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Cadmium Recycling in the United States in 2000

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FLOW STUDIES FOR RECYCLING METAL COMMODITIES IN THE UNITED STATES

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ABSTRACT

Recycling of cadmium is a young and growing industry influenced by environmental concerns and regulatory constraints. Domestic recycling of cadmium began in 1995, when International Metals Reclamation Co. Inc. (INMETCO) expanded its operations to include the metal. It is estimated that in 2000 about 13% of cadmium consumption in the United States was sourced from recycled cadmium, derived mainly from old scrap or, to lesser degree, new scrap. The easiest forms of old scrap to recycle are small spent nickel-cadmium (NiCd) batteries, followed by some alloys and flue dust generated during recycling of galvanized steel. Most of new scrap is generated during manufacturing processes, such as diecasting. All other uses of cadmium are in low concentrations and, therefore, difficult to recycle. Consequently, much of this cadmium is dissipated and lost. The amount of cadmium in scrap that was unrecovered in 2000 was estimated at 2,030 t, whereas an estimated 285 t was recovered. Recycling efficiency was estimated at 15%.

INTRODUCTION

The purpose of this report is to show trends in consumption and recycling of cadmium in the United States during 2000. However, the amount of cadmium that is recycled is difficult to estimate for a number of reasons. Because the production data by INMETCO, the only cadmium recycler in the United States, is confidential, important information for this study is not available. An additional reason is that the recovered cadmium from baghouse dust, generated by primary metal smelters, is processed during zinc refining and is usually included in the production statistics for primary cadmium metal. However, the main impediment to a study of cadmium recycling is that data on the amount of spent NiCd batteries in the marketplace is not available.

Cadmium is a soft, silver-white to bluish-white metal produced mainly as a byproduct from the mining, smelting, and refining of other nonferrous metals, mainly zinc. About three-fourths of cadmium is used for batteries, followed by pigments (12%), coatings and plating (8%), and stabilizers for plastics and similar synthetic materials (4%). Because cadmium is a byproduct of other metals, the price of cadmium is not subject to ordinary supply-demand dynamics. If zinc production increases, then cadmium supply will also increase, regardless of cadmium market demands. Since 1995, cadmium supply has generally exceeded cadmium demand, due to overall growth in the zinc market and to tightening regulatory controls. This imbalance has driven cadmium prices to such a level that, for many zinc smelters, it is more financially expeditious to dispose of raw cadmium than to refine it. For cadmium recyclers, most of the profit is in the fees collected from suppliers and not in the price of produced cadmium.

GLOBAL GEOLOGIC OCCURRENCE OF CADMIUM

Cadmium is a naturally occurring metallic element, present in trace amounts in the earth=s crust and oceans in concentrations between 0.001 and 25,000 parts per million and 0.2 micrograms per liter, respectively. The most common cadmium mineral, greenockite (CdS), does not form its own deposits but is usually associated with sphalerite (ZnS), the most common zinc ore mineral. About 80% of cadmium output worldwide is estimated to be a byproduct of primary zinc production. The average ratio between contained zinc and cadmium in sphalerite is about 250:1. The remaining 20% of cadmium is obtained from secondary sources, such as baghouse dust, recycled cadmium products, and from the production of other primary metals, mainly lead and copper (Morow, 2001, p.1). However, it is generally agreed that the cadmium in lead and copper ores is associated with the zinc sulfide present rather than with the other minerals.

The temperature of formation of zinc deposits has a partial bearing on cadmium concentration. In general, contact metamorphic and irregular replacement deposits formed at relatively high temperatures have less cadmium content than intermediate hydrothermal ores and sedimentary deposits.

Cadmium-containing zinc deposits occur in many diverse geological environments. Contact metamorphic or skarn deposits are deposits contained in metamorphosed sedimentary rocks, often limestone, which have been altered and enriched by zinc- and cadmium-bearing solutions from adjacent igneous intrusives. These deposits are usually low in cadmium, and U.S. deposits of this type are not important zinc or cadmium sources.

Another type of deposit, which is an evolution of the contact-metamorphic deposit, is the irregular replacement deposit. In these deposits, which tend to be higher in cadmium content, ore solutions migrate considerable distances from the igneous source. These zinc- and cadmium-bearing solutions seek out weaknesses in the surrounding rock and form irregularly shaped replacement deposits.

