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Mercury Flow Through the Mercury-Containing Lamp Sector of the Economy of the United States

Scientific Investigations Report 2006–5264

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By Thomas G. Goonan

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Mercury Flow Through the Mercury-Containing Lamp Sector of the Economy of the United States

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Introduction

This Scientific Investigations Report examines the flow of mercury through the mercury-containing lamp sector of the U.S. economy in 2001 from lamp manufacture through disposal or recycling (fig. 1). Mercury-containing lamps illuminate commercial and industrial buildings, outdoor areas, and residences.

Mercury is an essential component in fluorescent lamps and high-intensity discharge lamps (high-pressure sodium, mercury-vapor, and metal halide). A typical fluorescent lamp is composed of a phosphor-coated glass tube with electrodes located at either end. Only a very small amount of the mercury is in vapor form. The remainder of the mercury is in the form of either liquid mercury metal or solid mercury oxide (mercury oxidizes over the life of the lamp). When voltage is applied, the electrodes energize the mercury vapor and cause it to emit ultraviolet energy. The phosphor coating absorbs the ultraviolet energy, which causes the phosphor to fluoresce and emit visible light (Lighting Design Lab, 2005). Mercury-containing lamps provide more lumens per watt than incandescent lamps and, as a result, require from three to four times less energy to operate (National Electrical Manufacturers Association, 2005).

Mercury is persistent and toxic within the environment. Mercury-containing lamps are of environmental concern because they are widely distributed throughout the environment and are easily broken in handling. The magnitude of lamp sector mercury emissions, estimated to be 2.9 metric tons per year (t/yr), is small compared with the estimated mercury losses of the U.S. coal-burning and chlor-alkali industries, which are about 70 t/yr and about 90 t/yr, respectively (Brooks and Matos, 2005).

Lamp Stocks in Use

Lamp stocks in use are the combination of stocks in service and stocks held in inventory pending service, where service means illumination on immediate demand. Table 1 shows the types and numbers of mercury-containing lamps that were in service in the United States in 2001 and their distribution among selected service-use sectors. Of the nearly 4.2 billion mercury-containing lamps in service, more than 4 billion were fluorescent lamps that contained 43.2 metric tons (t) of mercury; they were distributed as follows: 57 percent in commercial buildings, 32 percent in residences, 11 percent in industrial facilities, and a negligible percentage in outdoor service. The 157-million high-intensity discharge lamps (which contained 2.7 t of mercury) were distributed as follows: 50 percent in outdoor service, 30 percent in commercial service, 15 percent in industrial service, and 5 percent in residential service. Combined, the two types of lamps in service contained a total of 45.6 t of mercury (Navigant Consulting, Inc., 2002).

In 2001, stocks held in inventory pending service contained about 1.5 t of mercury. This was taken to be 12.5 percent (author's assumption) of the total mercury flow through the four service sectors.

Table 1. Number and mercury content of mercury-containing lamps, by service use, for lamps in service in the United States in 2001.

[Units for lamps are in millions, and units for mercury are in metric tons. The service uses "commercial," "industrial," and "residential" represent use within facilities and buildings; "outdoor" represents illumination of roadways and parking lots (Navigant Consulting, Inc., 2002). Lamp quantities are rounded to three significant digits. Mercury content is rounded to one decimal. Totals and parts are independently rounded and may not add. —, negligible amount]

Service use	Lamp type					
	Fluorescent		High-intensity discharge		Both types combined	
	Lamps (millions)	Mercury content (metric tons)	Lamps (millions)	Mercury content (metric tons)	Lamps (millions)	Mercury content (metric tons)
Commercial	2,290	24.5	46.8	1.3	2,340	25.9
Industrial	456	4.5	22.8	0.7	478	5.2
Outdoor	2.73	—	79.1	0.7	81.8	0.7
Residential	1,280	14.2	8.32	—	1,280	14.2
Total:	4,020	43.2	157	2.7	4,180	45.6

