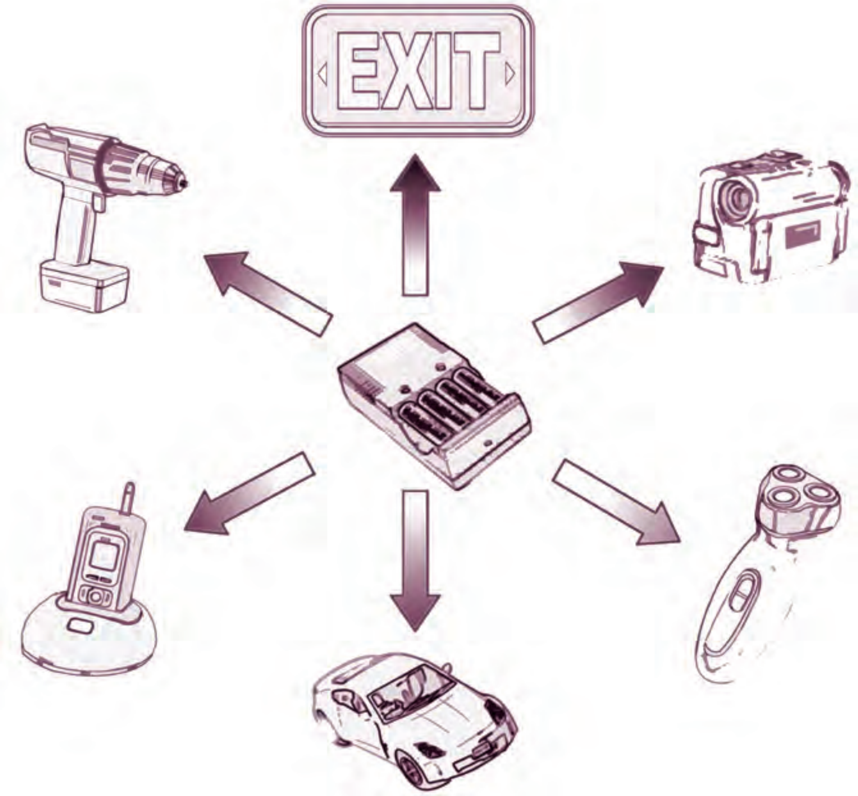
Flow of cadmium from rechargeable batteries in the United States, 1996–2005



Scientific Investigations Report 2007-5198

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

Multiply	By	To obtain
	Mass	
ounce, troy (tr. oz)	0.0311	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)

Flow of cadmium from rechargeable batteries in the United States, 1996–2005

By David R. Wilburn

Abstract

Cadmium metal has been found to be toxic to humans and the environment under certain conditions; therefore, a thorough understanding of the use and disposal of the metal is warranted. Most of the cadmium used in the United States comes from imported products. In 2005, more than 80 percent of the cadmium used in the United States was contained in batteries, mostly in rechargeable nickel-cadmium batteries used in popular consumer products such as cordless phones and power tools. The flow of cadmium contained in rechargeable nickel-cadmium batteries used in the United States was tracked for the years 1996 to 2005. The amount of cadmium metal contained in imported products in 2004 was estimated to be about 3,000 metric tons, or about three times the reported cadmium production in the United States from all primary and secondary sources. More than 40,000 metric tons of cadmium were estimated to be contained in rechargeable batteries that became obsolete during the 10-year study period. As much as 11 percent of this material was recycled, and the balance was placed in municipal solid waste landfills.

Introduction

More than 350 million rechargeable batteries are purchased annually in the United States (U.S. Environmental Protection Agency, 2002b). Rechargeable batteries, including nickel-cadmium (NiCd) batteries and sealed lead-acid batteries, contain toxic heavy metals such as cadmium, lead, and mercury, which, when used and disposed of properly, present little threat to human health. These materials can cause harm to the environment and humans if they are discarded or incinerated improperly. In 1992, the U.S. Environmental Protection Agency (USEPA) classified cadmium as a Group B1 probable human carcinogen (U.S. Environmental Protection Agency, 2000). In that same year, about 146,000 metric tons (t) of consumer batteries of all types, many of which contained cadmium, were discarded in the United States (Klimasauskas, Kuck, and Plunkert, 2006). In recognition of the potential environmental hazards associated with cadmium metal exposure, some States have limited cadmium use in some consumer products and are regulating cadmium disposal. Similarly, the European Union issued regulations in 1999 designed to regulate cadmium disposal. Recent regulatory emphasis appears to have shifted from the complete elimination of cadmium use to proper risk management of cadmium-containing products (Morrow, 2005).

Environmental concerns regarding the use of cadmium and increased reliance on foreign production of cadmium compounds have contributed to reduced cadmium production and consumption in the United States since 1990. Cadmium use in coating and plating, pigments, and plastics has dropped from 78 percent of cadmium apparent consumption in 1980 to 19 percent in 2005, whereas cadmium use in batteries has increased from 22 percent of cadmium apparent consumption in the United States in 1980 to 81 percent of apparent consumption in 2005. During the same period, cadmium use in batteries on a tonnage basis has decreased about 32 percent (Kuck, 2006). Although substitution by alternative battery chemistries (such as nickel-metal hydride and lithium-ion batteries) during this period has reduced demand for NiCd batteries in some applications, millions of rechargeable batteries are in use, in storage, or have been discarded as municipal solid waste (MSW) in landfills. Available data on cadmium battery recycling in the United States indicate that only a small portion of this material is currently being recycled.

In order to estimate the affects of cadmium from the battery sector on the environment, it is necessary to quantify the amounts of cadmium contained in batteries that are recycled or discarded as waste. There are several reasons why it is difficult to make such estimates. One impediment to quantifying the amount of cadmium that is being recycled from NiCd batteries is that data on the amount of obsolete NiCd batteries are not readily available. Detailed production data by International Metals Reclamation Co., Inc. (INMETCO), the only cadmium recycler in the United States, are considered proprietary.

The United States passed legislation in 1996 [U.S.C. 14301-14336 (Battery Act)] which, among other purposes, removed certain barriers to the collection and recycling of rechargeable batteries (U.S. Environmental Protection Agency, 2002b). Although no mandatory Federal regulations exist requiring cadmium recycling, 13 States (as of 2004) have passed legislation regulating battery labeling and removability from consumer products and 8 States have "takeback" requirements that apply to NiCd batteries (Klimasauskas, Kuck, and Plunkert, 2006). A voluntary collection program for rechargeable batteries in Canada and the United States was initiated in 1994 by the Rechargeable Battery Recycling Corporation (RBRC). The RBRC data are reported in terms of the number of batteries recycled; statistics on the types of batteries collected and their cadmium content are not released. Although the RBRC is the largest rechargeable battery recovery organization in the United States, other organizations also collect batteries for recycling, and some larger battery manufacturers collect batteries internally and send them directly to INMETCO or European recyclers (Boehme and Panero, 2003, p. 41).