Vein-type deposits occur as tabular masses filling faults and joints in the host rock. Generally, these deposits have straight walls. As zinc- and cadmium-bearing solutions move away from the point of origin, they deposit metals as a result of local temperature and pressure conditions. Hence, cadmium may be enriched greatly in certain parts of the deposit and depleted considerably in other parts.

Strata-bound-type deposits are the most important commercially. In platform carbonates, they occur as thin zones of replacement mineralization or breccia fillings. These are the classic Mississippi Valley-type deposits, which may cover several hundred square kilometers. Metamorphic equivalents of such deposits generally have mineralization in lenticular masses and are generally lower in cadmium. Stratiform deposits involve mineralization that forms lenticular masses at the contacts of metamorphosed sedimentary and interbedded volcanic rocks. Cadmium concentrations in these deposits are low to intermediate (Plunkert, 1985, p. 112-113).

PRIMARY PRODUCTION AND PROCESSES

By the end of 2000, only Pasminco Ltd. was producing primary cadmium, at its zinc smelter in Clarksville, TN. Big River Zinc Corp., Sauget, IL, ceased production of cadmium in 2000, owing to low cadmium price. It was more economically expedient to dispose of raw cadmium in the slag than to process it. Both companies used an electrolytic process and recovered cadmium as a byproduct during the roasting and leaching of zinc concentrate. After removal of various impurities, cadmium is electrowon to a 99.99% or more purity and cast into 50-millimeter (mm)-diameter balls or 250-mm-long sticks, or is oxidized to produce cadmium powder.

SOURCES OF SECONDARY CADMIUM

OLD SCRAP GENERATED

Because data are not available on trade in NiCd batteries, and imported batteries are a major source of old scrap generated, it is difficult to make an estimate of old scrap generated. Based on calculations of the amount of cadmium recovered and Fishbein=s estimate (Informinc, undated) of cadmium discarded in 2000 in household batteries and appliances, old-scrap generated is estimated at 2,400 t.

Over the past 30 years, cadmium applications have shifted steadily away from coatings (which accounted for about 50% of consumption in the 1960s) to NiCd batteries, which accounted for about 75% of consumption in 2000 (Plachy, 2001). Consequently, spent batteries are a major source of recycled cadmium. The recycling rate for spent batteries varies according to battery size. It is estimated that about 80% of large industrial batteries, containing about 20% of all cadmium used in batteries, are recycled, but only about 20% of small consumer NiCd cells and batteries are recycled (Hugh Morrow, President, International Cadmium Association, oral commun., 2002). The calculated recycling rate for cadmium in the United States was 13% in 1998. (See Appendix for definitions). Figure 1 shows the estimated quantity of old scrap generated, and the flow of this metal through processing and use.

There are two major categories of batteries that are recycled: wet cell and dry cell batteries. Most wet cell batteries are lead-acid batteries primarily used for motor vehicle purposes. Dry cell batteries, also known as consumer batteries, are either primary or rechargeable. About 80% of rechargeable batteries are made of nickel and cadmium. In 2000, an estimated 3.5 billion consumer batteries were sold in the United States, of which almost 10% were NiCd batteries (Informinc, undated ' [1]). The market for rechargeable batteries is growing faster than the market for non-rechargeable (primary) batteries mainly due to increased sales of portable and cordless products. About 80% of all rechargeable batteries are not sold separately but instead are inclosed in consumer products. These products require a broad range of power requirements, from low power drain (for example, portable computers) to high power drain (power tools). For low power drain applications, the NiCd batteries are gradually losing market share to batteries using new technologies, such as nickel-metal hydride (NiMH) and

[1] References that include a section twist (') are found in the Internet References Cited section.

lithium-ion (Li-ion) batteries. For high power drain applications, such as power tools, nearly all batteries are still NiCd.

Quantities of other sources of secondary cadmium, such as electric arc furnace dust (flue dust), electroplating wastes, filter cakes, and sludges, are small and diminishing because of low cadmium prices. The amount of these other sources was not available for this study.

Figure 2 shows how the share of various end uses of cadmium has changed since 1980, with batteries comprising a much larger share and coatings and plating diminishing significantly.

NEW SCRAP GENERATED

Almost all new scrap is generated at the plants that use cadmium, mainly battery manufacturing plants, and is recycled in house. The amount of this recycled cadmium is not available. There probably are some small quantities of new scrap generated at INMETCO, possibly caused if there is an equipment malfunction or some impure cadmium is recycled; data on the quantity of this scrap also is not available.

