# INDIUM

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No indium was recovered from ores in the United States in 1996. Domestic indium production was confined almost entirely to the upgrading of imported metal. There was no known production at domestic mines. Two refiners, one each in New York and Rhode Island, were the major producers of indium metal and indium products in 1996. Several smaller firms also produced high-purity indium alloys, compounds, solders, sputtering targets, and related products.

Domestic consumption increased from about 43 metric tons to an estimated 45 tons. Estimated uses were about the same as those in 1995: coatings, 45%; solder and alloys, 35%; batteries and electronic uses, 15%; and research and other uses, 5%. The estimated value of primary metal consumed in the United States in 1996 was more than $17 million, at an average producer price of $11.50 per troy ounce.

Recycling became very significant for the first time in 1996 and was said by industry sources to have affected the market and prices. However, an estimate of the amounts of refined indium produced through recycling is not available.

World refinery production was estimated at 200 tons, a 16% decrease from the 1995 figure. There were eight major producing countries; the top four, Canada, France, Japan, and Russia, accounted for 75% of the total.

World consumption increased slightly in 1996. The large increase in demand in 1995 had caused a corresponding price increase that year. In 1996, although total consumption increased, with the reportedly dramatic increase in recycling, the demand for primary metal decreased. The producer price dropped from more than $16 per troy ounce in January to $6.53 per ounce at yearend.

World reserves are sufficient to meet anticipated demand for the next decade. Canada has greater resources of indium than any other country–about 27% of world reserves and 35% of the world reserve base. The corresponding amounts for the United States are 12% and 11%, respectively.

### Legislation and Government Programs

The National Defense Stockpile inventory of indium on December 31, 1996, was unchanged from that of the previous year at 1,561 kilograms (50,187 troy ounces). The original stockpile goal for indium was 41,990 kilograms, but this was reduced to 7,740 kilograms in 1992. The first purchase of indium was made in 1992, with all the material supplied domestically. The inventory amount is the total of all purchases made for the stockpile. According to the Annual Materials Plan for fiscal year 1996, proposed by the Defense Logistics Agency, indium was to be eliminated from the stockpile, but congressional authority has allowed only 35,000 troy ounces to be offered for sale during any one fiscal year. No indium was sold from the stockpile in 1996.

### Production

U.S. primary production consisted of upgrading lower grade and standard-grade indium (99.97% or 99.99%) into higher purity metal. Indium can be refined to purities up to 99.99999%. There was no known production at domestic mines; all the indium to be upgraded was imported. Domestic secondary production was mainly from new scrap and spent sputtering targets. The amount of indium produced from scrap increased from “small” to significant in 1996. Recycling became more economically viable as the price of indium increased nearly fourfold during 1995.

### Consumption

Domestic consumption was estimated at about 45 tons, nearly a 5% increase from the 1995 level. Consumption in the diverse end uses increased proportionally. Indium was available in various forms, such as ingot, foil, powder, ribbon, shot, and wire.

Thin-film coatings on glass, which included indium oxide and indium-tin-oxide (ITO), constituted nearly one-half (45%) of total domestic indium use in 1996. The coatings, produced by sputtering the material onto a glass substrate, have been the largest area of research and growth for indium in the past several years.

There are two kinds of indium-containing coatings, electrically conductive and infrared reflecting. Electrically conductive coatings, the more commercially significant group, are used primarily in liquid crystal displays (LCD’s) for watches, television screens, portable computer screens, video monitors, etc. They are also used to defog aircraft and locomotive windshields and to keep glass doors on commercial refrigerators and freezers frost free. Infrared reflecting coatings limit the transfer of radiant heat through windows, thus helping to make the wintertime heating and the summertime cooling of buildings more energy efficient.