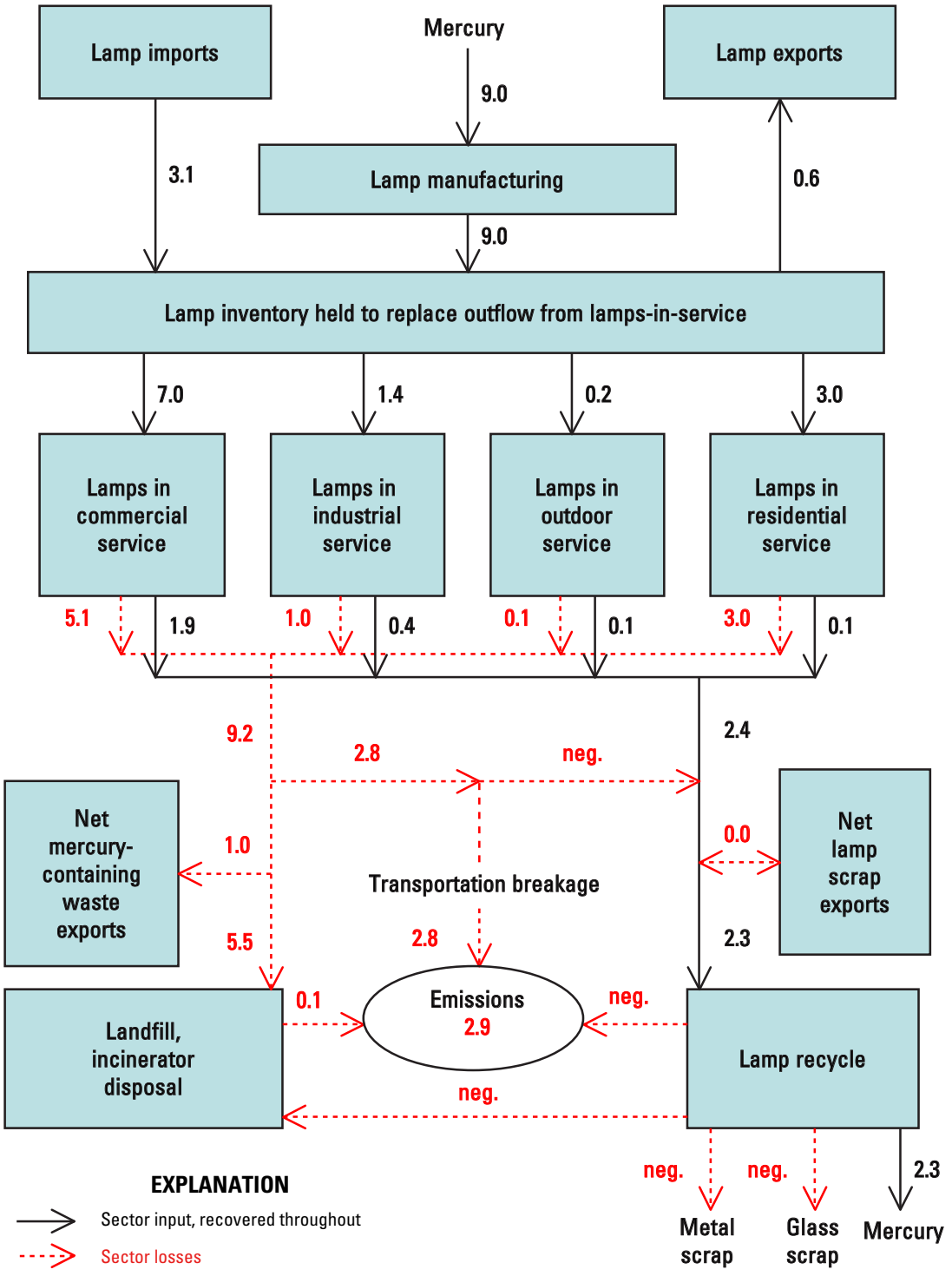

Figure 1. Diagram showing mercury flow through the mercury-containing lamp sector of the U.S. economy in 2001. Units of flow are in metric tons (t). "Neg." (negligible) means the flow was less than 0.05 t. Flow data have been rounded to the nearest 0.1 t; partial flows may not add to totals shown. Sources include the following: Association of Lighting and Mercury Recyclers (2004), International Trade Administration (2005a–d), Navigant Consulting, Inc. (2002), National Electrical Manufacturers Association (2001), and U.S. Environmental Protection Agency, Office of Solid Waste (1998).