DISPOSITION OF CADMIUM SCRAP

It is estimated that all consumer batteries take up less than 1% of Municipal Solid Waste (MSW) but contribute a disproportionately high percentage of certain toxic metals - mainly mercury and cadmium - to the waste stream. Mercury has been used as a gas suppressing additive in the batteries, and its use is being eliminated by design changes of batteries. Cadmium, however, is used as an electrode, and therefore is the basic power source of the battery. Any reduction of cadmium would cause a proportionate reduction in the energy output. Consequently, reduction of cadmium in MSW could only be achieved by increased recycling or replacement of NiCd batteries with less toxic alternates. About 2,030 t of cadmium in household batteries are in appliances and were discarded and unrecovered in 2000 (Informinc, undated').

Because a high percentage of NiCd batteries are being discarded, cadmium can accumulate at the MSW disposal site and could slowly leach into ground and surface water from these landfills. In order to lessen or even eliminate the likelihood of environmental contamination, public pressure forced local and federal governments to regulate disposal of toxic materials and encourage recycling of those that are reusable. This has been the main motivating force in the creation of numerous recycling programs for cadmium. Because small, spent batteries are one of the main sources of cadmium contamination when incinerated or disposed in landfills, most of the collection and recycling programs were aimed at NiCd batteries. The first Federal effort at regulation of all hazardous wastes was the Resource Conservation and Recovery Act of 1976. This regulation provided an exemption for residential use: different regulations applied to identical scrapped batteries, depending on who had used them. The Universal Waste Rule of 1995 unified the treatment of all hazardous waste, regardless of the origin. Under the rule, the assumption that NiCd batteries are non-hazardous until they reached the recycling facility was especially beneficial for battery recycling. However, individual States were allowed to accept or reject the new rule. Those states which did not adopt the rule, continued to consider NiCd batteries as hazardous material, requiring special safeguards for transportation through those states. The different requirements by individual States made interstate transportation of collected NiCd batteries to the recycler too expensive. As a result, collection of recyclable batteries suffered, despite of the adoption of the Universal Waste Rule by 32 States by 1996. This obstacle was eliminated with the passage of the Mercury Containing and Rechargeable Battery Management Act (also called the Battery Act), signed into law on May 13, 1996. The Battery Act had two purposes: (1) The phase out of mercury in batteries; and (2) the efficient and cost-effective collection, transportation, recycling, and/or proper disposal of used NiCd batteries, used small sealed lead-acid batteries, and certain other regulated batteries. The Battery Act also established national, uniform labeling requirements for regulated batteries and rechargeable consumer products, and easy removability of batteries in these products, manufactured domestically or imported and sold in the United States. A significant aspect of the Battery Act is that the act is mandatory for all States. This requirement enabled the creation and establishment of organizations for nationwide collection of spent NiCd batteries and guaranteed unhindered transportation of these batteries throughout the United States. These two aspects became the needed impetus for establishment of the Rechargeable Battery Recycling Corp. (RBRC) and the addition of a cadmium recycling facility at the nickel recycling works of International Metals Reclamation Co. Inc. (INMETCO) in Ellwood City, near Pittsburgh, PA. INMETCO is the only facility in the United States that recycles cadmium.

OLD SCRAP RECYCLING EFFICIENCY

Trade in batteries is significant, and data are not available on their trade, particularly on that of NiCd batteries. Since trade is an important factor in estimating old scrap generated and therefore old scrap recycling efficiency, it is difficult to make an estimate of old scrap recycling efficiency. However, based on Fishbein's study (Informinc, undated) and estimates of 2,032 t of cadmium discarded in 2000, a 15% recycling efficiency was calculated. This is believed to be an optimistic evaluation. With improved collection systems, this percentage could be raised significantly.

INFRASTRUCTURE OF CADMIUM SCRAP RECYCLING

Because large quantities of small batteries are discarded, most of collection efforts are aimed at improving the recycling rate of small NiCd consumer batteries. This, however, is proving to be the most difficult aspect of recycling, because changing the attitudes and habits of the public is not easy. In order to make recycling as convenient as possible, several different collection programs have been developed to meet the needs of battery manufacturers and numerous consumers, firms, organizations, and agencies that use many diverse products, such as power tools, cordless phones, and personal computers.

The RBRC and Kinsbursky Brothers Inc. are the two largest organizations collecting spent NiCd batteries. Kinsbursky Brothers is a California-based environmental management company specializing in an integrated waste management and resource recovery programs and services. The company was founded in the 1950s and gradually expanded to new areas, including recycling of lead acid and all non-lead acid battery chemistries, auto and petrochemical catalysts, and precious metal refining. Kinsbursky Brothers= latest expansion, in collaboration with RBRC, was into NiCd battery collection (Kinsbursky Brothers, Inc., undated').