About 35% of the indium consumed was used as an addition to combinations of bismuth, cadmium, lead, or tin to form low-melting-point alloys. These alloys are used in such applications as electrical fuses, fusible links, or as gripping material for the grinding of optical glass. Indium is used as a strengthening agent for lead solders and also as the base material for many low-melting-point solders. Indium-based solders have a number of advantages over ordinary solders: lower melting points, flexibility over a greater temperature range, and negligible leaching of gold components from electronic assemblies. Lead-free solders can be developed starting with indium-based alloys.

Indium can replace mercury in alkaline batteries, preventing the buildup of hydrogen gas in the sealed container. These batteries are available in popular small consumer sizes, and together with electronic uses, including semiconductors, accounted for 15% of the indium consumed domestically.

## Prices

The domestic producer price as reported by *Platt's Metals Week* for 99.97%- to 99.99%-pure indium declined steadily throughout 1996. Prices for higher grades of metal were not published. The course of the price during the year was nearly the reverse of that in 1995, except that the decline in 1996 was more gradual than the increase in 1995. The producer price fell from $16.25 per troy ounce at the beginning of the year to $6.53 per ounce at the end. This drop of nearly 60% was caused by an excess supply of metal, the result of much greater activity in the recycling of indium materials, which, in turn, was spurred on by high prices in 1995. The price dipped below $15 per ounce during the first quarter, reached $11.50 by midyear, finished the third quarter at $9.33, and in the fourth quarter, dropped to $6.53. During 1995, the price never went down; during 1996, it never went up. The major causes for the price collapse were greater (and cost competitive) recycling rates and—on a world basis—the increase in exports from China. As little as 35% of the indium in ITO used for LCD's for flat screen television sets reaches the product, owing to inefficiencies in the sputtering process. The rest is available as scrap, which can be recycled (Fineberg, 1996a). Industry sources said that the cost of recycling indium is only about $6 per troy ounce (Fineberg, 1996b). Some of the scrap was recycled under tolling arrangements between consumers and producers (Metal Bulletin, 1996d).

## Foreign Trade

Immediately after a record-high year for U.S. indium imports, a 21% increase for 1995 over that of 1994, 1996 brought a 61% decrease. Imports fell from 85.2 tons to 33.2 tons. This decrease apparently was made up for by increased recycling. With such a big decrease, comparative trade patterns with individual countries can appear skewed, but Canada retained its position as the top supplier by a wide margin. Next, in order of importance, were Russia, France, Belgium, and Peru. The top three countries provided 73% of U.S. imports, and the top five provided 88%. China fell from second to sixth rank in exports to the United States. Data for exports from the United States were unavailable.

## World Review

***Canada.***—The reopening of the Mount Pleasant Mine in New Brunswick would firm up Canada's standing as an indium producer. The mine, now owned by the Adex Mining Corp., based in Toronto, was previously operated by Billiton Metals as a producer of tungsten and molybdenum. Proven reserves reportedly include 9 million tons grading 1 ounce of indium per ton and 5.1 million tons grading 2.6 ounces of indium per ton. Reserves also include bismuth, copper, molybdenum, tin, tungsten, and zinc. Both the completion of final feasibility studies and a decision to proceed were expected by yearend (Metal Bulletin, 1996a).

Adex has obtained the partnership of the Malaysian Smelting Corp. (MSC), which is interested in the Mount Pleasant project as a long-term source of tin concentrate. MSC will invest $28 million in the project—$2 million for the final feasibility study and the balance for reopening the mine. The mine is expected to show a profit in 4 years with values from tin (55%), indium (30%), zinc (6%), copper (5.5%), and bismuth (3.5%). The biooxidation pilot plant studies for indium recovery were on schedule, and the mineralization zone appeared larger than previously estimated (Adex Mining Corp., 1996).

***China.***—As with a number of other "minor" metals, China holds at least one of the keys to the future of the indium market. With a general long-term backdrop of increasing demand, the world market has been in fairly close balance of supply and demand, with a few tons shortfall or oversupply not unusual or unexpected. China's relatively new ability to supply more than 25 tons per year to the world market from a combination of production and stockpiles is significant. China can produce at least 28 tons per year, while its current consumption is only 2 tons (Metal Bulletin, 1996b). Indium is produced in Shanghai, and in Shenyang and Huludao in Liaoning Province, and in Zhuzhou in Hunan Province.