Another difficulty in estimating the cadmium battery recycling rate in the United States is the measurement of cadmium battery consumption in the Nation. Cadmium metal consumption data attributed to battery production are not collected by the U.S. Geological Survey (USGS), although estimates of apparent consumption by end-use sector are available (U.S. Geological Survey, 2005). Data on cadmium contained in manufactured products that are imported to or exported from the United States also are not reported. Although the U.S. International Trade Commission (ITC) reports data on the number of individual NiCd batteries imported to and exported from the United States annually, the ITC does not provide a direct source of information as to the quantity of cadmium contained in these batteries, nor does it account for batteries contained in prepackaged products (containing both the product and a battery to power the product).

A third impediment to estimation of the domestic cadmium battery recycling rate is the lack of data showing the distribution of cadmium content among the numerous battery types and products that become available for recycling each year. Although large industrial batteries are easy to collect and are recycled at a reported rate of about 80 percent, smaller consumer NiCd batteries have a much lower reported recycling rate of no more than 20 percent (Klimasauskas, Kuck, and Plunkert, 2006). The reported recycling information does not provide separate estimates of the metal content of consumer and industrial battery type, so it is difficult to quantify the amount of cadmium recovered from each type.

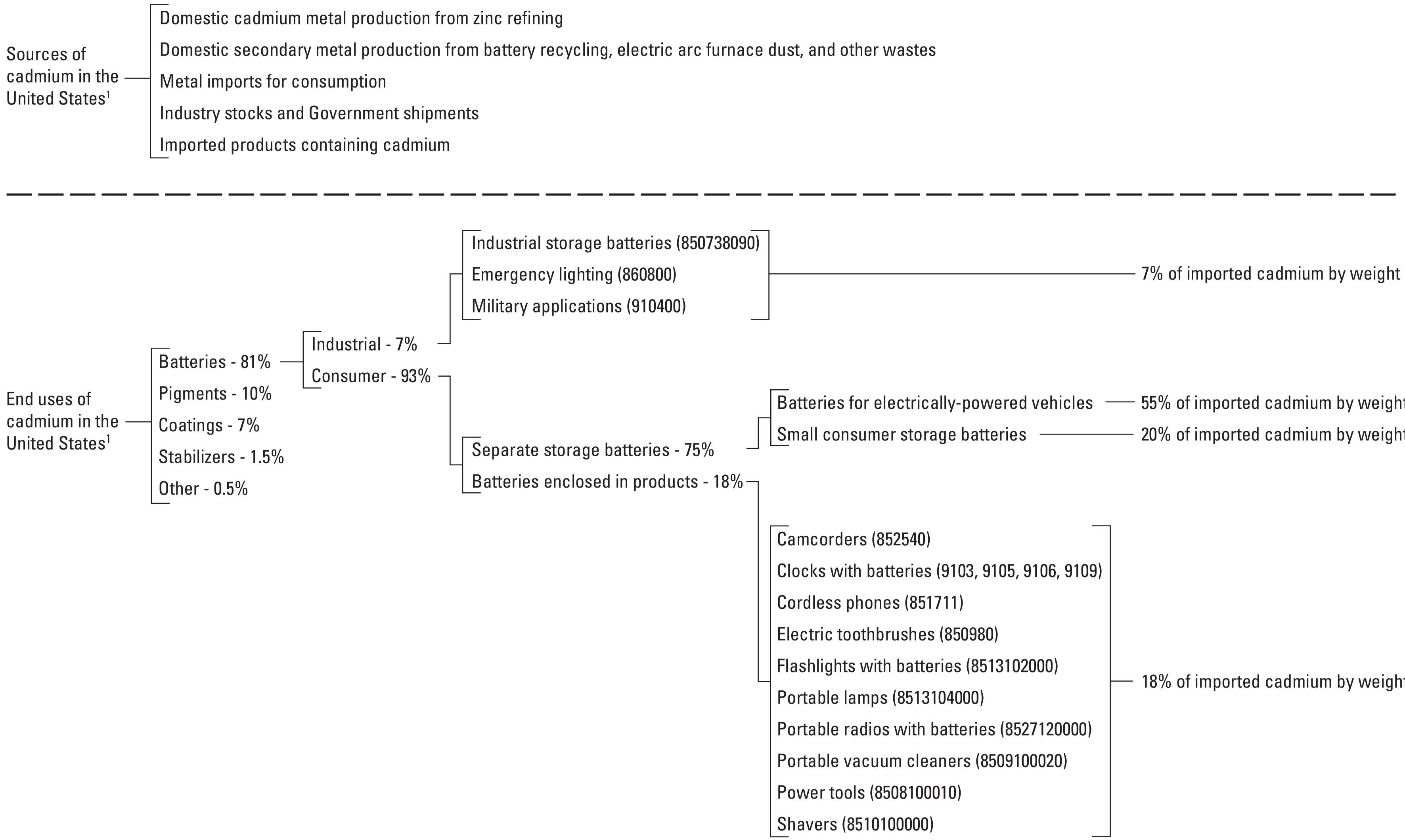
In an attempt to overcome these limitations, this study integrated information on the domestic production and consumption of batteries containing cadmium, the quantity of cadmium that was imported and exported either in separate batteries or contained in prepackaged products, and the quantity of cadmium that was recovered by recycling of both consumer and industrial NiCd batteries. The scope of this study was limited by its assumptions related to average battery weight, cadmium content by battery class, and trade category distribution. The assumptions that were made for this analysis are shown in the appendix. The study supplements USGS reported mineral production and mineral commodity consumption statistics, which provide information essential for government, non-government organizations, and the public to gain a better understanding of how and where materials are used and draw inferences as to their possible effect on the environment and society.

This report describes the flow of cadmium contained in rechargeable NiCd batteries used in the United States for the period 1996 to 2005 and presents estimates of the amount of cadmium that was in use, in consumer storage, and recovered by recycling during this period. It also presents an estimate of how much cadmium entered the municipal solid waste stream between 1996 and 2005.

