper content of cast alloys is at least 94%; copper content of wrought alloys is 96% to 99.3%. This class includes the cadmium, beryllium, and chromium copper alloys.

Brasses: Copper alloys containing zinc as the principal alloying element. There are 3 families of wrought brasses and 5 families of cast brasses. EnviroBrass I, II and III were recently introduced in 1999 as lead-free alternatives to the leaded-red brasses used in plumbing. These lead-free cast red brasses contain bismuth and selenium as principal additives.

Bronzes: Copper alloys in which the principal alloying element is usually tin, and which contain other metals such as aluminum, lead, phosphorous, and silicon, but not zinc or nickel.

Copper Nickels: Copper alloys with nickel as the principal alloying metal.

Copper-nickel-zinc-alloys: Copper alloys containing nickel and zinc, as the principal and secondary elements; commonly known as nickel silver.

Leaded coppers: Cast copper alloys containing 20% or more lead, usually a small amount of silver, but no zinc or tin.

Special alloys: Copper alloys with compositions not covered by the above descriptions

Master alloys and hardeners are also produced by a select group of ingotmakers for use by others in performing certain functions in their melt. Master alloys usually contain 10-15% of the desired metal and the remainder is copper. They perform the function of making the addition of potentially difficult metals easier to a melt. Master alloys are produced as shot or ingot form and are used as a melt addition to deoxidize, harden, improve fluidity or control composition in many base alloys. For example, phosphor copper master alloy is used as a deoxidizing additive in making copper tube.

Refined Copper. According to data collected by the U.S. Geological Survey, 53,200 tons of refined copper was produced from scrap in 2008 down significantly from 460,000 tons produced in 1993. Refined products formed include cathode, ingots, billets, shot (small metallic pellets), wire bar and continuous cast rod. In addition, only about 1,000 tons of copper powder was also produced from scrap in 2008. **Table 12** shows the manner in which copper is extracted from scrap and the form of recovery from 1995 through 2007. Owing to the few plants actually fire-refining, this data is currently withheld by the reporting agency (U.S. Geological Survey), but included in the total refined number. The historical production of refined secondary copper in the United States for the years 1968 through 2009 is shown on **Table 7**. The decreased recovery of secondary copper since 1980, from 30% to 4% in 2008 can be observed on **Table 7**.

Copper Anodes for Plating. Copper anodes are produced by ingot makers and foundries in several shapes designed for ease use in plating. Copper anodes that contain phosphorus are designed for use in copper sulfate plating systems. Pure copper anodes are used in copper cyanide and other alkaline plating systems. Selecting the correct anode for plating depends on the following characteristics: Anode area and copper concentration; the size and shape (balls, nuggets, bars), the potential for bridging (caused by small baskets and large nuggets), sludge build-up, the grain structure of the anode, the phosphorus content and lastly, the preparation of the anode (cleaning).

Black copper. Black copper is an intermediate product produced in a blast furnace from low -grade scrap. Black copper still contains some iron and zinc along with most of the tin, lead, and nickel of the charge. A typical black copper composition is 75% to 88% copper, 1.5% tin, 1.5% lead, 0.1% to 1.7% antimony, 3% to 7% iron, and 4 to 7% zinc. Traditionally, this material can be refined in a scrap converter with the addition of liberal coke to the charge, which adds extra heat, provides a mildly reducing condition, and facilitates the removal of zinc, tin, and lead. Copper anode is then poured for further refining in an electrolytic tank house. Slag, produced as a by-product, may contain 1.5% copper, or more, and can be granulated and sold as aggregate, or reprocessed when the copper content is high enough.

Copper Chemicals and Powders. Most copper chemicals made in the United States today, such as the copper oxides and hydroxides and copper sulfate, are derived from processing copper scrap, copper sludge, or from the process waste liquors associated with refining copper, copper etchants, brass pickle solutions, and other metal processing. Generally, the purer, less contaminated forms of scrap are preferred for making chemicals to avoid inclusion of deleterious metals. Even so, some hydrometallurgical processes permit the use of some types of mixed scrap, such as copper-plated steel, and printed circuit boards. Copper powders are also made from refined metal derived from scrap. Copper powder and copper sulfate production in the United States is shown on **Table 10.** Trade in these products are shown in **Tables 10A and 10B.**

According to the U.S. Geological Survey, copper sulfate production was down to 22,600 tons in 2007. This continues the significant decline in production that is down from 33,200 tons in 1989, and from about 55,000 tons produced in both 2000 and 2001. A copper sulfate production facility closed during the 2004. Griffin Corp closed its secondary chemical plant in Texas during 2004. In 2006, Phelps Dodge was started a new 40 million- pound, primary leach, copper sulfate plant at Sierrita in Arizona. Exports of copper sulfate have increased since 2005 to around 6,500 tons (gross weight) in 2010. Imports of copper sulfate have decreased slightly over the same period, from 56,000 tons in 2004 to about 49,700 tons in 2010

Copper powder production from scrap has ranged between 8 tons to 11.7 thousand tons in recent years, but was about 1,000 tons in 2008 (USGS 2008 MYB). A major decrease in production occurred in 2003, according to data published by the USGS (See **Table 12**). Even so, total copper powder exports (HTS 740610-20) were as high as 12,250 tons in 2005 (See Table 10A) , but these also have been decreasing since that time. Total copper powder exports were around 10,000 tons in 2010. Only 3,000 tons of copper powders (both flakes and non-lamellar) were imported in 2009, but had been as high as 4,600 tons in 2006.

According to Queneau and Gruber (1997), about 13,320 metric tons of contained copper per year was being extracted from copper-based scrap as chemicals each year during the 1990s. The USGS (2008 Minerals Yearbook) reported copper recovered from scrap in chemical compounds as 5,000 metric tons in 2008. This copper was produced as copper oxides and hydroxides, copper sulfates and other copper chemicals extracted hydrometallurgically from copper-bearing scrap. In addition, a small amount of low-grade cathode is produced from electrowinning pickle liquors and sludge. According to U.S. ITC trade data, exports of copper oxides and hydroxides have been increasing since 2003, and were as high as 28,000 tons in 2010. Destinations were China, Canada, Korea, Sweden, Singapore, Portugal and the United Kingdom. Imports (see **Table 10B**), on the other hand, were extremely small. Copper hydroxide imports in 2010 were only 240 tons. This would indicate that domestic production of oxides and hydroxides were at least 28,000 tons in 2010, if all were presumed to be exported.

Secondary Copper By products. In the process of Ingot making, fire-refining and casting of copper and its alloys, some low-copper or mixed scrap materials are generated, such as: scalper and other dusts, grindings, mill scale, drosses, skimmings, ashes, slag and other residues. Most of these residues are marketable, or can be used and recycled at the plant of generation. Scalper scrap and dusts generated in the process of cleaning billet and other pure copper forms may be entirely copper. Copper skimmings and drosses from melting furnaces can run 20% to 65% copper and contain notable amounts of other metals such as nickel and zinc. Grindings may be as much as 100% metal, and contain 10% to 76% copper. Many of these residues contain valuable byproducts other than copper, such as precious metals, tin, antimony, lead, nickel or zinc, for example, which can be recovered and upgraded.

Copper slag resulting from fire-refining can run up to 65% copper, making them highly desirable and marketable products. This is especially true of slag resulting from fire-refining no. 1 scrap, where there are few associated deleterious metals. However, more metals may result in the slag than is desirable from cleaning up less pure scrap. These slags may require further metallurgical treatment to recover the valuable by product metals. High silica slag has been used for many non- metallurgical purposes when they are free of deleterious elements. Among other uses, slag has been used for the production of lightweight aggregate and rock wool.

In making some master alloys, special types of residues are generated. In the case of making phosphor copper master alloy, the dominant residue contains phosphoric acid. Most of the phosphoric acid by-product thus formed is collected and sold to fertilizer manufacturers for use in making fertilizers.

Some brass mills process their own pickling solutions to recover copper by electrolytic processes. In recent years, there have been several hydrometallurgical plants that have thrived on processing other companies' sludge and residuals for copper, zinc, selenium and tellurium and other metals. A wide variety of metals and other products are recovered from chemical waste generated by various metal working industries, such as printed wire board manufacturers, electroplating shops, chemical milling operations, brass mills, and rotogravure plate producers. Problems associated with landfill disposal of waste materials are avoided by taking advantage of the benefits of recycling at these hydrometallurgical plants.

Waste treatment plant sludge may contain 15% copper and a 1% to 2% zinc content. Nickel dross from copper/nickel alloys may run as high 40% copper and 6% nickel, making it a valuable market material. Copper and brass drosses may run as high as 55% copper and contain notable amounts of other metals such as antimony, zinc, tin and nickel. Scalper dusts generated by scalpers that remove copper oxide from mill products may also contain enough copper to be recoverable and are often recycled within the plant of origin.

Baghouse Dusts. Baghouse dusts are usually sold for their zinc, copper and tin content. About 30% of U.S. zinc consumption (James Jolly, 1993) is derived from all secondary materials, including flue dust collected during copper alloy processing. About 86% of U.S. recycled zinc in 2004 (USGS 2004 MYB, Table 9) was derived from the new scrap generated mainly in galvanizing and die casting plants and at brass mills. Recycled zinc was used for the production of zinc metal and alloys, and zinc oxide, zinc sulfate and other chemicals. The Zinc Corporation of America's plant in Monaca, PA, is the largest processor of secondary zinc. Clean new brass scrap and clippings usually require only remelting. Most of the zinc from flue dust is recovered through various pyrometallurgical methods.

Bag house dusts collected from the typical blast furnace or cupola used in melting low-grade copper scrap generally contain (Spendlove, 1961) 58 to 61% zinc, 2 to 8% lead, 5% to 15% tin, 0.5% copper, 0.1% antimony, 0.1 to .5% chlorine, and some unburned carbon. When high (about 65% zinc) in zinc and low in lead (less than 3% Pb), these materials can be used for animal feed and for making fertilizer components. Most of the zinc oxide is shipped either in large (2,000 lb.) plastic bags (Supersaks), or in metal drums. Some of the zinc oxide collected, however, may be lower in zinc (20% to 40%) and higher in some of the less desirable elements. In this case, when they are sent to another plant for treatment, they may be shipped as hazardous materials.

Other Metal Recovery. In the process of making copper-based alloys from scrap, notable amounts of other metals, such as tin, antimony, lead, zinc, nickel and aluminum are also recovered as part of the scrap consumed. According to the 2008 USGS Minerals Yearbook, Table 9, brass and bronze ingot production from scrap resulted in the recovery of 101,000 tons of copper, 4,170 tons of tin, 6,170 tons of lead, 10,300 tons of zinc, 157 tons of nickel and 11 tons of aluminum. Secondary metals content of brass mill products were estimated to be 601,000 tons of copper, 1,400 tons of tin, 2,580 tons of lead, and 118,000 tons of zinc, and smaller amounts of other metals. In addition to 35,200 tons of copper recovered at U.S. foundries, 1,180 tons of tin, 604 tons of lead, 1,450 tons of zinc and smaller amounts of other metals also were recovered from copper base scrap sources.