Mercury Flow

Figure 1 shows the flow of mercury used in fluorescent and high-intensity discharge lamps through the economy in 2001, which was the most recent year for which data were available. U.S. manufacturers used a reported 9 t of mercury in the production of mercury-containing lamps (National Electrical Manufacturers Association, 2001). In addition, 269 million lamps that contained about 3.1 t of mercury were imported, and 40 million lamps that contained about 0.6 t of mercury were exported (International Trade Administration, 2005a–d). The net amount of mercury that flowed into the U.S. lamp sector in 2001, therefore, was 11.6 t.

By convention, mercury flow out of lamps in service is assumed to approximate closely the flow into lamps in service for a given year. Accordingly, mercury flow out of lamps (stocks) in service was as follows: commercial, 7.0 t; residential, 3.0 t; industrial, 1.4 t; and outdoor, 0.2 t, for a total of 11.6 t.

In 2001, lamp replacement rates were about 21 percent for lamps in residential service and 27 percent for lamps in commercial, industrial, and outdoor service (U.S. Environmental Protection Agency, Office of Solid Waste, 1998). Dividing these lamp replacement rates into the flows through the four subsectors of lamps in service allows one to estimate the level of stocks for each subsector (table 1).

Lamp recycling rates[1] were as follows: commercial, industrial, and outdoor, 28 percent, and residential, 2 percent (Association of Lighting and Mercury Recyclers, 2004). This information, combined with the estimates of the flow of mercury into stocks in service, provides the following estimates for the fraction of mercury that flowed from service into the recycling process: 1.9 t, commercial; 0.4 t, industrial; 0.1 t, outdoor applications; and 0.1 t (or about 25 percent of the nonrecycled amount), residential, for a total of 2.4 t. The amount of mercury in lamps that left service and was not recycled was as follows: 5.1 t, commercial; 3.0 t, residential; 1.0 t, industrial; and 0.1 t, outdoor, for a total of 9.2 t.

Very little information is available concerning the movement of mercury-containing waste, including spent lamps, into and out of the United States. The author assumes that within this mercury-containing waste there is a net outflow to Canada of 12.5 percent of lamps leaving U.S. stocks in service. Another assumption is that there is zero net trade in lamp scrap because lamp scrap has little value (National Electrical Manufacturers Association, 2005).

A total of 2.9 t of mercury flowed from stocks in service as emissions. Sources of the emissions include losses that resulted from transportation breakage, landfill storage, and the recycling process.

Transportation breakage is a factor that complicates the process of estimating the amount of mercury that flows from stocks in service into recycling and disposal. Lamp breakage is 100 percent and mercury loss is 30 percent of the original lamp content for lamps shipped to municipal landfills and waste incinerators, but lamp breakage is only 2 percent for lamps shipped to recyclers (Aucott and others, 2004). Of the 2.9 t of mercury that flowed into emissions in 2001, 2.8 t was from lamps broken in transit to landfills or waste incinerators and the remainder was from the small number of lamps broken in transit to recyclers.

Approximately 1 percent of the total mercury load in a landfill is lost to emissions each year (U.S. Environmental Protection Agency, Office of Solid Waste, 1998). Applying this factor to the annual increment of mercury attributable to mercury-containing lamps that enter landfills, the emissions loss from landfills in 2001 was estimated to be 0.1 t of mercury.

The recycling activity is 97 percent efficient for the recovery of mercury and generates minor system mercury outflows to direct emissions, landfill debris, and metal and glass scrap (U.S. Environmental Protection Agency, Office of Solid Waste, 1998). Recycling process losses (which are considered negligible) were as follows: emissions, 4.2 kilograms (kg); landfill, 7.5 kg; and scrap, 58.5 kg.

Although the release of mercury into the environment is a matter of concern, two trends have developed that tend to reduce the future potential for mercury to reach the environment from the mercury-containing lamp sector. First, the use of mercury in T8[2] fluorescent lamps, which decreased significantly to 5.6 milligrams per lamp in 2002 from 48.2 milligrams per lamp in 1985 because of new technology, is expected to continue to decrease (fig. 2). Second, the rate of recycling of mercury-containing lamps is expected to continue to increase (fig. 3) largely because of regulatory changes and because some recyclers are operating at only one-third of capacity (Association of Lighting and Mercury Recyclers, 2004).