Contribution of the NiCd Battery Sector to the Rechargeable Battery Industry in the United States

It is necessary to understand the contribution of the NiCd battery sector to the U.S. rechargeable battery industry before it is possible to determine the material flow of cadmium in the United States from this sector. The 2005 sources and principal end uses of cadmium metal in the United States are shown in figure 1. Domestic production of cadmium metal in the United States occurs in two principal ways. It is a byproduct of the smelting and refining of zinc and a remnant of the recycling of scrap containing cadmium. Other sources of secondary cadmium, such as electric arc furnace dust, electroplating waste, filter cakes, and sludges, are small and diminishing (Plachy, 2003b), so are not considered in this study. Although domestic cadmium consumption data are not compiled by the USGS, end use distribution data are reported annually (U.S. Geological Survey, 2005; Kuck, 2006), on the basis of global end use distribution percentages reported in the Mining Journal, Annual Mining Review issue by Hugh Morrow, President of the International Cadmium Association (Hugh Morrow, oral commun., 2007). Distribution data on mineral consumption in the United States are not readily available by individual end use, so international estimates were used in this study to estimate the amount attributed to batteries. For 2005, approximately 81 percent of the cadmium consumed in the United States was estimated to have been consumed in batteries (Kuck, 2006), and most of the cadmium that was consumed came from batteries imported primarily from China and Japan. Although battery end-use applications vary over time, the principal end uses for NiCd batteries in 2005, based upon the amount of cadmium contained in each type, are industrial batteries (such as batteries used in the transportation sector for emergency lighting), batteries for electrically powered vehicles, and small consumer rechargeable batteries (such as batteries used in cordless phones, electric lamps, and power tools). Batteries are imported separately and as part of prepackaged consumer products.

Environmental concerns about cadmium toxicity and technological advances have led to the development and



[1]Sources of cadmium in the United States as reported by Plachy (2003b) in U.S. Geological Survey Circular 1196-O.
End use percentages reported for 2005 by Kuck (2006) in U.S. Geological Survey Mineral Commodity Summaries 2006, p. 42–43.

Figure 1. Principal cadmium sources and end uses in the United States. [Numbers in parentheses reflect classifications of cadmium-containing batteries in the Harmonized Tariff Schedule (HTS) as reported by the U.S. International Trade Commission (ITC). Weight percentage estimates for 2005 were developed from ITC data for each of the reported HTS classifications and average battery content data as reported by selected battery manufacturers.]

increased use of alternative battery chemistries (such as the nickel-metal hydride and lithium-ion batteries) within the rechargeable battery sector. Data on rechargeable battery sales in the United States are not readily available, but worldwide data published by the Battery Association of Japan (2006) show that (1) NiCd battery sales peaked in 1992, (2) the nickel-metal hydride battery market share increased significantly between 1992 and 2000, and (3) the market share for the lithium-ion rechargeable battery has grown rapidly since 2000. These trends are shown in figure 2. In 2004, NiCd batteries accounted for about 25 percent of the worldwide rechargeable battery market, nickel-metal hydride batteries accounted for about 20 percent, and lithium-ion batteries accounted for about 52 percent (Battery Association of Japan, 2006). In spite of declining NiCd battery sales, ITC data indicate that the United States imported over 72 million NiCd batteries in 2004, and many more NiCd batteries were imported as part of prepackaged electronic products (U.S. International Trade Commission, 2006). Although this study focuses on the 1996 to 2005 period, some batteries produced prior to this period (when NiCd batteries accounted for a much larger market share, as shown in figure 2) are included when considering the amount of cadmium available for recycling during the study period.

Study Methodology

The study methodology applies a materials flow approach to help gain an understanding of what happens to materials we use from the time a material is extracted, through its processing and manufacturing, to its ultimate disposition. In order to describe the cadmium flows in the United States, it is necessary to estimate cadmium consumption in the Nation. Apparent consumption of cadmium metal in the United States, as calculated by the USGS using the production data of individual companies, U.S. foreign trade statistics, and reported inventory stock changes, is reported annually in the USGS Minerals Yearbook and USGS Mineral Commodity Summaries series. For this study, apparent consumption is defined as mine production + secondary refined production + metal imports for consumption – metal exports + adjustments for industry and Government stock changes. Such consumption data, however, do not include the amount of mineral commodities contained in manufactured products that are imported to and exported from the United States. Available data indicate that the amount of cadmium metal contained in products imported into the United States, particularly from the NiCd battery sector, is much larger than the amount of cadmium that is annually consumed from domestic refined metal production.