Items that go to the Landfill. While most low-grade residues have traditionally found markets for further processing or use, it sometime becomes economically impracticable to further process a material, or for economic reasons, to find a buyer for the materials. In these cases, these materials are sent to a landfill. The kind of landfill selected is determined by the tests the materials must pass. At a minimum, all production by-products being sent to a land fill must pass the USEPA TCLP test (see Chapter 4, this report) before a dumping permit is granted. Even so, at times, the landfilled material can serve a useful purpose at the landfill. For example, some brass mill slags and the black glass residue from a slag cleaning process can play an important part in the operation of the local dump as a suitable substitute for sand, which is usually purchased and used to cover a landfill at the end of the day. Spent refractory and furnace brick were also used in a similar way at some localities.

Some materials, such the mildly acid water resulting from making phosphor copper shot are treated to make an inert calcium phosphate sludge before being landfilled. Spent sulfuric acid (pickling solutions) that has already had metals removed from it may be shipped as a hazardous material to another plant for treatment and disposal as gypsum in a landfill. Some firms specialize in treating spent sulfuric acid for disposal.

The most commonly land-filled materials associated with metal-making are the spent metallurgical brick and ceramic materials used for lining the furnaces when these are not high enough in metal value to attempt recovery. These materials also must pass the TCLP tests prior to dumping. Most brass mills, foundries and ingotmakers ship some spent furnace brick to the landfill, although some have indicated that the material also may be used as road material. Spent brick may also be purchased by a scrap dealer for further distribution in the market, used in making concrete, or may be sold for its metal content. Some firms have indicated that spent furnace brick containing significant cadmium or lead will be shipped as a hazardous material.

Description of the U.S. secondary industry. The main consumers of copper and copper-based alloy scrap are smelters, refineries, ingot manufacturers, and the brass and bronze mills. Brass and bronze ingot-makers and mills make cast and wrought alloys mainly from brass and bronze scrap. Copper alloy scrap may be supplemented by other materials such as No. 1 copper scrap, small amounts of refined copper, and alloying additives such as tin and zinc and master alloys. According to data collected by the USGS (Dec. 2009 MIS, Table 5), ingotmakers accounted for 12% of total copper recovered from U.S. copper-base scrap consumption in 2009, 83% of which was from "*old*" scrap.

Brass mills make wrought alloys poured in shapes, such as billet and slab, that are then fabricated to finished mill products, such as sheets, tubes, rods, and pipe. Brass, copper tube, and wire-rod mills accounted for 76% of the copper recovered from copper-base scrap in 2009, only 3% of which was estimated to have come from old scrap. Brass mills use purchased copper alloy scrap and No. 1 copper scrap along with significant quantities of home-generated scrap, refined copper, and alloying additives such as slab zinc, lead, tin, and nickel. No. 2 and lower grades of copper scrap are usually refined before use by the mills. Copper tube mills utilize a higher percentage of "old" scrap than brass mills, but demand a high quality number 1 copper scrap from dealers and scrap preparers when a refinery is not associated.

Refiners use both low-grade and high-grade scrap as raw material. Low-grade scrap is treated by a series of pyrometallurgical operations followed by electrolytic refining. The electrolytic cathodes are then melted and cast into various shapes by the mills. Higher grades of scrap can be introduced in the later stages of processing. For example, No. 2 copper is generally introduced before the anode melting step that is required before electrolytic refining in a tank house. No. 1 copper may be either fire-refined or introduced at the cathode-melting step, as a substitute for cathode. Refineries accounted for only 6.2% of copper recovered from copper scrap in 2009, 55%% of which was from "old" scrap.

The U.S. copper industry has undergone significant changes since the early 1980's. The extent of this change in productive capacity is shown in **Figure 8**. Most U.S. reverberatory furnaces closed in the early 1980's in response to environmental pressures to clean up the air, as well as to cope with the strong dollar and a deteriorating competitive position. These useful, workhorse furnaces were replaced in the primary copper industry with flash furnaces that depend upon a high sulfur content in their feed for efficient operation. This action not only cut the need for copper scrap by the primary smelters, but it also trimmed the potential capacity available for processing low-sulfur, low-copper ashes and residues. The reverberatory furnaces also began to disappear in the secondary industry for similar reasons. The large secondary smelter at Carteret, New Jersey closed during this period owing to environmental requirements and poor markets of the time. Air quality standards forbid the burning of associated materials to old scrapped metal, such as plastics and circuit boards associated with electronic and electrical scrapped items, making it nearly impossible to process these materials by smelter. Although replaced in part by rotary and submerged arc furnaces and improved air-particle capture systems, capacity has nearly ceased in the United States for processing low-grade copper scrap and residues.

The Nassau metals facility in Gaston, South Carolina, which was based on the need to process-scrapped wire from AT&T operations, was purchased in the early 1990's by Southwire. For several years, Southwire operated both its Carrolton, Georgia and Gaston, South Carolina secondary smelters and refineries. However, in 1995, Southwire closed the Gaston plant to concentrate its recycling efforts at Carrolton. In 1999, Southwire announced its intention to sell its Carrolton plant and, by 2000, had closed both its smelter and electrolytic refinery associated with its wire rod plant in Carrolton, Georgia.

In 1996, there were 7 primary and 4 secondary smelters, 8 electrolytic and 6 fire refineries, and 14 primary electrowinning plants operating in the United States. Two of the electrolytic refineries were dedicated to two of the secondary smelters; processing anode made from scrap. Several of the primary smelters and refineries also processed some scrap and secondary anode. The U.S. fire-refiners processed only scrap. In addition, there were about 23 ingot makers, 53 brass mills, 15 wire rod plants and about 600 foundries, chemical plants and other manufacturers consumed copper scrap in the United States. In September 1996, the Franklin Smelting and Refining Co. in Philadelphia, a relatively small secondary smelter with capacity to produce about 15,000 tons per year of blister copper closed as a result of the high cost of environmental compliance. It soon became a Superfund site (see Appendix B), along with many others of the same era.

Cerro Copper Products and Chemetco in Illinois and Southwire in Georgia once operated secondary smelters. Chemetco produced anode for sale to others for electrolytic refining. Cerro had a completely internal process dedicated for use in its associated copper tube plants and Southwire produced copper for use in its wire rod mill. In April 1998, Cerro Copper

Figure 8. Trends in U.S. Copper Smelter and Refinery Capacities

(Thousand Metric Tons, Copper)

	1982	1989	1994	2004	2010
Secondary Smelters	315	481	511	0	0
Secondary Refineries	545	315	311	123	123
Reverb. Smelters	1526	474	210	0	0
Primary Flash Smelters	173	868	1315	900	710

suspended operations at its 40,000 ton-per-year electrolytic refinery and associated secondary smelter, but still retained use of its 30,000 ton-per-year fire refinery until 2001. The Sauget and Cahokia areas in Illinois were proposed in 2001 to the National Priorities List (NPL) of the Superfund. This site includes wastewater from Cerro Copper Company and the Monsanto Chemical Company (see Appendix B). Though in 2003, there were still five secondary fire-refiners, the last of the secondary electrolytic refineries, at Southwire, closed in 1999.

In addition to continued retraction of the secondary industry in 1999, three of seven U.S. primary smelters also closed in response to lower copper prices and market surpluses, and remained closed through 2003. By 2006, U.S. primary smelter and refinery capacity had declined to 700,000 tons (see Table 8) and 2.1 million tons, respectively, owing to permanent closures. Four primary electrolytic refineries and 14 solvent extraction-electrowinning (SX-EW) facilities operated during 2006.

Difficult times had come for the secondary smelters, stemming from the low copper price, high cost of environmental compliance and the cost-squeeze that these two had created. In 2001, the smelter at Chemetco in Illinois closed. Chemetco also had been under suit for potential water contamination associated with its operations. The Chemetco site was also added to the Superfund list, but was archived in late 1987. (See Appendix B) According to the USGS, U.S. copper smelter and refinery production fell in 2000 by 42% and 26%, respectively, compared with 1998. The loss of capacity and the effect of lower prices on scrap availability also impacted the availability of copper from secondary sources.

There continued to be generally a shortage of scrap for fire refining in 2003. Although the fire-refinery at Warrenton, Missouri had closed in 1999 and reopened again in 2000 under new ownership, it was to close briefly again in 2003, but was operating again in 2004. There would appear to be still a large number of nonferrous foundries, but only the strongest of the ingot makers have done well under the difficult market conditions of the past few years. The ingot maker of Lavin & Sons closed at North Chicago during 2003.

Most high-grade U.S. copper base scrap is consumed at brass and copper sheet and tube mills. One copper wire rod mill has a direct cast operation in conjunction with fire-refining its own wire mill-generated scrap. Although it is estimated that there currently are about 45 primary brass and tube mills, it is difficult to count the actual number since these have tended to change ownership as well as to expand the number of plants under the same company name. It is sometimes also difficult to separate downstream mills, such as rolling mills, from those that process metal to make semifabricates. Only plants that melt raw material to make primary forms are considered "primary" brass or tube mills. Reroll and redraw mills, or mills that operate with imported basic shapes are not included in the primary mill lists. One copper rod mill closed in Chicago during 2008.

Brass Mills. U.S. primary brass mills (a generic term that includes copper tube and sheet mills) have been concentrated in the middle and northeastern United States. The largest brass mills are located in Missouri and Ohio. The following is the number of brass mills operating in the United States, by State:

Ohio (4)	Missouri (2)
Michigan (2)	Tennessee (3)
Texas (1)	Alabama (1)
New York (2)	Oklahoma (1)
New Jersey (4)	Rhode Island (1)
Illinois (5)	Mississippi (2)
Pennsylvania (5)	Connecticut (4)
North Carolina (1)	Iowa (1)
Virginia (1)	Kentucky (2)
Arkansas (1)	

It should be noted that reroll, or redraw mills are not included in the above list. About 16 brass and tube mills have closed in the United States since 2002. See the list presented in **Table 13A**. There are apparently no brass or tube mills remaining in California, Indiana, Rhode Island or Massachusetts.

Foundries. Foundries are mostly small, family-owned operations located near major industrial centers, such as those in Illinois, Alabama, Indiana and Wisconsin. Foundries, as a rule, do not produce alloy ingot for making their products. Even so, there are a few large foundries that have an associated ingot making facility. Virtually all foundries remelt the gate scrap and the sprues, risers and rejected castings scrap generated during production. According to the U. S. Geological Survey, about 59,000 tons of purchased copper and copper alloy scrap was processed by the foundry industry in 2007. Foundries prefer some types of scrap, such as No. 1 chopped wire, because of its small size and easy melting. However, most foundries do not have the capability to perform smelting, refining, and chemical analysis of purchased scrap. Therefore, large quantities of scrap cannot be used and the purchase of ingot with a known chemistry is relied upon. U.S. foundries consumed 81,800 tons of copper alloy ingot in 2007. In effect, foundries are remelters and producers of engineering shapes. Although 100% ingot charges may be used, charges comprised of combined ingot, returns, and scrap are not uncommon. Experience, the quantity of shop returns, and the cost of available raw materials will dictate the exact proportions.