The RBRC, created in 1995 by the Portable Rechargeable Battery Association, is a financially independent non-profit organizationCit generates revenues for the recycling program by licensing its seal of approval to individual companies involved in the manufacture, import, and distribution of rechargeable batteries or battery-operated products. The collection program, called *Charge Up to Recycle!,* contains several key elements required by Federal and various State laws, including uniform battery labeling, removability from appliances, national network of collection systems, regulatory relief to facilitate battery collection, and widespread publicity to encourage public participation. To deal with batteries generated by many different sources, RBRC has set up four separate collection systemsC 1) retailers, 2) communities, 3) business and public agencies, and 4) licensees. Batteries from these collection systems are transported to two consolidation points located in Minnesota and New Jersey. All batteries from these consolidation points are shipped to INMETCO by the United Parcel Service or by national common carriers. In 2000, RBRC and Kinsbursky Brothers collected 1,770 t of batteries (Norm England, Portable Rechargeable Battery Association, oral commun., 2001). Most of the NiCd batteries collected by Kinsbursky Brothers in the 13 Western States were sent to a processing facility in France, while batteries collected by RBRC in the remaining States were sent to INMETCO.

In 1995, INMETCO began reclaiming cadmium from spent batteries and currently produces about 290 t of cadmium metal per year (Cassidy, 2001). The $5 million High Temperature Metal Recovery plant addition, built by Davy International Ltd., was the first facility of its kind in the world. It is capable of processing more than 2,500 metric tons per year (t/yr) of spent NiCd batteries. During the past few years, the amount of industrial batteries that were recycled remained constant, while recycling of small consumer batteries increased and now comprise about 60% of all batteries recycled. In addition to RBRC, which is the largest collector and supplier of spent batteries, INMETCO developed its own collection programs because a larger recycling operation lowers the unit cost of the secondary metal production. INMETCO=S programs were devised to meet the varied needs of battery manufacturers and the numerous consumers, firms, organizations, and agencies that use many diverse products containing NiCd batteries, such as power tools, cordless phones, and personal computers. The most successful collection program is INMETCO=s prepaid container program, in which companies generating spent batteries purchase a 14-kilogram container for collection and shipment of spent batteries. The fee for the container includes shipping by UPS, handling, sorting, and processing. Additional collection programs, initiated by INMETCO, include mail-back envelopes, a small package program, and so called Amilk runs@. The mail-back program is used by companies who want to provide their individual customers with means to recycle their batteries without using a consolidation location. The company sends their customers a prepaid envelope addressed to INMETCO when a new battery is purchased. There is no direct cost to the customer. The small package program is intended for small businesses that are not part of the RBRC program. The transportation cost for this program is the responsibility of the generator. The milk-runs are used by generators that are too far from INMETCO and want to share transportation expenses. In this program, one transporter travels to several sites, usually in conjunction with other trucking business, picking up several drums of spent batteries that happen to be on its truck-route. Because industrial users of NiCd batteries are prohibited from discarding the batteries in municipal waste dumps, they are recycled through collection programs, in which producers of these batteries collect and send their spent batteries to INMETCO (Money, Tomaszewski, and Bleakney, [undated]).

PROCESSING OF CADMIUM SCRAP

The process of cadmium recovery from industrial and consumer sealed NiCd batteries, differs only in the manner of battery preparation. Industrial batteries, containing up to 7% cadmium, are drained of sodium hydroxide electrolyte, the battery tops are cut off, and the nickel and cadmium plates are manually separated. The cadmium plates are washed, dried, and sent to a cadmium recovery facility. Nickel plates, metal cases and retort residues are smelted into remelt alloy pig for the stainless steel industry; they are not recycled by INMETCO. Small sealed batteries, containing up to 16% cadmium, must be hand sorted, because only newer batteries are color coded, and very few of them carry bar codes, making optical scanning and other automated sorting very difficult. At the request of recycling organizations, INMETCO collects not only NiCd batteries, but also other batteries, such as Ni-MH, Li-ion, lead acid, and alkaline batteries. All these batteries are manually sorted by three people, and NiCd batteries are then transported by conveyor belt to a 330-kilograms-per-hour (kg/h) crusher. About 20% of the total weight of small consumer batteries is plastic. It is reduced to about 7%, using magnetic separation of crushed batteries. The remaining plastic cover is burned off at the thermal oxidizer at a temperature of about 500EC. When temperature inside the oxidizer drops to about 200EC, due to new charge, additional burners are engaged.