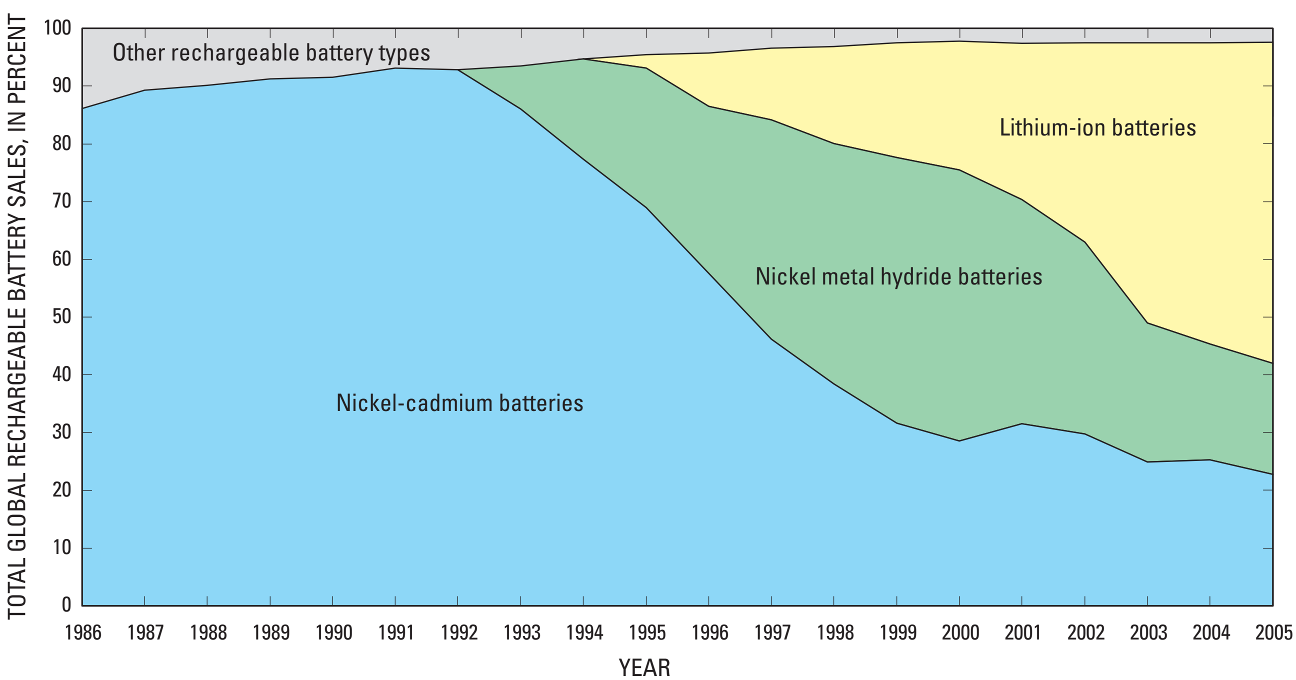


Figure 2. Percentage of global rechargeable battery sales for the principal battery types, 1986–2005. [Data modified from Battery Association of Japan (2006).]

Import and export trade data, expressed in terms of the number of battery units, as reported by the ITC (U.S. International Trade Commission, 2006) were reviewed for this study. Data were available for 1996 to 2005, so this period was chosen for study. The 10-digit Harmonized Tariff Schedule (HTS) classifications were reviewed to determine which classifications contained NiCd batteries or products using these batteries. Import and export data were collected for each selected classification, including classifications for separate storage batteries and prepackaged products thought to contain NiCd batteries.

Because NiCd battery trade data are reported by the ITC in very general categories for separate batteries and batteries contained in prepackaged products, it was necessary to estimate the battery distribution within each category prior to determining the amount of cadmium included in that category. The distribution of some categories was straightforward; for others, many assumptions were required. Assumptions are presented in the appendix.

Battery distribution assumptions related to the category "nickel-cadmium storage batteries, not elsewhere specified" (HTS code 8507308090), which includes most industrial NiCd batteries, requires further discussion because of the quantity of batteries found in this category. The data indicate that this category includes large industrial batteries and small consumer batteries and battery components. Trade data were reported as both units of quantity and value, by country. After discussions with ITC personnel and the USGS cadmium specialist, it was decided that the calculated unit value ($/unit) would provide a means of estimating the relative percentage of distribution between these two imported battery types, by country. A sliding scale was set up to determine the percentage attributed to industrial batteries by using the reported unit value. In general, the higher the unit value reported for a particular country, the greater was the percentage of industrial batteries attributed to that country. The total number of units attributed as either industrial type batteries or consumer type batteries were developed by aggregating the estimates for the individual countries. Estimates were found to be in close agreement with nonpublic information available to the ITC, which provided support for this data estimation methodology.

Estimates of the average cadmium content included in each selected HTS NiCd battery classification were developed. Because individual HTS classifications may include more than one battery type, it was necessary to review each classification and make assumptions as to the distribution of battery types for each category. Worldwide market data were used as an approximation for the types of batteries included in each of the major battery applications in the United States (Pillot, 2004). Because data were most often expressed in terms of the quantity of batteries, an estimate for the average amount of cadmium contained within each battery or battery product classification was developed, so that an estimate of the total amount of cadmium contained in that classification could be made. The amount of cadmium contained in NiCd batteries varies substantially with battery type and slightly by manufacturer. Estimates of cadmium content were based on data provided by selected battery manufacturers for various battery types. On the basis of the reported description for each classification, a specific battery or group of batteries was selected to depict the "average" battery for that classification. From the weights of these batteries as reported by the manufacturers and assuming a typical cadmium content for that battery type (Vangheluwe, Verdonck, and Versonnen, 2005, p. 11), cadmium content for each classification was determined. In cases where the classification was thought to contain battery types other than NiCd batteries, the percentage attributable to NiCd batteries was based on the reported distribution of battery types, by application, in the European battery market (Pillot, 2004, 2005). Estimates for the average amount of cadmium contained in generalized battery types are summarized in the appendix.

Analysis of the Data

Total Consumption

Estimates for the amount of cadmium contained in NiCd batteries imported to and exported from the United States for selected years within the 1996–2005 study period, based on ITC data, are summarized in table 1. Trade classifications included in this analysis also are reported in table 1. Estimates for the entire study period indicate that the United States imports many more NiCd batteries than it exports, making it a net importer of cadmium contained in rechargeable batteries. The distribution of cadmium metal contained in imported and exported batteries for the study period is shown in figures 3 and 4, respectively. In 2005, about 55 percent (by weight) of the imported cadmium in NiCd batteries was contained in batteries for electrically powered vehicles, about 20 percent of the cadmium was contained in small sealed consumer batteries, about 18 percent of the cadmium was contained in batteries enclosed in prepackaged consumer products, and about 7 percent of the cadmium was contained in industrial batteries. NiCd batteries are not used in mass-produced passenger vehicles but may be used in industrial vehicle applications and passenger vehicle research. About 60 percent of the exported cadmium contained in NiCd batteries (by weight) was contained in separate batteries, and about 40 percent of the cadmium was in batteries enclosed in prepackaged products in 2005. The United States imported about 2,500 t more cadmium in NiCd batteries than it exported in 2005.

Combining these data with cadmium production and consumption data reported annually by the USGS allows the total consumption of cadmium metal in the United States to be calculated for each year of the study period. For this study, total consumption in the United States is defined as apparent consumption + cadmium contained in imported products – cadmium contained in exported products. The quantity of

Table 1. Estimates of the amount of cadmium metal contained in nickel-cadmium batteries imported to and exported from the United States, for selected years.