Ingot Makers. These plants produce a wide variety of copper and copper alloy and master alloy ingot for foundry, brass mill and other industry consumption. In addition to purchasing a large proportion of the "old" copper and copper alloy scrap collected each year, ingotmakers also purchase significant quantities of skimmings, grindings, high-grade drosses and other by-products for their metal content. There are about 21 currently operating ingot makers, down from the 28 counted in 1991. Two plants closed in 2003 and 2004. The active plants are concentrated near the industrial centers of Chicago, Los Angeles, and the eastern United States (**Table 14**). Ingot makers are consumers of a wide variety of copper and copper alloy materials and other metals. Most U.S. ingotmakers are independent, largely family-owned and operated businesses.

Secondary Smelters and Refiners. From a total of 5 plants in 1991, there currently is no secondary smelting plant operating in the United States that is capable of processing the lower grades of copper scrap. The last operating plant in Illinois closed in 2001. There are no operating secondary electrolytic refineries. One fire refining plant, located in Warrenton, Missouri, produces refined copper ingot and wire bar from scrap. This plant closed in early 1999, reopening in 2000 under new management, closed again briefly in 2003, but is currently operating. Four fire-refining furnaces are associated with tube and wire-rod plants, making a total of 5 fire-refineries remaining in the United States since 2001.

Hydrometallurgical Plants. A number of plants in the United States have created thriving businesses based on hydrometallurgical processing of secondary by-products produced by other metal production and metal finishing companies. Some of these companies are listed in **Table 14**. Using circuit board scrap, bimetallics , no 2 and no. 1 scrap, most of these companies produce products such as cupric oxide, copper sulfate, and copper carbonate. A few companies produce low-grade copper cathode and other metal products from wastes, sludges and pickling liquors.

Classic secondary copper feed for hydrometallurgical processing includes:

- Wire choppings, mill scale, mud from wire drawing, tubing, turnings and grindings, clips and leaded cable.
- Scrapped brass and bronze such as plumbing fixtures
- Auto radiators
- Shredder pickings from automobiles
- Spent etchant and pickling solutions
- Circuit-boards
- Spent catalyst, including metallic copper
- Waste water and other sludges (F006 wastes)

Metal finishing facilities. Although beyond the scope of this paper, a brief mention should be made of the metal finishing industry and its contribution to the flow of secondary copper by-products. There are over 31,000 metal finishing facilities in the United States, a modest proportion of which uses copper products. They vary in size, age and type of operation. Typical wastes generated include industrial wastewater and treatment residues (sludges), spent copper plating and process baths, spent cleaners and waste solvents and oil. The metal-laden sludges (F006 wastes) generated at these plants provide a source of copper and other metal raw material for some hydrometallurgical recovery plants.

Flow of Materials

Summary of scrap flow. The chart in Figure 9 shows the flow of purchased secondary copper-base materials from the various sources to the final manufacturing destination. The chart traces the scrap flow from old and new, unalloyed and alloyed, and low-grade copper scrap types as they are processed from sources through secondary smelters, refineries, ingot maker, brass mills, foundries to final products. The domestic sources for low grade ashes and residues are the processing facilities (ingotmakers, secondary smelters & refineries, brass and wire mills) themselves. Some low-grade ashes and residues are also imported and exported. Not shown on this chart, but also important, is the significant amount of run-a-round, or home scrap that is used by the industry. At tube mills, this in-house scrap can amount to as much as 30% of the material first poured to make billet and then processed to tube. Since this material generated within the plant can be easily remelted, or fire-refined, much of the home scrap generated is not sold to the open market. Although about 28% of the skimmings and slag and other by-products generated are processed in house, most enter the purchased scrap market. The home scrap environment is similar at a brass mill that is fully integrated. The clean copper alloy scrap generated from milling and edge trimming operations is recycled back to the brass mill casting shop, were it is remelted and cast into cakes and other forms for further use.

A current trend in response to the disappearing secondary smelting industry has been the effort by some ingotmakers and brass mills to process their own by-product skimmings, slag and other residues. It has been estimated that as much as 28% of the slag and skimmings generated are reprocessed in house. Home scrap data will not appear in the published data on purchased scrap since it never leaves the plant and is not purchased or sold. It forms an essential part of the production process, however, and is commonly known as run-a-round, since this is what essentially happens. This particular scrap source goes around and around and is not considered a "new" source of copper supply. As a useful reference, the purchased scrap data collected by the U.S. Geological Survey for 2008 are shown at the major points to indicate the gross weight quantity of scrap processed. Most of the numbers used in this flow sheet can be found in the tables included with this report. Others are published in various U.S. Geological Survey reports (2008 Minerals Yearbook and Mineral Industry Surveys).

As a point of interest, it can be noted on the flow sheet that about 2.9 million tons of mill and foundry products equate to about 835,000 tons of new scrap returned for use in 2008. These figures would indicate about a 29% return of mill products as new scrap. Exports on this diagram are presumed to be mostly old scrap, since the amount of old scrap consumed by the domestic industry has decreased significantly in recent years. Most of the facilities that once processed significant quantities of old (end use) scrap have closed and, in large part, this scrap is being exported. Chemical products are generally used and dissipated. Copper sulfate is the only chemical product shown in this flow diagram but other products such as about 25,000 tons per year of copper oxides and hydroxides are also produced and generally dissipated where used. A large proportion of U.S. produced hydroxides and oxides are exported annually. See Table 10A, where 28,240 tons of oxides and hydroxides were exported in 2010.

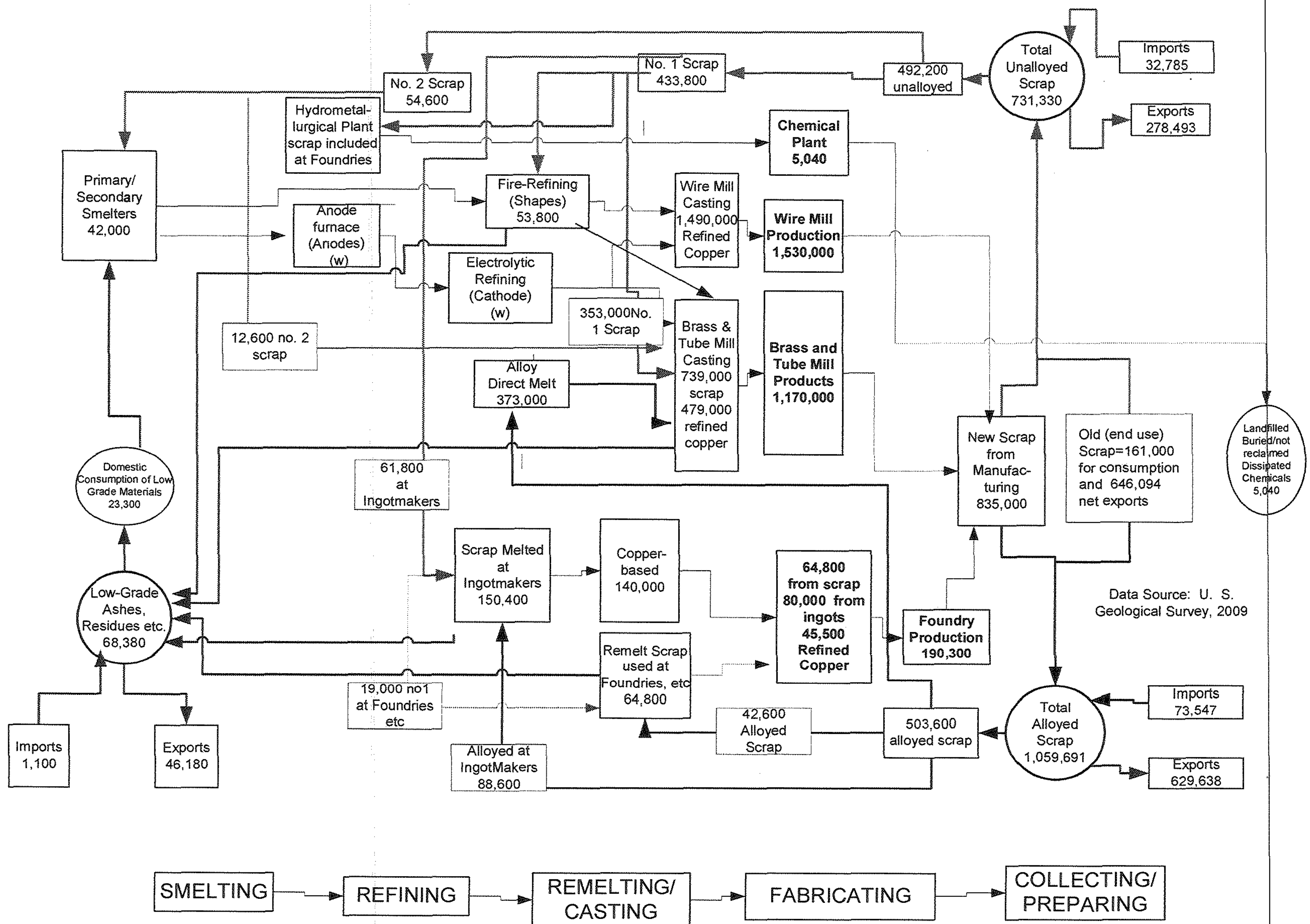


FIGURE 9. U.S. COPPER AND COPPER ALLOY PURCHASED SCRAP FLOW CHART for 2008 (metric tons, gross weight.)

Total U. S. Scrap Consumed: 995,800 tons

CHAPTER 2: Overview of Scrap Sources and Types

Scrap Sources and Types

The Institute of Scrap Recycling Industries, Inc. (ISRI) recognizes about 53 classes of copper and copper alloy scrap. The organization publishes a scrap specification circular that details guidelines for nonferrous scrap. Although there are several grades within each, the major unalloyed scrap categories are No. 1 copper (common names – Barley, Berry, Candy and Clove), which contains greater than 99% copper and often is simply remelted, and No. 2 copper (common names – Birch, Cliff and Cobra), which usually must be re-refined. No. 2 copper consists of unalloyed copper having a nominal 96% copper content (minimum 94%) as determined by assay. Light-copper scrap (Dream) contains between 88% and 92% copper. All grades are clear of excessively leaded, tinned or soldered copper scrap and bronzes and brasses, etc. Refinery Brass has a minimum of 61.3% copper and maximum of 5% iron and consists of brass and bronze solids and turnings, and alloyed and contaminated copper scrap. Copper alloy scrap of various types may be classified by alloy type, or by end-use derivation, since certain alloys are consistently used for the same machine part or other useful item. For example, composition or red brass scrap derived from valves, machinery bearings and other machinery parts is used again for making similar cast items. Red brass scrap should be free of semi-red brass castings (78% to 81% copper), railroad car boxes and other similar high-lead alloys. **Table 15** shows a list of generalized chemical compositions for various scrap types.