***Japan.***—Japan, the world's largest consumer of indium, also experienced a large drop in imports as well as a decrease in primary production. These decreases in imports and production despite strong consumption are explained partly by increased processing of ITO scrap, which had previously been stockpiled. It had been unprofitable to process this material at the low (before 1995) market prices for indium. Since 1995, more than one-half of Japanese indium consumption has been used for ITO applications (Roskill's Letter from Japan, 1996). Further, it was reported that Japanese consumers may have been stockpiling indium in 1995—albeit unintentionally perhaps—as LCD production unexpectedly outstripped demand. Consumption then declined in 1996 as stocks were used. Also, the rate of growth of devices using LCD's may have declined. Such softening in a market that was expected to maintain previous high growth rates resulted in lower demand and lower prices.

## Current Research and Technology

The most significant technological development for 1996 was the large increase in recycling of indium-containing materials, mostly used sputtering targets and scrap from their manufacture. Details on the technology itself are not available, although it has been reported that one domestic processor uses a coprecipitaion process to reclaim ITO and other indium products (Roskill, 1996).

Researchers from many academic and industrial laboratories followed various approaches to developing lead-free solders for electronic applications. The studies included indium-base systems in general as well as the specific systems tin-indium, tin-zinc-indium, tin-silver-indium (-antimony), and tin-bismuth-indium. Research done by the industrial laboratories included potential applications in communications and transportation (Journal of Metals, 1996).

### Outlook

Consumption of indium is expected to increase through the next decade, especially for LCD's, high-definition television, semiconductor materials, batteries, and low-temperature solders for military and electronic applications. Demand for other uses, such as replacement nuclear control rods and fusible alloys, should remain steady. Surges in demand or breaks in supply have caused increases in price in the past. If indium prices rise, research and development into substitutes for ITO for LCD's, and on recycling, will be stimulated. Zinc-tin-oxide could possibly be used as a substitute, but currently its properties are not as good as those of ITO. If the price of indium is sufficiently high, recycling will be economically attractive and will tend to limit upward movements in price as long as there is a supply of appropriate scrap. World reserves, together with increases in production capacity, through increased yields in primary recovery and improvements in recycling technology (Metal Bulletin, 1996c), are expected to be sufficient to meet the demand for indium through the next decade.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDIUM, BY CLASS AND COUNTRY 1/

| Class and country | 1995 Quantity (kilograms) | 1995 Value (thousands) | 1996 Quantity (kilograms) | 1996 Value (thousands) |
|---|---|---|---|---|
| Unwrought and waste and scrap: | | | | |
| Belgium | 4,030 | $1,120 | 2,600 | $748 |
| Cameroon | -- | -- | 112 | 29 |
| Canada | 32,800 | 12,700 | 13,000 | 3,780 |
| China | 14,500 | 6,390 | 1,700 | 768 |
| Finland | -- | -- | 21 | 10 |
| France | 4,770 | 2,020 | 5,420 | 2,360 |
| Germany | 2,670 | 537 | 202 | 24 |
| Hong Kong | 1,450 | 555 | 194 | 80 |
| Israel | -- | -- | 170 | 36 |
| Japan | 3,620 | 1,370 | 679 | 265 |
| Lithuania | 75 | 18 | -- | -- |
| Netherlands | -- | -- | 276 | 93 |
| Peru | 1,630 | 705 | 2,480 | 757 |
| Russia | 14,300 | 5,420 | 5,900 | 2,930 |
| Spain | 1,450 | 465 | -- | -- |
| Switzerland | 2,000 | 884 | -- | -- |
| United Kingdom | 1,810 | 809 | 486 | 214 |
| Total | 85,200 | 32,900 | 33,200 | 12,100 |

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.