Since the installment of three original batch-type thermal oxidizer retort vessels at INMETCO in 1995, supply of collected spent batteries soon outpaced the processing capacity and a fourth retort furnace was added a year later. Soon this new addition proved to be inadequate. As battery recycling expanded, bottlenecks that had developed in the recycling flow were eliminated; during the past 3 years, improvements have cost about $3.3 million. First, a continuous-flow rotary thermal oxidizer was installed, capable of processing about 250 kg/h of

NiCd batteries with virtually no operator involvement (there is only one operator for all oxidizers). Second, with a subsequent addition of a mechanical plastic removal mill, the capacity of the new rotary oxidizer was increased to over 500 kg/h. The third project was the addition of three new retort furnaces, dedicated entirely to portable NiCd battery recycling. The last project undertaken was the enlargement and improvement of the small battery receiving and sorting area and improved ventilation of welding fumes at the cadmium recovery equipment repair shop where retort furnaces and crucibles are repaired/welded.

The washed and dried cadmium plates from industrial batteries and the crushed small batteries, from which most of the plastic casing has been removed, are charged into a cadmium recovery furnace, called a crucible. The charge is augmented with carbon, which is added as a reductant. The furnace is heated to a temperature higher than the melting point of cadmium (321EC) but below the melting temperature of nickel (1,453EC). For a more even heat in the oven, the crucible is equipped with burners both at the bottom and in the middle. Melted cadmium is continuously collected in a water bath. The final products, called Cadmet shots, are small flattened discs, 4 to 6 mm in diameter, which facilitate handling and reduce erratic rolling. They have a purity of greater than 99.95% cadmium, some as high as 99.999% cadmium. As the final step, Cadmets are drummed, weighted, and assayed. Cadmets of at least 99.95% cadmium are shipped to NiCd battery manufacturers for reuse in new batteries. Lower purity Cadmets, between 99.95% and 99.75%, are used in the manufacture of corrosion-resistant coatings or in the manufacture of cadmium-containing stabilizers, alloys, and/or pigments.

In addition to NiCd batteries, INMETCO processes other batteries, but only to the degree that is possible with equipment that is already available. For example, NiMH batteries are shredded and melted at the company=s rotary hearth furnace or submerged electric arc furnace to produce an alloy. The rare earth components from batteries are added to the nonhazardous slag, and sold as a replacement for limestone. Zinc carbon, alkaline, and carbonaire cells are also shredded, then added to a rotary hearth or submerged electric arc furnace, where most of the zinc is reduced and then fumed off into the waste gas stream. The fume particulate is collected and sent off site as a crude zinc oxide for zinc and lead recovery. The remaining zinc, manganese, and other metal portions are fed to an electric arc furnace, where final zinc volatization is accomplished. The metal casing is smelted, and the bulk of the manganese is incorporated into the metal product. The carbon is used as a reductant, a replacement for coke, during cadmium distillation. Lithium ion and lithium polymer batteries are processed to recover lithium, cobalt and copper. The metal casings are added to the electric arc furnace for smelting into a metal ingot consisting of iron (64%), chromium (14%), nickel (13%), and other elements. Lead acid and mercury batteries are not processed at INMETCO, but are sent to appropriate secondary lead and mercury producers (INMETCO, oral commun., 2002).

In addition to the pyrometallurgical process, in which cadmium vapor is collected and then solidified by condensation or oxidation, there are hydrometallurgical cadmium recycling processes as well. In these wet chemical processes, batteries are dissolved in strong acids, then subjected to selective precipitation or ion exchange reactions to separate cadmium compounds from nickel and iron compounds.

OUTLOOK

Statistics indicate that worldwide sales of rechargeable NiCd batteries have been declining by about 1%-2% per year since 1993. This decline is mostly caused by the loss of certain market segments to other batteries, such as NiMH or Li-ion. NiCd batteries, however, are not expected to completely disappear from the market, because they are renowned for their long life and minimum maintenance requirements, along with good charge retention and reasonable price. For many applications, such as cordless power tools and emergency lighting, there is currently no better alternative. At the same time as the sale of NiCd batteries declined, recycling rates have been increasing at an average rate of more than 6% per year since 1995 (Money and Griffin, 2000, p. B75). Both of these trendsCdecline in sales and increase of recycling C bode well for the environment.