Several alloy scrap type groups, such as mixed unsweated auto radiators (Ocean), provide sizeable amounts of copper scrap each year. Other important sources of scrap, by volume, include cartridge cases (70/30 brass) from the military and other yellow brass castings, rod turnings and rod ends. Significant amounts of unalloyed copper are derived from discarded wire, bus bars, clippings and tube. A relatively new scrap type, derived from aluminum/copper radiators, also is finding use among scrap remelters. As shown in **Table 16**, copper derived from new and old aluminum-based scrap has been increasing significantly since 1980. Copper from aluminum-based scrap increased from about 35,000 tons in 1980 to around 74,900 tons in 2007. Copper from all scrap sources increased from 886,000 tons in 1950 to a peak of nearly 1.5 million tons in 1997. Since then, however, copper recovered from total U.S. scrap consumption has dropped to around 851,000 tons per year in 2008. In addition to the many copper and copper alloy scrap types, there are many special types, such as skimmings, ashes, refining slags and residues, which contain 10% to 65% copper. Copper may also be recovered from other mixed scrap of lower copper content, such as electronic scrap, printed circuit and other clad materials, and metal-laden waste liquors. The markets for these products are different from those for the purer grades of copper-base scrap, because they must be reprocessed, smelted or electrowon to obtain the valuable metals contained in them. In the market, products of less than 65% but higher than 10% copper, including refinery brass and low-grade copper-containing materials, have been traditionally processed by copper smelters and refiners or ingot makers.

Several terms have been applied to copper-containing materials with less than 65% copper but more than 10% copper. The U.S. Department of Commerce trade classifications describe this material as "metal-bearing materials used for extraction of metal, with chief weight of copper" (prior to 1989), and "copper materials containing over 10% copper" (since 1989), but they are not listed under primary ores and concentrates. These materials are commonly called copper-containing ashes and residues as a general group, but they contain a wide variety of products that are generated as by-products of copper and copper alloy metal manufacture. In examining the trade lists, it is impossible to distinguish between skimmings, residues or slags containing copper. It becomes even more difficult in the international trade arena with the earlier SITC (Standard Industrial Trade Classification) codes used by the United Nations, which contain other products, lumped together with the copper items.

EPA Secondary Product Definitions

The U.S. Environmental Protection Agency (EPA) plays such a big role in how the secondary industry carries out its business, it is worth reviewing that agency's definitions for secondary products. According to the EPA (40 CFR Chapter 1, 7/1/98 Ed. (261.2)), a material such as process slags and residues is reclaimed if it is processed to recover a usable product, or if it is regenerated. A material is used or reused if it is either:

(1) Used as an ingredient (including as an intermediate) in an industrial process to make a

product. However, a material will not satisfy this condition if distinct components of the material are recovered as separate end products. For example, this is the case when metals are recovered from secondary materials.

(2) Used in a function or application as a substitute for a commercial product such as sludge conditioner in wastewater treatment. Scrap metal is defined as bits and pieces of metal parts. This includes turning, bar, rod, sheet, wire or metal pieces that may be combined together with bolts or soldering (car radiators, etc.) that can be recycled.

A material is a by-product if it is not one of the primary products of a production process and is not solely, or separately, produced by the production process. Examples are process residues such as slags. The term does not include a co-product that is produced for the general public's use and is ordinarily used in the form produced by the process. A spent material is any material that has been used and, as a result of contamination, can no longer serve the purpose for which it was produced without further processing.

A material is recycled if it is used, reused or reclaimed. A material is accumulated speculatively if it is accumulated before being recycled. It is not speculative, if it can be shown that there is a feasible means available for recycling it. There is a 75% turnover requirement for recycling The amount of material that is recycled or transferred to a different site for recycling must equal at least 75% by weight or volume of the amount accumulated starting on January 1 of the period. The 75% requirement is applied to each material of the same type that is recycled in the same way. Materials are no longer in this category once they are removed from accumulation for recycling.

Excluded scrap metal is processed scrap metal, unprocessed home scrap metal, and unprocessed prompt scrap metal. Processed scrap metal is that which has been manually or physically altered either to separate it into distinct materials to enhance economic value or to improve the handling of said materials. Processed scrap metal includes, but is not limited to, scrap metal that has been baled, shredded, sheared, chopped, crushed, flattened, cut, melted or separated and sorted by metal type. It also includes fines, drosses and related materials that have been agglomerated. Shredded circuit boards being sent for recycling are not considered processed scrap metal. They are covered under the exclusion from the definition of solid waste for shredded circuit boards being recycled. (261.4(a) (I3).

In a document issued March 1, 1990, EPA clarified the reclamation of unused, off-specification printed circuit boards. When reclaimed, unused printed circuit boards (30% copper, 68% fiberglass, 2% tin and lead) are considered as commercial chemical products; used circuit boards are spent materials; and circuit board trimmings are by-products. The unused circuit boards are secondary materials. Under 40 CFR 261.2, the Agency designates those secondary materials that are RCRA Subtitle C solid wastes when recycled. According to Section 262.2 (c) (3), unused off-specification commercial chemical products listed in 40 CFR 261.33 are not considered solid wastes when sent for reclamation. They are considered to be non-listed commercial chemical products and, thus, not solid wastes when reclaimed. The printed circuit board trimmings meet the definition of by-product, rather than scrap metal, and are not solid wastes when reclaimed under Section 261.2 (c)(3). Although the trimmings are physically similar to scrap metal, to meet the definition of scrap metal, the material must have significant metal content; i.e., greater than 50% metal.

Home scrap is scrap metal as generated by mills, foundries and refineries, such as turnings, cuttings, punchings and borings. Prompt scrap is metal as generated by metal working and fabrication industries. It includes scrap such as turnings, cuttings, punchings and borings. Prompt scrap is also known as industrial or new scrap metal (See FR 83119, May 19, 1990, and amendments through May 12, 1997 (FR 26018).

By not distinguishing adequately between home scrap, runaround scrap and purchased scrap, EPA has not recognized the market potential of all scrap generated. When a scrap or by-product of any type leaves the plant for a market, it becomes purchased scrap. Purchased scrap of all types is traded at all levels of the industry. Home scrap, or runaround scrap is completely contained and never leaves the plant.

Consumption by Scrap Type.

According to the U. S. Geological Survey, the major copper-base scrap types consumed in the United States during 2008 were: No. 1 copper, (44%); No. 2 copper (6%); yellow and low brass (29%); automobile radiators (2.8%); red brass (4.4%); cartridge brass (7.4%); and low-grade ashes and residues (2.3%) (see **Table 17B**). A wide variety of other alloy scraps makes up the remaining 4.1%. Brass and copper sheet, wire and, tube mills processed 84% of the No. 1 copper and most of the cartridge cases and yellow brass, while the fire refiners and ingot makers processed 68% of the No. 2 scrap and most of the auto radiators and red brass scrap. About 23% of the scrap consumed in 2008 was lead-bearing, including auto radiators using lead solder (27,750 tons), red and leaded-red brasses (43,780 tons) and leaded-yellow brasses (287,630 tons).

In recent years the amount of No. 2 scrap reported as consumed by the U.S. industry has been decreasing. The decrease in No. 2 scrap consumed by U.S. industry is related to several changing factors. One such factor is the significant increase in better quality wire and cable recovery by scrap choppers and processors. More chopped wire is converted to No. 1 scrap quality than has ever before been possible, owing both to an increase in this type of activity and to better technology. Other factors included the lower prices of 1998-2003 (**Table 1**) and increased export competition for such scrap in more recent years.

The consumption of No. 2 scrap decreased markedly at U.S. plants since 2002, as a result of secondary smelter and electrolytic refinery closure. Some primary smelters have been accepting limited tonnage of No. 2 scrap. However, apparently, scrap exports were filling the gap left by the loss of U.S. capacity, as discussed in the previous section on international trade. It has been difficult to quantify the total volume of No. 2 scrap recycled each year, since the only statistics reported for the United States are consumption-based. Scrap traders are not surveyed. Adding exports to the No. 2 scrap consumption statistics also is not a certain solution to compensate for the apparent loss, since these materials have not been always specifically defined as to type in trade statistics. One might use a percentage calculation applied to the unalloyed copper scrap exports based on the ratio of No.1 to No.2 consumption for the years before the demise of the smelter industry. In 1988, the ratio of No. 1 to No. 2 scrap consumed by the U.S. industry was about 1:1, but the ratio has been deteriorating since that time (see Table 17). In 1990, No. 2 was 45% of total unalloyed scrap consumed. Using 45% applied to 2004 exports (325,000 tons) of unalloyed scrap yields a total of 146, 250 tons of number 2 scrap exported. Recent data indicates that the percent of number 2 scrap exported in 2004 was much higher.

Recent U.S. trade reports have been breaking down scrap types exported. In 2004, the Harmonized Trade (HTS) items were reviewed and revised by the U.S. government. HTS 7404000020 (waste and refined scrap from refined copper) has been broken into two Number 1 scrap categories (HTS 7404000010 and --15), two Number 2 scrap categories (HTS 7404000025 and –30). The results of the new trade breakouts are shown for 2005 to 2009 in **Table 8A** of this report. From this table, it can be seen that Number 2 scrap comprised a large share (more than 80%) of the unalloyed scrap exported. Of the total of 308,000 tons of unalloyed scrap exported in 2010, Number 2 scrap comprised 82% of the total. About 215,000 tons of number 2 scrap was exported in 2008. These scrap exports yield an average of about 18,000 tons per month that can be added to the domestic consumption of 4,800 tons per month for a total of 22,600 tons per month of number 2 scrap, compared with an estimate of 51,000 tons per month that was common domestic consumption in 1997 (See **Table 17B**).

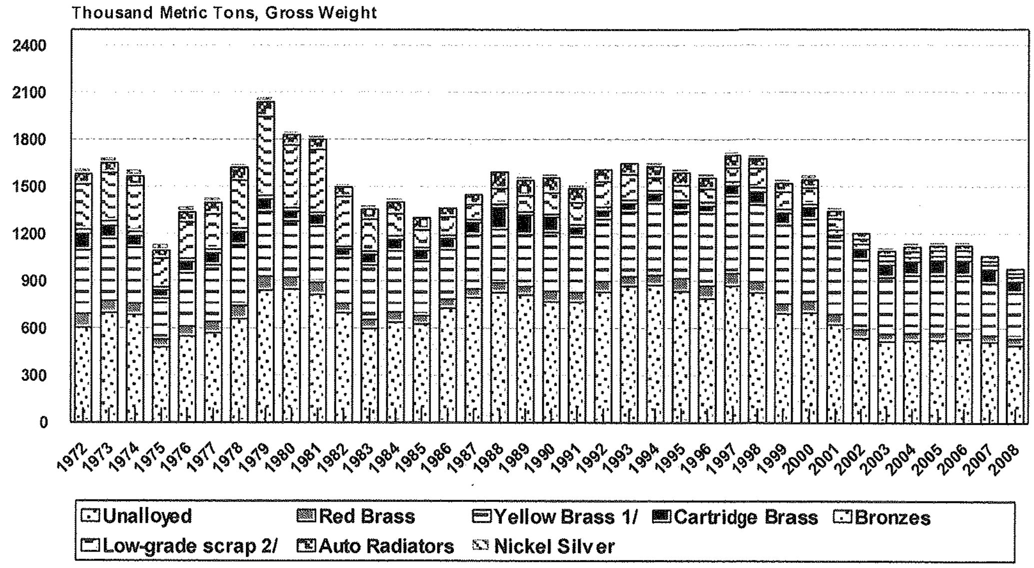
Not surprisingly, China imported 85% of the number 1 scrap and 67% of the number 2 scrap exported from the United States in 2005. South Korea and Taiwan followed with 3% - 7% each of unalloyed scrap imports from the United States. This trend continues.