[Data are reported in metric tons of cadmium metal contained in selected batteries and products containing batteries, modified from U.S. International Trade Commission (2006), and discussions with Peter Kuck (U.S. Geological Survey, oral commun., 2006). All values expressed as metric tons of contained cadmium metal. Values may not total because of rounding; <. less than]

Classification	1996		1998		2000		2002		2004		2005	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Storage batteries, separate[1]	NA	130	NA	150	NA	140	NA	85	NA	41	NA	52
Electrically-powered vehicle batteries[2]	2,600	NA	360	NA	410	NA	450	NA	1,000	NA	1,400	NA
Sealed consumer batteries[3]	1,600	NA	1,000	NA	960	NA	630	NA	530	NA	520	NA
Industrial batteries[4]	130	NA	82	NA	390	NA	150	NA	250	NA	180	NA
Miscellaneous batteries and battery waste[5]	32	NA	31	NA	18	NA	13	NA	< 10	NA	< 10	NA
Subtotal: nickel-cadmium batteries	4,300	130	1,500	150	1,800	140	1,200	85	1,800	41	2,100	52
Batteries enclosed in products												
Power tools[6]	15	< 10	25	< 10	38	< 10	46	0	56	0	68	0
Cordless phones[7]	140	< 10	210	19	260	21	270	29	250	20	230	15
Camcorders[8]	83	< 1	47	< 1	41	< 1	42	< 1	16	< 1	< 10	< 1
Portable radios[9]	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 1	< 1	< 1	< 1
Shavers[10]	13	< 1	15	< 1	16	< 1	16	< 10	33	< 10	24	< 10
Electric toothbrushes[11]	< 10	0	< 10	0	13	0	47	0	51	0	40	0
Portable vacuum cleaners[12]	31	15	38	15	50	16	76	14	39	10	21	< 10
Flashlights[13]	18	< 1	25	< 1	29	< 1	28	< 1	28	0	20	0
Portable electric lamps (bicycle, etc.)[14]	69	29	63	33	100	50	92	34	81	19	69	13
Clock batteries, reported separately[15]	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
Military batteries, reported separately[16]	< 10	< 1	< 1	< 1	< 1	< 10	< 1	< 1	< 1	0	< 1	< 1
Subtotal: nickel-cadmium batteries in products	380	54	430	70	500	90	620	80	570	50	480	35
Totals	**4,700**	**180**	**1,900**	**220**	**2,300**	**230**	**1,900**	**160**	**2,400**	**90**	**2,600**	**90**
Net cadmium from imported batteries[17]	**4,500**		**1,700**		**2,100**		**1,700**		**2,300**		**2,500**	

[1] Includes cadmium contained in separate nickel-cadmium storage batteries exported as Harmonized Tariff Schedule (HTS) codes 8507300000 and 8507300050 (8.4 g/unit) as reported by the International Trade Commission.

[2] Includes cadmium contained in separate nickel-cadmium storage batteries imported as HTS code 8507304000 (2.3 kilograms per unit).

[3] Includes cadmium contained in separate nickel-cadmium storage batteries imported as HTS code 8507308010 (8.4 grams per unit).

[4] Includes cadmium contained in separate nickel-cadmium storage batteries imported as HTS code 8507308090 (1.2 kilograms per unit). Industrial batteries determined by country on a unit value basis.

[5] Includes cadmium contained in separate nickel-cadmium storage batteries imported as HTS code 8507308090 (8.4 grams per unit), estimated from residual after industrial battery component removed.

[6] Includes cadmium contained in nickel-cadmium batteries enclosed in power tools imported as HTS codes 8467210000 and 8508100010 and export code 8508100010 (6 grams per unit).

[7] Includes cadmium contained in nickel-cadmium batteries enclosed in cordless phones imported and exported as HTS code 8517110000 (11.2 grams per unit).

[8] Includes cadmium contained in nickel-cadmium batteries enclosed in camcorders imported and exported as HTS codes 8525408020 and 8525408050, and import codes 8525400020 and 8525400050 (22.4 grams per unit).

For the years 1996-99, still image cameras containing nickel cadmium batteries HTS codes 8525400090, 8525404000, and 8525408085 were included in this classification.

[9] Includes cadmium contained in nickel-cadmium batteries enclosed in portable radios imported and exported as HTS code 8527120000 (2.9 grams per unit).

[10] Includes cadmium contained in nickel-cadmium batteries enclosed in shavers imported and exported as HTS code 8510100000 (2.9 grams per unit).

[11] Includes cadmium contained in nickel-cadmium batteries enclosed in electric toothbrushes imported as HTS code 8509800045 (2.9 grams per unit).

[12] Includes cadmium contained in nickel-cadmium batteries enclosed in portable vacuum cleaners imported and exported as HTS code 8509100020 (13.6 grams per unit).

[13] Includes cadmium contained in nickel-cadmium batteries enclosed in flashlights imported as HTS code 8513102000 (6.9 grams per unit).

[14] Includes cadmium contained in nickel-cadmium batteries enclosed in portable lamps imported as HTS code 8513104000 and export code 8513100000 (9 grams per unit).

[15] Includes cadmium contained in nickel-cadmium batteries enclosed in clocks imported as HTS codes 9103102020, 9103102040, 9103104030, 9103104060, 9103108030, 9103108060, 9105114030, 9105114050, 9105118040, 9105118070, 9105214030, 9105218050, 9105914030, 9105918050, 9106905520, 9109111030, 9109112030, 9109114030, 9109116030, 9109191030, 9109192030, 9109194030, 9109196030, and export code 9103100000 (2.9 grams per unit).

[16] Includes cadmium contained in nickel-cadmium batteries enclosed in military products imported as HTS codes 91040000520, 9104001020, 9104002520, 9104003020, 9104004520, and 9104005030, and export code 9104000000 (2.9 grams per unit).

[17] Net value reflects quantity imported minus quantity exported; a positive number indicates that the quantity imported is greater than the quantity exported; totals may not add owing to rounding of data.