[1] The National Electrical Manufacturers Association (NEMA) provides the best estimate available for assessing lamp recycling rates. The annual lamp recycling rate equals lamps available for recycling (this number is provided by NEMA) divided by the number of lamps that enter the recycling process (this number is provided by the Association of Lighting and Mercury Recyclers (ALMR). Because of the many issues regarding the data, the ALMR advises caution when using these estimates. A committee that is sponsored by the ALMR is working to upgrade the recycling rate estimates.

[2] T8 is a standard designation for a long fluorescent tube.

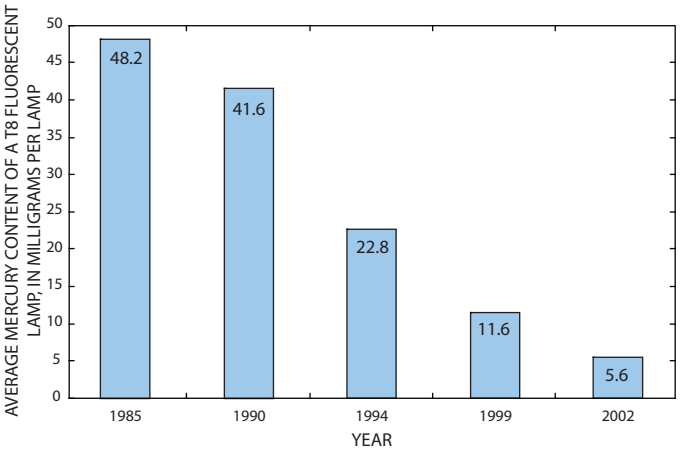

Figure 2. Graph showing average mercury contained in T8 fluorescent lamps based on available data for 1985 to 2002. Units are milligrams of mercury per lamp. Data are from the National Electrical Manufacturers Association, 2001.

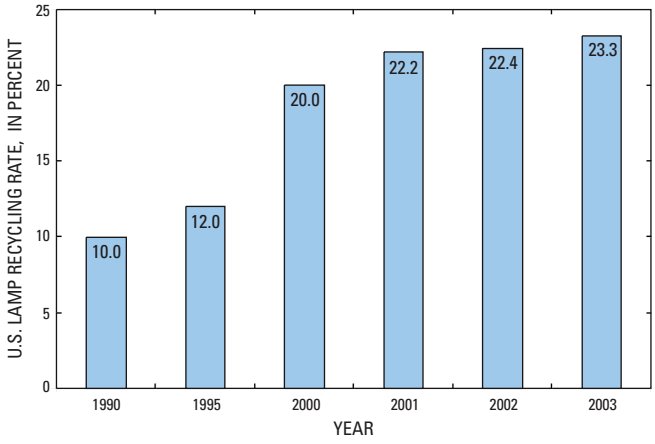

Figure 3. Graph showing annual percentage of U.S. spent mercury-containing lamps recycled based on available data for 1990 to 2003. Units are percentage of lamps flowing from stocks in service into recycling. Data are from the Association of Lighting and Mercury Recyclers, 2004.

Conclusion

In 2001, the stocks in use (including inventory) of fluorescent and high-intensity discharge lamps contained 45.6 t of mercury. About 11.6 t of mercury flowed into and out of stocks in service during the year. Of the amount that left stocks in service, 47 percent went to domestic landfills or municipal waste incinerators, 25 percent was released to the air, 20 percent was recovered for resale, 8 percent was exported, and a negligible amount (one-half of 1 percent) left the recycling process adsorbed to metal and glass scrap generated by the crushing process that precedes recycling. In the mercury-containing lamp sector of the U.S. economy, stocks and flows are widely distributed, which creates the potential for emissions to the environment. The total estimated emissions loss to the environment in 2001 from mercury-containing lamps was 2.9 t. Because the loss to emissions during recycling is negligible, increasing the recycling rates above the 2003 level of 23 percent is a means to reduce mercury emissions from this sector. Mercury use per lamp in the lamp sector has decreased nearly to the technical limit. However, the use of mercury-containing lamps steadily grows. Further emission reductions from this sector are most likely to come from increased recycling.

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