A few trends in consumption rates, shown in **Table 17** and in **Figure 10**, for certain types of scrap are worth mentioning. The amount of auto radiators (does not include aluminum/copper radiators) consumed by the U.S. industry has ranged between 31,000 tons and 104,000 tons per year since 1970, with the peak occurring in 1988. That amount has been steadily decreasing since 1988 to the current rate of around 27,000 tons. Auto radiators were reported in tight supply by ingot makers during 2009. Yellow (including leaded-yellow) and low-brass scrap consumption steadily increased through 2000. Since 2000, however, yellow brass consumption has decreased to only 287,000 tons in 2008. The yellow brass categories were lumped together in **Table 17** to allow for possible definition changes over the period of statistical collection between types of yellow brass scrap. The amount of bronze scrap consumed has ranged between 18,000 tons and 32,000 tons per year since 1970. Although aluminum bronze scrap has remained at a more or less constant rate of consumption, the number of plants using it has diminished, resulting in this statistic being withheld by the government statistical collectors since 1991.

Cartridge brass consumption reached 131,000 tons during the last three years of the Vietnam conflict (1970–1973). Since that time, cartridge brass consumption has remained in the range of 46,000 tons to 94,000 tons, with the exception of the 1988–1990 period, when consumption reached as high as 140,000 tons during a time of temporary military buildup for Desert Storm. The slight increase in cartridge brass consumption from a low of 36,000 tons in 2001 to a high of 94,000 in 2006 may be the result of the military activity in Iraq and Afghanistan. In 2002, cartridge brass consumption nearly doubled to 70,900 tons from the low point of 36,400 tons in 2001. Cartridge brass consumption was 86,000 tons in 2004 and more than 94,000 tons in 2005 and 2006. In 2008, cartridge brass consumption was down to 74,000 tons in 2008.

Figure 10: U.S. Copper and Copper Alloy Scrap

Consumption, by General Alloy Group



1/ Includes yellow brass, leaded yellow brass and low brass.
2/ 20%-65% copper. Refinery brass is excluded.

Source: U.S. Bureau of Mines, U.S. Geological Survey Minerals Yearbooks and Mineral Industry Surveys, see Table 17B, this report

The amount of marketed low-grade scrap processed in U.S. plants has been decreasing since 1985, as indicated by data collected from the industry by the U.S. Geological Survey and U.S. Bureau of Mines (**Table 17** and **Figure 10**). While the amount of low-grade, copper- bearing materials consumed in 1998 and 1999 was marginally higher than the previous 4 years, it still was only one-third that of the 1970s and early 1980s. Low-grade scrap and residues consumed annually in 2002-2007 was only 35,000 tons, down significantly from 124,000 tons in 1998. This compares with 161,000 tons per year of low-grade scrap and residues processed in the United States in 1992 and 1993. Consumption of low-grade residues was reported to be 23,300 tons in 2008, according to the U.S. Geological Survey (2008 MYB).

Scrap consumption was lowest during the recession years of the middle 1970s, early 1980s, and again in 2001–2003. Some of the underlying causes for these trends are discussed in Chapter 1 and in Appendix A. In particular, lower copper prices and the closure of adequate processing capacity for domestic copper-bearing scrap has been responsible for many of the observed declining usage trends. In recent years, foreign competition for U.S. scrap materials also has been a considerable factor bearing on the reduction in scrap consumption by U.S. industry.

Scrap available for collection was also impacted by the slowdown in domestic manufacturing and construction activity over the period 2007-2010. Construction activity in North America began to taper down after a peak reached in 2007, even before the collapse of markets in late 2008. Since then, construction has dropped severely. New construction contract values were reported (Recycling Today, December 2010) to be $506. 9 billion for the first 9 months of 2007, but was valued at only $314.6 billion for the same 2010 period. This performance has played out in the form of less demolition scrap and less scrap from new construction or renovation projects over this period.

Volumes of Scrap Generated

Since 1906, at a rate ranging between 10,000 tons and 1.6 million tons per year, the calculated U.S. cumulative consumption of copper from old and new scrap amounted to 82.9 million tons by 2009. Of this amount, 43% (35.4 million tons) was from old recycled scrap. More will be discussed about these statistical relationships in the next section on life cycles and the scrap reservoir.

In 2008, (USGS, 2008 MYB, Table 6) recycled copper was derived 82% from purchased new scrap generated in the process of manufacture and only 18% from old scrap derived from used products. Copper from scrap recovery exceeded I million tons per year in 1965 and continued to be above this level through 2002, dropping to 800,000 tons in only one year (1975). Copper recovered from scrap has been well below 1 million tons since 2003 (**Table 6**).

According to the U.S. Geological Survey, a total 851,000 tons of copper was recovered from copper base and non-copper-base scrap in 2008. Purchased new scrap derived from fabricating operations yielded about 697,000 tons of contained copper, 84% of which was recovered at brass mills. A manufacturer may generate more than 60% scrap in the form of slippings, trimmings, stampings, borings and turnings during the processing of copper and copper-base products into finished articles. This new, or mill-return, scrap is readily used by brass and copper tube mills to generate new semi fabricates. Secondary materials that require minimal processing commonly are called direct-melt scrap. In the United States, direct-melt scrap provided about 758,000 tons (**Table 2C**), or about 94% of copper (803,900 tons) from all secondary materials in 2009. New scrap made up about 24% of U.S. apparent consumption of copper from all sources (primary and recycled) in 2009 (see **Table 6**). Copper in old and new scrap together comprised about 30% of U.S. apparent total copper consumption in 2009.

The U.S. Government (U.S. Bureau of Mines and the U.S. Geological Survey) has long collected data from plants consuming purchased low-grade scrap and residues. By current definition, this material is comprised of copper-bearing ashes, residues, drosses, skimmings and other materials of less than 65% copper. Long-term trends (**Table 17**) for this statistic, however, are complicated by the fact that the definition has changed subtly several times. Material that might more appropriately be classified as refinery brass or a higher-grade copper material, but less than 65% copper, may also be included in the reported numbers from time to time. In addition, some slags and residues from primary copper processing may have also been included in some of the historical data. It also should be emphasized that this number reflects only the marketed component of this material as it is consumed, it does not count the same material as it is generated and reused as home scrap. It also does not include exported materials.

The purchased scrap market for domestically shipped, low-grade copper ashes and residues may be estimated by using a formula that adds exports to the amount reported as consumed and, then, subtracts imports to eliminate the foreign component. Using this procedure, the domestic industry low-grade scrap shipments are estimated to have ranged between 31,000 tons and 169,000 tons gross weight per year over the last 17 years (**Table 9**). Copper content of this material ranged between 11,000 tons and 60,000 tons per year. This is the approximate size of the purchased scrap market within the low-grade copper scrap category. These statistics do not include any of the materials that are processed in-house as runaround scrap. Both exports and domestic consumption reported for low-grade residues have diminished in recent years, especially since 2001. This coincides with the shutdown of US secondary smelters, but is also, In part, a result of secondary plants recycling more of this type of material internally where possible. New production methods that have been implemented specifically to cut down on the volumes of residues created have also been responsible. The goal is, generally, that only the most innocuous and uneconomic material will leave the plant for a landfill or purpose other than metal recovery. The severe drop in domestic market consumption of low-grade reflected the closure of the last U.S. secondary smelter in 2001.

The data in **Table 17** show a distinct reduction in U.S. consumption of low-grade material as purchased scrap beginning in the early 1980s. Reduction in the use of low-grade material for industrial feed coincides with several events over the period: (1) capacity cutbacks and decreased use of reverberatory furnaces by the primary copper industry, and (2) the closure of secondary smelters. The increased use of flash furnace technology by the primary industry, which relies on a high sulfur content of the ores processed to maintain a high heat, has lessened the use of low-grade scrap by the primary industry. Previous primary smelters, such as the AMAX smelter at Carteret, New Jersey, were significant consumers of low-grade scrap and residues prior to the 1980s. Low-grade scrap, residues and slag are currently exported or consumed by the several ingot makers who may have cupolas, reverberatory or other furnaces adequate to handle these materials. In the 1970s, the U.S. smelting and ingot-maker industries were consuming 300,000–500,000 tons of low- grade scrap and residues. This compares with a rate of about 80,000–100,000 tons in the 1990s, and only 35,000 tons per year since 2001. Special surveys were made by the Copper Development Association in 1994, and again in 1999, for by-product information. The combined response rate for the two surveys was about 72% for the brass mills, 62% for the ingot makers, and about 15% for the foundries, based on the total production for each group. The data were aggregated by industry group and matched with similarly aggregated production data provided by the U. S. Geological Survey. The result was statistically adjusted to derive a full industry estimate for 1998.

While most fire refiners were included in this survey, two of the secondary smelters were not. It might be presumed that most of the low-grade residues produced by these firms are recycled in-house.

It is interesting that the total production of these products, as shown in **Table 18**, for 1998 is similar to the total low-grade, purchased ashes and residues scrap data tracked by the U.S. Geological Survey (see Table 17B). This observation lends credence to the reliability of both sets of data. The total by-product production shown in Table 18 is larger than the purchased scrap data of the USGS, owing to the fact that some home or runaround scrap is included in Table 18, but not in the USGS data. It was estimated that at least 28% of the skimmings and slags are recycled in-house, as indicated by the reports.

Not surprisingly, the brass mill group (including tube mills, wire rod mills and their associated refineries) was the source for most of the by-products surveyed. Next in size, and commensurate with its share of scrap consumed and types of processing, was the ingot maker group. Though their numbers are many, the total amount of by-products generated by copper-base foundries is small compared with the rest of the secondary processing industry.

A wide variety of by-product materials were reported, not all of which could be classified into uniform product groups. Reported drosses included a variety of copper, nickel and brass drosses. Other products included in other residues of **Table 18** are copper residues from refinery and pickling processes, water pit and other sludges, anode recovery solids, machine shop turnings, cupola flue cleanout, afterburner dusts, scalper dusts, other reclamation dusts, metal skimmings, mill scale, and copper cathode recovered from pickling solutions. Of all the products reported, very few were indicated as being sent directly to a landfill; most firms were able to find some market or other processor that could accept it as useful material. Most were sold to ingot makers, secondary U.S. and foreign smelters, hydrometallurgical plants, concrete makers and zinc smelters, or they were shipped for direct use as agricultural products and animal feed.