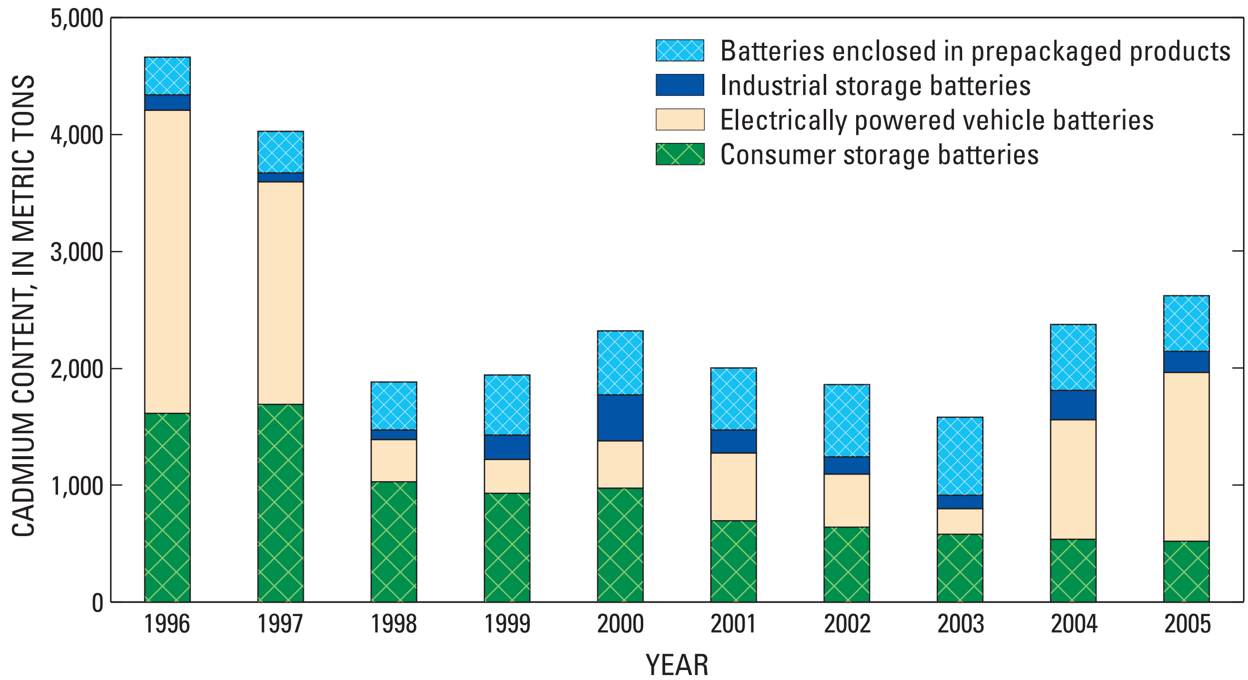


Figure 3. Distribution of cadmium metal contained in batteries and battery products imported to the United States, 1996–2005. [Based on data available from the U.S. International Trade Commission (2006).]

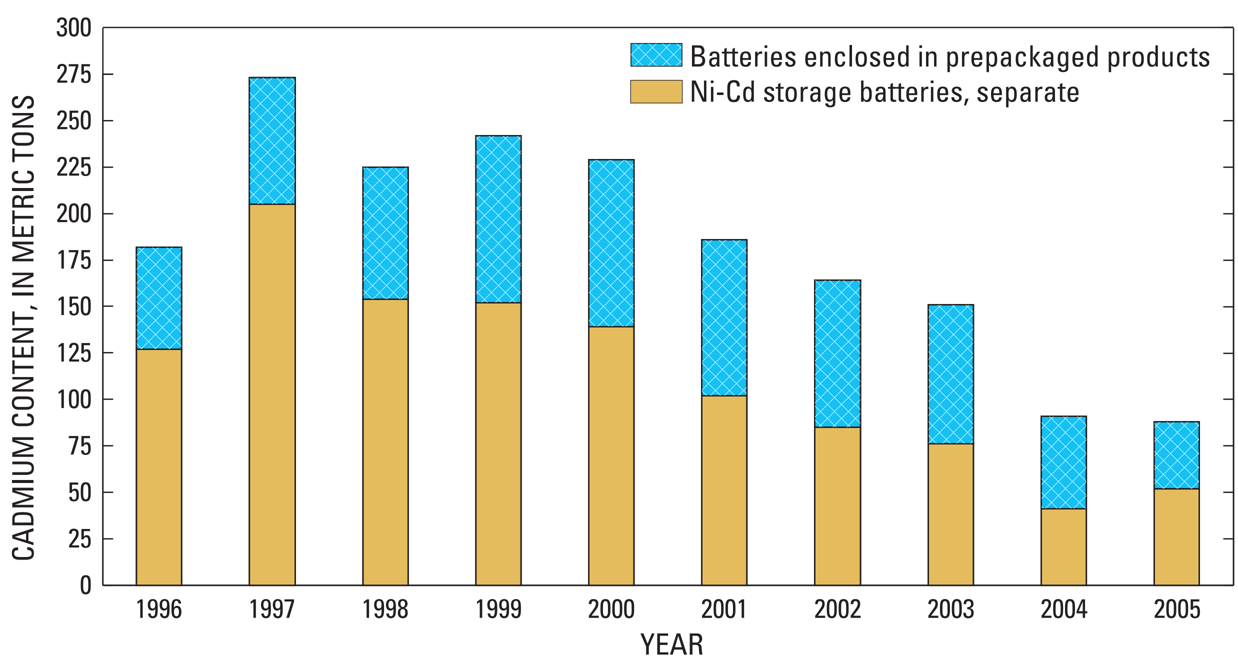


Figure 4. Distribution of cadmium metal contained in batteries and battery products exported from the United States, 1996–2005. [Based on data available from the U.S. International Trade Commission (2006).]

each component of total cadmium consumption in the United States for all sectors in 2004 is shown in figure 5; the battery sector accounted for 78 percent of cadmium consumption for all sectors in that year. For 2004, the United States apparent consumption of cadmium metal is reported as 1,170 t (Kuck, 2007). When the quantity of cadmium contained in imported and exported manufactured products (shaded boxes) is taken into account, however, the total consumption of cadmium metal in the United States is estimated to be about 4,000 t. Much of the difference between the two estimates can be attributed to the inclusion of cadmium contained in imported and exported manufactured products in the total consumption statistics.

Recycling

Estimates of the amount of cadmium that is available for possible recycling were developed on the basis of cadmium metal apparent consumption and cadmium use attributed to batteries as reported by the USGS [Kuck, 2006; Plachy, 2001, 2002, 2003a, 2004, 2005; U.S. Geological Survey, 2005] and the net amount of cadmium contained in traded batteries (imports minus exports, as reported in table 1). An estimated battery service life distribution pattern (shown in figure 6 for an industrial battery with an assumed 15-year life) was developed for each of the four principal NiCd battery groupings (batteries enclosed in products, consumer batteries, electrically