Recyclers are counting on increased recycling in the United States, and not only of NiCd batteries, but also of alkaline and Li-ion batteries as well. Toxco Inc., a subsidiary of Kinsbursky Brothers, is planning to acquire Moltech Corp.=s patented cadmium recovery facility and equipment for recycling NiCd batteries. Since about 80% of all batteries are alkaline, Toxco is also planning to recycle alkaline batteries at its Trail, British Columbia, facility. Using established technology, Toxco will be able to reintroduce the recycled materials into the manufacture of downstream metals. Ozark Fluorine Specialties, a division of Toxco in Tulsa, OK, is to produce lithium salts and electrolytes used in the manufacture of lithium batteries and ultra capacitors from recycled Li-ion batteries. With these new initiatives, Kinsbursky Brothers appears to be positioning itself as the forerunner of battery recycling, both primary and rechargeable (Kinsbursky, [undated]'). However, these new initiatives in themselves will not increase battery recycling. Their success will be determined by the extent to which the battery manufacturing industry is able increase the collection rate of spent batteries. This may turn out to be the biggest hurdle to overcome.

The rate of recycling could probably be improved by raising the awareness about the advantages of recycling as opposed to disposal of spent batteries or offering some type of other incentives. Increased recycling would reduce seepage of hazardous constituents from landfills, and reduce harmful airborne components that are released during incineration of waste. Recycling would also help to sustain our natural resources, not only by recycling the material content of batteries, but also by saving the energy used for processing of these materials. For example, INMETCO=s recycling process is about 50% more energy efficient than metal production from virgin ore (Money and Griffin, 2000, p. B76). Less fuel consumption means less air pollutionCan additional environmental benefit. Increases in the recycling rate would likely require a variety of efforts, such as an expensive multimedia advertisement campaign, government-mandated pealable stickers on products to remind consumers to recycle spent batteries, etc. At current prices for revenue-generating materials recovered from the spent batteries, especially cadmium, and the realized benefit for the environment, the expense that would be required to significantly increase the recycling rate may not be cost effective. At present, only a gradual increase in recycling rate can be expected in the near future.

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Table 1. Salient statistics for U.S. cadmium scrap in 2000. (metric tons)

Old scrap:	
Generated[1]	2,400
Consumed[2]	285
Value of old scrap consumed [3] (thousand dollars)	100
Recycling efficiency[4]	15
Supply[5]	2,400
Unrecovered[6]	2,030
New scrap consumed[7]	5
New-to-old-scrap ratio[8]	2:98
Recycling rate[9]	13
U.S. net exports of scrap[10]	85
Value of U.S. net exports of scrap [3] (thousand dollars)	29.8

[1] Cadmium content of products theoretically becoming obsolete in the United States in 2000. Amount of cadmium in batteries, sold separately and in products, and in other finished products is not available.

[2] Cadmium content of products that were recycled in 2000.

[3] Value of cadmium scrap, based on primary and secondary cadmium metal price.

[4] (Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imported plus any old scrap stock decrease or minus any old scrap increase), all of which is not available.

[5] Old scrap generated plus old scrap imported (not available) plus old scrap stock decrease (not available).

[6] Old scrap supply (not available) minus old scrap consumed minus old scrap exported (not available) minus old scrap stock increase (not available).

[7] Including new (prompt) industrial scrap but excluding home scrap.

[8] Ratio of quantities consumed, in percent.

[9] Fraction of the apparent metal supply that is scrap, on annual basis.

[10] Trade in scrap is assumed to be principally in old scrap. Net exports are exports of old scrap minus imports of old scrap (not available).

APPENDIX & DEFINITIONS

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

apparent supply. Apparent consumption plus consumption of new scrap.

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

downgraded scrap. Scrap intended for use in making a metal product of lower value than the metal product from which the scrap was derived.

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

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

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

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

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

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

$$\frac{\text{COS + OSC}}{\text{OSG + OSI + decrease in OSS or - increase in OSS.}} \times 100$$

old scrap supply. Old scrap generated plus old scrap imports plus old scrap stock decrease.

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

primary metal commodity. Metal commodity produced or coproduced from metallic ore.

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

recycling rate. Fraction of the metal apparent supply that is scrap, on annual basis. It is defined as [consumption of old scrap (COS) plus consumption of new scrap (CNS)] divided by apparent supply (AS)—measured in weight and expressed as a percentage:

$$\frac{COS + CNS}{AS} \times 100$$

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

secondary metal commodity. Metal commodity derived from or contained in sc