The zinc oxide dust reported in this survey was shipped to zinc processing and smelting firms such as Zinc Corporation of America, Big River Zinc, M&M Metals, Phillip Environmental Services, American Micro Trace and the Horsehead Resources Development Co. The zinc oxide was most often shipped in 55-gallon steel drums by truck. However, some companies prefer to ship zinc oxide in 2,000-pound plastic bags (supersaks). Most zinc oxide is sold; very few reported the occasion to dump it.

Secondary smelters such as Chemetco, and Franklin Smelting and Refining (both of which are now closed) were significant purchasers of furnace slag and skimmings shipped. Some of this material also was exported to Noranda in Canada. The furnace slag and skimmings ranged between 8% and 65% copper, up to 6% tin, up to 25% zinc, and less than 5% lead. Spent furnace brick is often sent to the landfill, but it generally contains less than 1% of all elements (Cu, Sn, Zn, Pb, Cd) analyzed and, thus, does not require special permits for handling. The only products shipped as hazardous included some low-grade metal oxide dust, baghouse dust and some furnace and refractory bricks. Elements such as cadmium and lead usually caused the product to be classified as hazardous, when these were present in significant amounts.

The average product yield from certain melts was the subject of a 1961 U.S. Bureau of Mines research report (Spendlove, 1961). According to this study, the following products may be expected from processing 190,000 tons of brass and copper scrap in a tilting, cylindrical reverberatory furnace. The melt had the following average composition: 84.5% Cu, 4.4% Sn, 5.25% Pb, 5.4% Zn, 0.15% Fe, 0.22% Sb (from babbitt in tin scrap), and trace Al and Si. Also added were 2000 pounds of zinc, tin and lead metal, and 4,000 pounds of flux. From this mixture, about 178,000 pounds of brass ingot resulted, with a 93% metal recovery rate. In addition to the ingot, about 10,000 pounds of slag was produced as a by-product. The slag had an average composition of 20% zinc oxide, 20% iron oxides, 35% silicon dioxide, 20% copper prills, 5-8% copper oxide and small amounts of cadmium oxide, magnesium oxide, and aluminum oxide. Estimated losses, gases, dust and other residues amounted to 1,600 pounds.

Spendlove (1961) also reported that in producing 85-5-5-5 red brass ingot from a 50 ton-per-day rotary furnace, the following charge is typical: 50.3% red brass solids, 18.5% red brass borings, 13.7% radiators, 7.6% light copper, 3.9% hard brass borings, 3.7% spatters, 0.5% scrap lead, 0.1% phoscopper and 1.7% nonmetallic. The following can be expected to be produced from this charge: 89.8% red brass ingot, 7.2% slag, 1.8% splatters and 1.2% losses (gases, dusts, etc.).

Use of Home Scrap

At Brass and Wire Mills. All copper and brass mills use home scrap derived in the process of making wrought products. Considerable home scrap can be derived from the process of making brass or tube mill products. Whether or not the scrap is used for direct melt back into the melting furnace depends upon its character at the time of collection. Dirty or contaminated scrap cannot be used directly, but good, clean scrap of known composition can be, and is used. Most home scrap generated within the brass mill or copper tube plant is reused in house and also is called runaround scrap. As much as 30% of the material poured for making tube ends up as home scrap generated in the process of making tube. This material is reprocessed in a fire refinery at the plant when one is available. When pure enough, such as scalper residues from cleaning billets and tube ends, it can be put back into the production process directly. It is otherwise sold as No. I or No. 2 scrap for processing and use outside the plant of origin. Wire mills must be more particular with in-house-generated scrap, requiring a fire-refining step before reintroduction to an Asarco shaft furnace for recasting. Items such as flue dusts, drosses and other minor materials generated are not usually runaround, since these items may be shipped to other companies for reprocessing. Home scrap ceases to be runaround scrap when it is sold to another plant for further processing. The scrap is then referred to as new purchased scrap, entering the secondary materials market for trade. The marketed drosses, skimmings and other residues are new purchased scrap.

At Secondary Smelters and Refiners. The by-product scrap generated at smelters and refiners, such as slag, flue dusts and spilled metal, can be partially or wholly reprocessed in-plant. Some, such as the flue dusts generated, must be sold or shipped to other facilities for treatment and disposal. Slag is often sold into a direct use market, but depending upon its metal content, may also be reprocessed in the home plant, sold to other smelters or locally landfilled. Some slag resulting from fire refining of scrap can contain as much as 65% copper and, thus, is a very desirable and marketable product.

At Foundries. Every foundry generates scrap returns from gating systems, risers, and occasional scrapped castings. A shop with its own machining and stamping operation will also produce considerable quantities of turnings and borings. It is common practice to absorb these materials in the melting operation as a portion of the charge makeup, rather than to use a 100% return charge. However, gates and risers from sand castings may not be completely clean of mold materials and other contaminants; turnings may be covered with cutting fluids; residual deoxidizers or impurities may be building up in the return materials. Each of these can contribute to casting defects and are not normally used without preparation. With successive remeltings, there will be a decided trend toward the gradual loss of volatile elements, such as zinc, as well as an accumulation of contaminants, such as iron. Depending upon melting and subsequent deoxidization practices, the level of residual phosphorous in the melt may rise to undesirable levels. Thus, a consistent monitoring of internal scrap composition should be made before reuse. A particularly serious contaminant in the case of copper-tin-lead-zinc alloys is aluminum. Unfortunately, aluminum beverage cans and foil wrappers may accidentally find their way into the charge material. When this happens, not only are serious problems generated in the melt, but also such metals must be discarded and resold to a smelter, since their reuse could cause the same problems over and over. Many foundries restrict the use of these materials to confined areas.

Use of Purchased Scrap

When purchased scrap is used, a complete analysis of each melt is necessary to assure freedom from contamination. Some forms of purchased scrap are relatively reliable such as heavy copper wire, bus bar or automotive radiators. Obsolete old scrap from certain sources and applications also may be reasonably reliable. However, in some cases, it will not have been properly sorted and, therefore, if used directly, could result in contaminated heats. The increased use by the U.S. consumer of imported faucets, tube and other products made from foreign-made alloys has increased the need for constant vigilance of the scrap purchased. Most ingot makers and mills must have sophisticated procedures for analyzing purchased scrap, adding to the cost of using this material. Purchased customer-returned scrap to brass mills can usually be presumed reliable for direct melt, but even these must be closely monitored. Product specifications call for a very low content of certain elements, such as aluminum and silicon. In the red brass series, for example, the maximum acceptable levels of aluminum and silicon are 0.005% and 0.003%, respectively. Meeting these specifications is achieved by controlling the composition of the scrap charged to the furnace. Impurities such as iron, sulfur, cadmium, bismuth, phosphorus and manganese can be removed by various techniques involving oxidation and the use of slags.

Life Cycles and the Theoretical Resource for Scrap

The availability of secondary copper is linked with the quantity of copper consumed and product life cycles. Many estimates for life cycles have been made for individual products. Product life cycles may even vary from country to country according to construction methods and concepts. However, copper in electrical plants and machinery generally has been estimated to average 30 years; in nonelectrical machinery, 15 years; in housing, 45 years; and, in transportation, 10 years. The average useful life for copper products is said to be about 25 years before being scrapped and entering the market as old scrap.

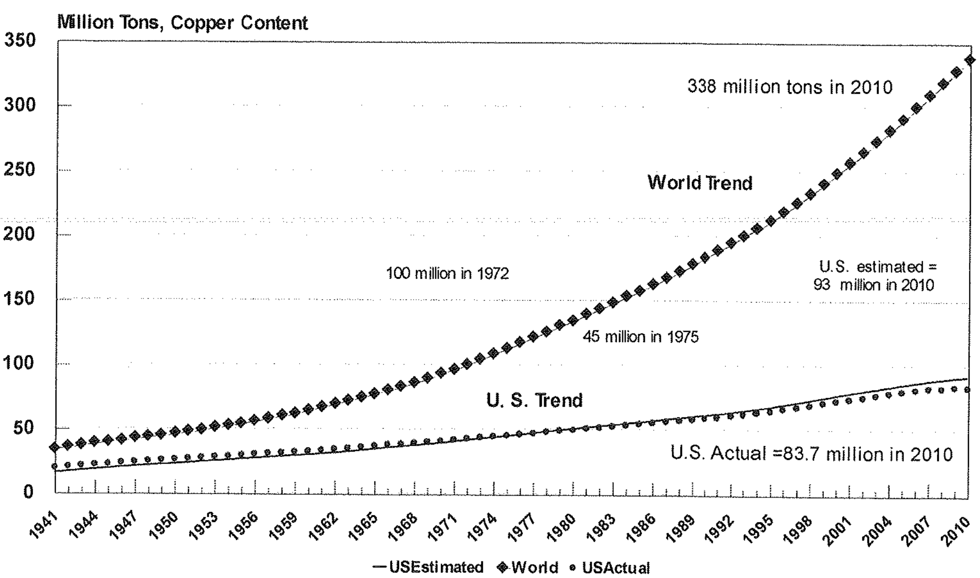
Keeping these longevity measures in mind, it is not hard to visualize that copper being recovered today is from scrapped items that were produced for use about 25 years ago. New (manufacturing) scrap, on the other hand, has a short life of about 30 days, and domestic manufacturing rates and efficiencies limit its recovery. This wide difference in turnaround and availability, in addition to the growing manufacturing base from which it is generated, has resulted in a gradual increase of new scrap versus old scrap collected in the United States since the 1930s (**Table 6**). The rate of copper consumption in the United States and the world has more than doubled since the 1960s. Scrap copper (old and new) has made up more than 40% of annual U.S. copper consumption over most of this period, only dropping below 40% since 1993 (**Table 6**).

The current downward trend in scrap copper consumption was coincidental to the significant increase in consumption of primary (mined) copper since the early 1990s, and the lower copper prices 1998 through 2003. Following this trend was the decreasing rate of semi fabricate production in the United States since 2000. Semis production was 1 million tons lower in 2007 than in 2000, see Table 10. Scrap comprised only 30% of total U.S. copper consumption in 2007 (See **Table 6**).

Though copper is one of the most recycled of metals, some still enters solid waste disposal sites. Copper that is not recovered from end-use products may be placed in one of three categories: (1) still in use, or buried and unaccountable, (2) solid waste disposal, (3) dissipated and lost. Recovery of copper from the first two categories is always possible with adequate incentives and technology. Copper has few applications that are dissipative in nature, such as in chemicals, paints and some powders. It has been estimated (Carrillo, 1974) that in 1970 only 0.5% of total copper consumed was lost and not retrievable. Most copper is used in some metal form, easily recognizable and easily recoverable. Some household products such as toasters, motors, TVs, electronic equipment, etc., may have been dumped into landfills in the past, rather than collected or sold for their metal content. However, with the current emphasis on the selection of household and municipal-dump items for recycling, the amount of copper actually placed in a

Figure 11. U.S. and World Copper Resource for Old Scrap

Pool of Copper Materials In Use



Sources: JJolly, Jan. 2011. McMahon, 1965
World Resource= Copper mine production increase less 40% deducted for: recirculating scrap(25%) and process losses (15%)
U.S. estimated Resource= Primary copper consumption increase less 25% for annual recirculating copper.
U.S. Actual resource = Primary copper consumption increase less annual reported new scrap generated (1864-2009)

landfill is probably not only small, but is diminishing.