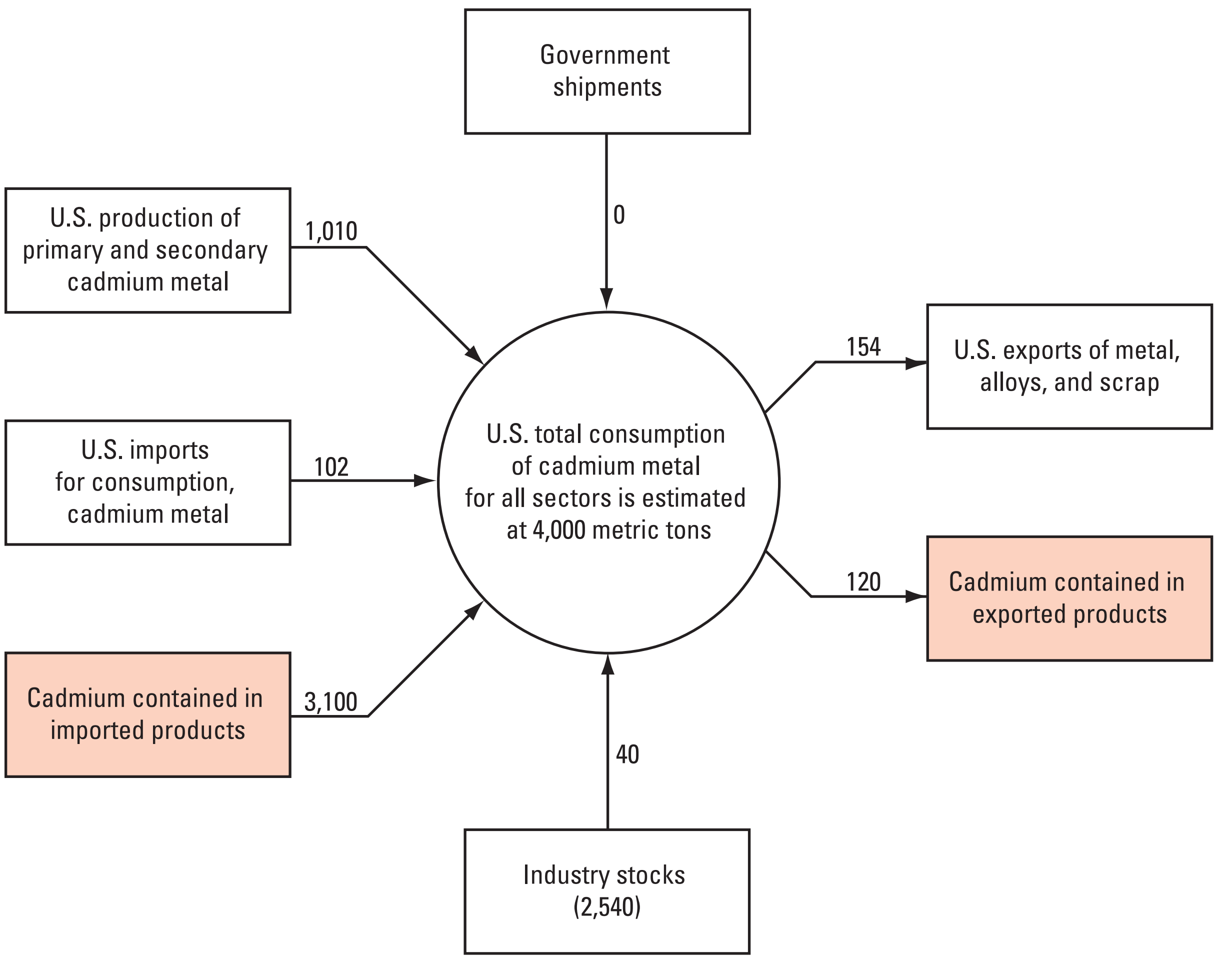


Figure 5. Total consumption of cadmium metal in the United States in 2004. [Total consumption is defined as primary and secondary cadmium metal production + cadmium metal imports for consumption + cadmium contained in imported products - cadmium contained in exported products + adjustments for Government and industry stock changes. Boxes represent sources of cadmium. Values represent 2004 flow estimates expressed in metric tons of cadmium metal, as adapted from data reported by the U.S. International Trade Commission, 2006 (shaded boxes) and the U.S. Geological Survey Mineral Commodity Summaries 2007 (Kuck, 2007). Units are expressed in metric tons. Values may not total because of rounding.]

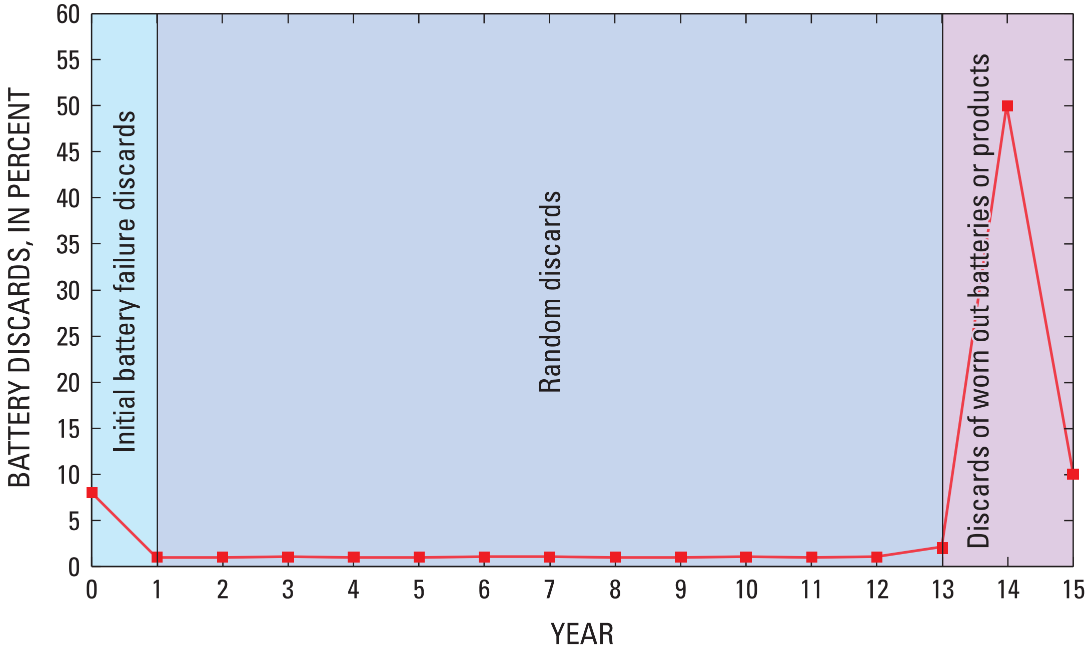


Figure 6. Estimated service life distribution pattern for a 15-year life battery. [Based on data provided by Sanyo Energy (USA) Corporation (2006) and C. Norman England, Rechargeable Battery Recycling Corporation, oral commun., 2006.]

powered vehicle batteries, and industrial batteries) on the basis of data reported by Sanyo Corporation (Sanyo Energy (USA) Corporation, 2006) and discussions with C. Norman England, President, Rechargeable Battery Recycling Corporation (oral commun., 2006). Battery discards are assumed to be a function of rates of acquisition of replacement batteries or associated products by the consumer, battery or associated product failure, and rates of removal of obsolete batteries from storage. The discard rate was determined to be greatest near the end of battery life (fig. 6). The amount of cadmium contained in batteries discarded for each year within the 1996-2005 study period was estimated from battery consumption data from prior years, estimated battery service life distribution patterns, and battery lives assigned to each group of batteries. Because each battery classification was assigned a different battery life, separate evaluations of each type had to be performed. Further assumptions related to battery life are reported in the appendix. The amount of cadmium that has been recovered from recycling in the United States and the amount of cadmium available for recycling but not recovered for the entire 10-year study period was then determined on the basis of an aggregation of these annual estimates. These data for 1996 to 2005, including estimates of average service life for each of the four principal battery groups, are shown in figure 7 and table 2.