The variances in estimates for the amounts recycled are directly related to a lack of reliable data as well as to the procedures used for making the estimations. Because time is always a factor, it has been difficult to quantify how long a product has been in use and how much of it was recovered over what time period. Some have estimated copper not recovered to be as high as 50% of all products reaching the end of a useful life. However, other estimates have suggested that the recovery (recycle or reuse) rate may be in excess of 70% for copper products no longer in use. Because, generally, it has been cost effective to collect, prepare and sell copper-base scrap over recent years, a much higher percentage of copper may be recovered from outcast products than may have been previously estimated. It is widely known that it may not be cost effective at all times to recover some buried cable and pipe, and, thus, it may remain buried for years. Even so, the metal is not destroyed or dissipated and may eventually be reclaimed, if recovery cost and incentives are right.

The estimated resource calculations made below, and in **Table 6A** indicate that more than 65% of total primary copper consumed in the United States has been returned and reused as new and old scrap over time. This calculated scrap recovery rate was as high as 70% between 1989 and 1994, but has dropped currently to around 64%. This change undoubtedly is related to the drop in old scrap consumption, as reported for the United States. The rate of old scrap recovery (52%, including exports) from the calculated primary copper end-use resource has been decreasing since a peak of 54%, which was reached 1991- 1993.

The rate of old scrap recovery is limited not only by copper's long life and its essential uses, but also by the sensitivity of scrap collection to market prices. When copper prices are depressed, old scrap tends to be less available and is directly related to the cost to recover and process it. The distinct decrease that is observed in the old-scrap to new-scrap recovery ratio since 1990 (**Table 17B**) has more than a price relationship attached to it. Since the closing of all secondary and primary copper reverberatory smelters occurred over this time period, one can only assume that the sharp drop off in consumption of old scrap over the same period is related to the decrease in adequate processing capacity in the United States. Once sought out for its metal content, this material is either being exported, or it is not being collected for consumption. U.S. copper and copper alloy scrap exports have increased significantly in recent years and might logically be presumed to be mostly old scrap. At the same time, new scrap recovery has been increasing at a rapid pace in tandem with the higher rate of copper consumption and manufacturing.

Resource Theory and Calculations. Primary (mined) copper forms the only contribution to a theoretical accumulating resource base. Most of the copper ever extracted from the earth can be determined by using primary copper consumption or production statistics that have been collected and published over time. However, scrap, old or new, is excluded as a primary constituent of the theoretical resource base, since no new (primary) copper can be generated from it.

According to McMahon (1965), a large reserve for secondary (recyclable) copper, in the form of recoverable end-use products, has been accumulating in the United States and in the world. This end-use resource is continually being augmented because of consumption patterns and the indestructibility of copper. Each year, copper in the form of old scrap is recovered from this reservoir. In the United States, old scrap copper recovery in 1960 comprised about 21% of annual consumption, but more recently it has been much lower. Not counting old scrap in exports, old scrap comprised only 8% of U.S. apparent consumption in 2008. In 1960, McMahon also estimated about 25% of annual consumption was new scrap that was generated from fabricating and manufacturing semi finished and finished products. McMahon recognized that new scrap copper does not form a reservoir supply to supplement production of primary copper. New scrap such as defective castings, clippings, punchings, turnings, etc., represents a circulating quantity of copper previously accounted for as a supply of primary copper and returned to the fabricating process without reaching the product stage. It is, in effect, 100% recycled. Even so, data on the movement of new scrap have significance as indicators of business activity in the fabricating and scrap reclamation industries.

The resource estimation procedure adopted by McMahon deducts an estimate of 25% annually from the cumulative series of primary copper consumed. McMahon (1965, Table 10, p. 77). The estimation procedure also purposely does not include old scrap in the calculations. Although McMahon does not specifically identify the 25% deducted for unused primary copper as new scrap, it is here presumed to be the case, based on his detailed description of scrap relationships. In other words, he presumes that only 75% of the primary copper consumed each year goes to the end-use market, and 25% of it does not. This copper has not been dissipated or lost, but has been recirculated and recycled in small amounts every year.

McMahon's calculation procedure provides a resource base of end-use copper from which to retrieve old scrapped items. Using the above estimation method, the U.S. industry's contribution to the secondary materials reservoir of items in use, or abandoned in place, has increased from about 14.5 million tons in 1940 to around 93 million tons in 2010 (see **Figure 11**). According to McMahon (1965, Table 10, p.75), about 52% of the end-use reservoir so calculated had been returned and reused as old scrap by 1960.

McMahon's method for estimating the world resource involved a simple ratio equation based on the assumption that the rest of the world consumes copper in much the same manner as the United States. Using this formula with cumulative world copper consumption, as McMahon suggests, yields some 314 million tons of copper for the resource base in 2002. This estimation is a little too high, however, because the consumption statistics used for the world include copper from scrap.

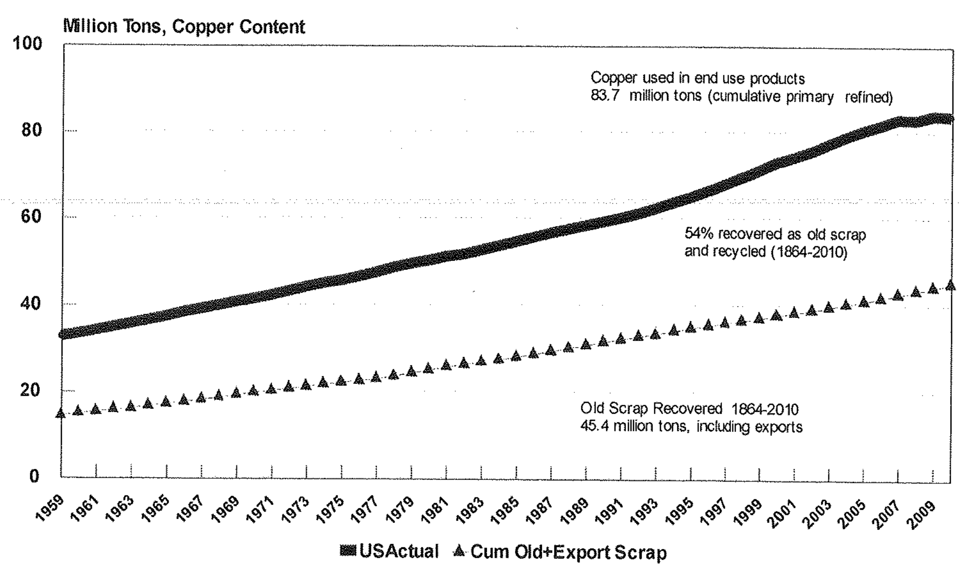
Since imports and exports between countries are not an issue, it is not necessary to use consumption statistics to estimate the end-use (old-scrap) resource base for the world. We can use, instead, statistics for either world primary refined or mine production. Mine and smelter production are used for this paper because these are the longest, most reliable, historical statistics available. The primary world end-use reservoir also does not include the pool of new scrap that is recycled and reused every year. Therefore, an estimated 40% is deducted annually from the world production of primary mined copper to account for (1) processing losses and (2) for recirculating scrap. Because new and home scrap are, by definition, almost 100% recycled and recovered, 25% is deducted for recirculating scrap that, in theory, never reaches the product reservoir in the year that it is generated. Another 15% is deducted from world mine and smelter production for the process losses incurred in conversion to refined copper. Using world mine production, the world resource of copper in use, in place or buried was calculated to have grown to about 334 million tons of copper (**Figure 11**) by 2010.

The resource of available copper in end-use products for the United States may also be estimated by using actual primary copper and scrap-consumption statistics reported each year, instead of an estimate for new scrap (**Table 6A**). A certain amount of new scrap that is generated as home and mill-return scrap in the United States is sold to other companies for use in their semi fabricating processes. In 2008, the United States derived about 24% of its total copper (primary plus scrap) consumption from new purchased scrap (**Table 6**). See also the data on flow sheet **Figure 9** for gross weight new scrap returned (32%) from copper products produced.

It has been suggested (Thomas Baack, pers. Communication 2005) that because new scrap has a short life span, the potential exists for the same

Figure 12. U.S. Copper Resource for Old Scrap

Pool of Copper Materials In Use, 1959-2010



Source: JJolly, Jan. 2011

USActual = Cumulative primary copper consumption increase less annual new scrap generated (1864-2010).
Old Scrap Cumulative = Cumulative recovery of copper in old scrap returned from end use sector and reused, plus copper in net exports of scrap.

physical quantity to be recorded many times as it passes through a production stream during a year. It might therefore be possible that the real physical quantity of new scrap used each time over and over might be a fraction of the total amount reported as used for the entire year. Hence, if the scrap was returned and reused 4 times per year, for example, the total value for returned new scrap would be 25% of the cumulative amount. This would increase the cumulative end use pool by about 30.5 million tons and reduce the new scrap volume significantly. Application of this applied time philosophy is difficult, but may be worthy of consideration in future research.

Based on reported U.S. annual data, the cumulative primary refined copper consumed in the United States since 1864 amounted to 130.6 million tons by 2010 (**Table 6A**). From this initial mined source, a cumulative 83.7 million tons (64%) of copper from old and new scrap had been returned for consumption by the industry through 2010. New scrap was recycled at rates ranging between 4,000 and 1.5 million tons per year between 1906 and 2010. New scrap made up about 25% of the total copper consumed over the period (see **Table 6**). At the same time, old scrap from obsolete end uses was recovered at a rate ranging between 6,000 tons and 613,000 tons per year, 1906 through 2010. This resulted in a cumulative 45.4 million tons (54% of the end-use resource) of old scrap being returned for consumption by 2010(see **Table 6A**).

In the United States, old scrap copper estimated to be consumed by industry in 2010 was only 150,000 tons. However, by adding net copper in scrap exports (presumed to be all old scrap) to the copper in old scrap consumed by U.S. industry, about 949,000 tons may have been recovered as old scrap in the United States in 2010. Thus, it would appear that about 6 times the amount of old scrap recovered for use by the U.S. industry, also was exported. An increasing amount of old scrap collected in the United States has been exported since the mid-1970s. This can partially explain the consistent decrease over this period in U.S. old scrap consumption, as illustrated in **Figure 13**.

Old scrap derived from finished products has customarily been considered a new resource of copper in the year of reuse, as it re-enters the manufacturing stream. For the purposes of calculating a current year's copper consumption, old scrap is a legitimate augmentation to available primary copper. New scrap, on the other hand, is derived from manufacturing and processing. It has a short shelf life and, in theory, recirculates before ever reaching the end-use market. As McMahon (1965) points out, new scrap does not, at any time, form a reservoir supply to supplement new copper. To include recirculating new scrap in consumption estimates each year by adding it to new mined copper (primary), would present a double-counting problem, as the same (primary) copper goes through the processing chain over and over, never reaching the end-use market. Because of this phenomenon, new scrap also is excluded from total copper use annually in order to calculate an estimated primary end-use resource without scrap. This primary end-use resource is the total pool of copper from which to estimate the percentage return of old scrap, which is derived from the copper used in final products.

These calculations yield an estimated 83.7 million tons of copper accumulated over the period 1864 through 2010 as the U.S. resource of copper in manufactured products in use (**Figure 12**). Interestingly, about 54% (45.4 million tons) of this adjusted, theoretical end-use resource had been recovered and reused as old-scrap copper (including exports) through 2010. (**Table 6A**). Net exports of copper scrap were added to old scrap copper consumed by the U.S. industry to achieve a total old scrap yield. Calculations related to the cumulative primary copper resource yield an estimate of about 38% of the resource remains in products in use by 2010. This is derived by deducting the cumulative old scrap recycled from the cumulative end-use resource of 83.7 million tons. This estimate includes items that are still in use, buried or, to a much lesser extent, possibly dissipated. Copper used in chemicals can be presumed to have been dissipated, but beyond this, nothing can be definitively quantified as irretrievably lost. Furthermore, it should be noted that these calculations do not take into account the growing amount of copper in end-use products that enter this country as manufactured goods. The contribution of these finished-goods imports to the scrapped products reported and to the U.S. resource of end-use products is not easily quantifiable or estimated.

The rate of old-scrap recovery from the copper end-use resource increased rapidly prior to 1945, when the rate increased in excess of 1% per year, between 1906 and 1938. The recovery of cumulative old scrap from the total resource was only about 9% by 1914 but had reached 37% by 1938. The rate of copper in old-scrap recovery has been increasing by a little less than 1% per year since 1945 and has hovered around 50% to 54% of the cumulative resource since 1980 (see **Table 6A**). The annual U.S. contribution to the copper reservoir of items in use has been increasing at a rate of 1–2 million tons of copper per year since 1963.

The available copper in the end-use resource may seem large but, as discussed above, the potential rate for retrieval in a uniform and reliable way is limited by many factors. Of particular significance is copper's long life in many of its end uses. With a recovery life of 25 to 45 years, copper items produced in the 1960s and 1970s may only be in the recovery process today. It would appear that a sizeable portion of all copper consumed is still very much in use today. This would amount to around 40% of the so-called, end use resource base, as currently calculated.

Of all world copper (23 million tons) consumed in 2010, 33% was from direct melt and refined copper scrap sources (**Table 2A**). Of the total 7.7 million tons of copper derived from all scrap sources (**Tables 2B** and 2D in 2010, only 3.2 million tons were recovered by refining (42%) and might be considered mostly from old scrap sources. Copper from refined scrap comprised about 13% of total world copper consumed from all sources in 2010. Another 7% of total world copper might also be presumed to be from old direct melt scrap, making a total of 20% of copper from old scrap sources in 2010.

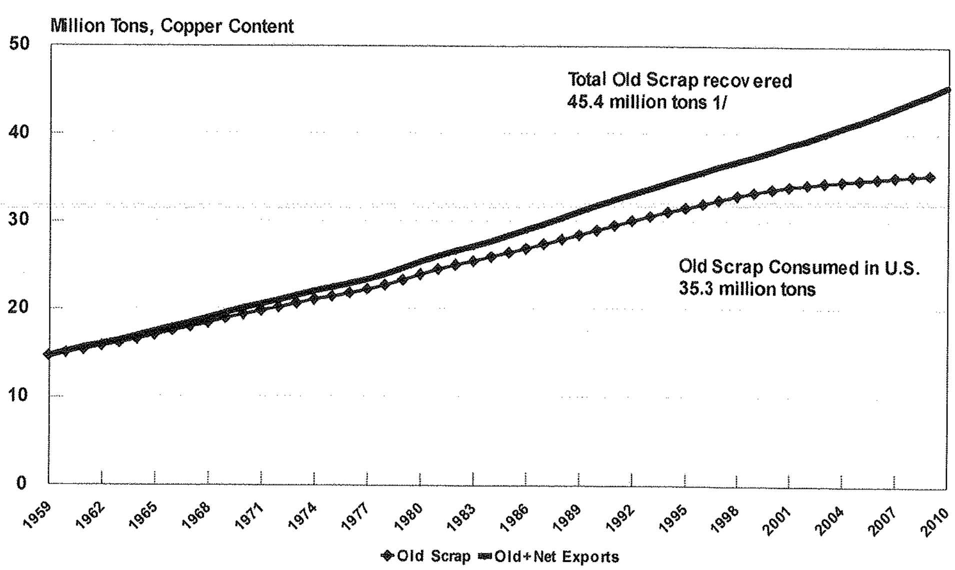
In a paper issued in 2002, several European analysts (Spatari, Bertram et al. 2002) traced the flow of copper as it entered and left the European economy during the course of one year. Russia was not included. Across the life cycle, a net total of 1.9 million tons of copper was imported into Europe. About 40% of cathode produced within the flow system was directly from old and new scrap. It was estimated that about 8 kilograms of copper per person enters the end-use market each year, only 30% of which is in alloy form. They also estimate that the waste management system in Europe recycles about 60% of the copper from "waste." The net addition of copper to the end-use "stock" in the copper flow system is about 6 kilograms per person per year. They conclude that given the in-service lifetime of the applications of copper identified in their flow model, most of the copper processed during the last few decades still resides in use, mostly in nondissipative uses.

The International Copper Study Group recently (2004) completed a study on recycling in Western (ICSG's Copper Flow Model on Recycling Ratios in Europe). One consideration outlined in this paper is a statistical methodology for the estimation of a recycling input ratio (RIR). This recycling input ratio is derived by dividing the total scrap consumed in a region by the total semi fabricates produced. The RIR illustrates trends in the relative amount of scrap used versus primary material in semis production. The RIR calculation is put into perspective for the United States in **Table 6B** of this report and shows a consistent decrease from the mid-1980's through 2000. These statistical trends are the result of several significant events that have occurred in the United States over the past ten years or so.

In addition to a decreased amount of scrap consumed, relative to primary material, the U.S.

Figure 13. Cumulative Old Scrap Copper

In the United States, 1959-2010



Source: JJolly, Jan. 2011
1/ Copper in net scrap exports are added to old scrap consumption.

recycling input ratio (RIR), as calculated above, has been much influenced by the increased amount of copper scrap exported since 2000. To calculate a more complete picture of U.S. scrap use and recovery, total copper scrap exports must be added to the amount of industry consumed scrap reported. Looking at **Table 6B**, a striking trend emerges of a decreasing recycling recovery ratio (ROR) from 1992 forward to 2004. Between the years 1981 through 1993, the rate of recovery (ROR) is consistently over 61%, reaching as high as 81% in 1986. From 1993 forward, however, the rate of recovery is shown to decrease to as low as 46% 1999 and 49.5% in 2002. The rates have been increasing since 2004, reaching 79% in 2010. The higher scrap recovery ratio undoubtedly relates to the higher copper prices since 2004 and the influence of higher scrap exports.

The decrease in RIR shown between 1993 and 2002 in **Table 6B** and rate of recovery (ROR) can be explained by at least two factors that affected the U.S. semi fabricating industry and scrap recovery trends over this period. One was the increased availability and use of primary copper in the production of semi fabricates over much of this period. The increase in primary copper consumption was partially attributable to an increase in wire rod production (which consumes less scrap) vis-à-vis a coincidental decline in secondary smelting of scrap for use in brass mill production (which customarily uses more scrap). Secondary smelting and refining of scrap for use in the U.S. industry has been impacted by plant closures and capacity loss over the past ten years (see **Table 17B**). In addition, primary copper was to become more available at a more reasonable price as copper supplies were in world surplus over much of the 1990's. The second factor is the reduction in amount of new scrap produced by the fabricators as processes became more efficient and streamlined. Because of the surplus supplies and consequent depressed copper prices, less old scrap also was returned to the market, as might be expected. This resulted in less scrap being made available to the U.S. industry for consumption, or for export, over the 1993-2001 period. If the years prior to 1993 can be presumed to be considered more normal, it would appear that a more normal rate for the recycling recovery ratio (ROR) in the United States was in excess of 63%.

During 2005, owing to near term copper market shortages, several articles appeared in the press regarding a possible high percentage of copper already mined as compared with an estimated total copper available in the earth's crust. Since the Paley Commission Report of 1950, there have been many such discussions and reports attempting to resolve the many issues involved with determining the amount of copper resources available in the world. One such report worth remembering is that appearing in U. S. Geological Survey Professional Paper 820, pp 21-25. This 1973 article, entitled "Crustal Abundance of Elements, and Mineral Reserves and Resources", by R. L. Erickson, proposes a methodology for estimating the recoverable amounts of several metals in the earth's crust. The potential recoverable resource for most elements should approach $R=2.45A X 10^{6}$, where A is the abundance expressed in grams per metric ton, or parts per million and R is the resource expressed in metric tons. Those metals whose reserves most closely approach the calculated potential recoverable resource are the metals that have been most diligently sought, such as copper. The formula calculates the minimum total resource available, largely because it relates to currently recoverable resources and does not include resources whose feasibility of economic recovery is not established.

Using this formula (called the McKelvey formula) assumes (1) the Bureau of Mines (now USGS) estimate for world reserves are the correct order of magnitude, (2) that McKelvey's relation of reserves to crustal abundance is valid, and (3) that trace elements are log-normally distributed in the earth's crust. Using the world copper reserves reported then by the Bureau of Mines, Erickson estimated that for 1970 the reported reserves of 200 million tons resulted in a recoverable resource potential of 2.12 billion tons of copper. This contrasts with reported world copper reserves (2005 Mineral Commodity Summary, USGS) for 2004 of 470 million metric tons of copper (and, a reserve-base of 940 million tons). Using this latest data with the McKelvey formula would yield about 5 billion tons of potential recoverable copper, more than double the amount estimated for 1970. Using this minimal resource calculation to compare with the accumulated world consumption figure of 282 million tons (2004) can give us a minimal percent of copper already used from an estimated world resource. The estimated world consumption of 282 million tons is only about 6% of the minimal estimated world resource. A more recent (1998) assessment of U.S. copper resources indicated 550 million tons in identified and undiscovered resources in the United States, more than double the previous estimate (USGS Circular 1178, 2000).

A word of caution -- It is obvious that these reserve/resource numbers are very fluid and change with time. One must read and understand the definitions for reserves, reserve-base and resources to understand the reasons underlying the near doubling of reserves between 1970 and 2004. Absolute amounts are impossible to quantify, thus a definitive statement about the percentage copper already used in the world, compared with that possibly available is at best, wildly speculative. Statements made about running out of the potential for copper ore are irresponsible and generally are made for various political and notoriety reasons.

In testimony before the Committee on Resources Subcommittee on Energy and Mineral Resources in the U.S. House of Representatives (May18, 2006), a spokesman for the U.S. Geological Survey reported that a current study estimated that about 1.1 billion tons of copper will be needed between 2000 and 2020 at current rates of consumption. This will necessitate additional producing reserves equivalent to three times the amount of copper as is contained in the 5 largest known deposits. Although some of this material exists in discovered deposits, much will need to come from yet undiscovered deposits. The need for active exploration and mine development continues.