An adjustment was made for the period 1996 to 1997 to account for the large amount of cadmium in batteries that were imported during these years (as shown on figure 3) to be used for electric vehicle development and testing. These batteries were not used in production vehicles; consequently, the life of such batteries was assumed to be shorter than a typical electric vehicle battery. A life of 3 years was assumed for these batteries.

The overall cadmium recovery rate has been increasing (table 2). The average amount of cadmium that was recovered from batteries increased from about 4 percent of the total amount of cadmium believed to be contained in such batteries in 1996 to about 11 percent in 2004. The rates reported in table 2 reflect estimated cadmium recovery rates rather than battery recovery rates, as reported by RBRC (2005). Estimates provided by RBRC indicate that the 4.4 million pounds (2,000 t) of batteries recovered in 2004 fell about 70 percent short of its 2004 recycling goal (INFORM, Inc., 2005) estimated in 1998. Cadmium recovery rates reported here for the years 1996 through 2000 likely are lower than rates reported elsewhere because of the relatively large amount of cadmium from developmental electric vehicle batteries that was assumed to become available for recycling during 1996-2000 (a major contributor to the large amount of cadmium available for recycling during these years as illustrated in figure 7). The estimates reported in table 2 are in line with an overall battery recovery rate for RBRC of less than 10 percent reported in 2002 (Sheehan, 2003). The USEPA issued a report in 2003 that stated that although lead-acid batteries had the highest recycling rate in 2003, about 93 percent, metals contained in

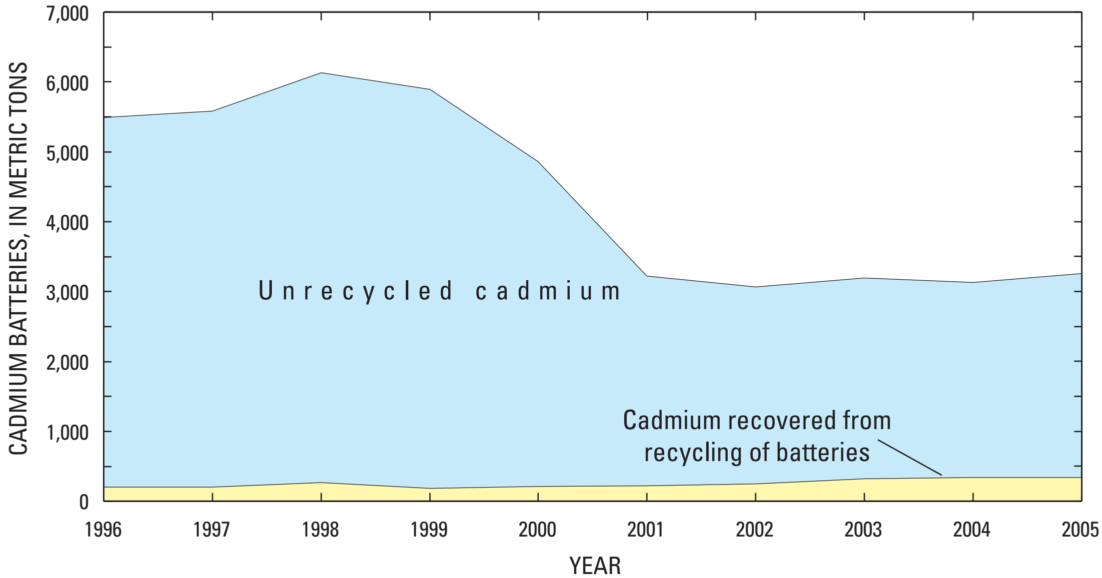


Figure 7. Estimated quantity of cadmium recovered from the recycling of batteries in the United States, 1996–2005. [Weight units expressed in metric tons. Estimated from U.S. International Trade Commission and U.S. Geological Survey data using an exponential distribution to estimate the amount of material available for recovery based on an assumed battery life of 15 years for an industrial battery, 6 years for an electric vehicle battery, 3 years for research testing batteries, and 3 years for sealed, consumer batteries and those contained in prepackaged products.]

consumer electronics (including cadmium in batteries) had a recycling rate of about 10 percent (U.S. Environmental Protection Agency, 2003).

Ancillary unpublished data provided by INMETCO indicated that the effective recovery rate of all types of consumer batteries in 2005 was about 16 percent; the effective recovery rate for industrial batteries (excluding electric vehicle batteries) was about 86 percent. These figures are generally in line with reported recycling rates of about 20 percent for consumer batteries and 80 percent for industrial batteries (Plachy, 2003b).

An important corollary to the cadmium recovery data reported in table 2 is shown in figure 7, which reveals that, although the amount of NiCd batteries collected for recycling (Warren, 2006) is gradually growing, the amount of cadmium recovered from these batteries is still small in comparison to the amount that is unrecovered. After use, millions of NiCd batteries are "retired"; they are either stored or discarded. The magnitude of unrecycled cadmium contained in batteries, estimated at about 40,000 t for the 10-year period since 1996 (the implementation date of the Battery Act), is illustrated in figure 7. The general downward trend in the overall quantity of unrecycled material since 1996 reflects increased recycling and the decreasing consumption of NiCd batteries in favor of other battery types. The cumulative amount of unrecycled cadmium in batteries provides an indication of the total amount of cadmium that is discarded by consumers, stockpiled, and (or) emitted into the environment.

A 2005 survey conducted by the RBRC found that, in the United States, consumers daily use an average of six wireless products that require rechargeable batteries (Rechargeable Battery Recycling Corporation, 2005). About half of the survey respondents reported that they had obsolete batteries or old unused electronic products containing batteries of various types stored in their homes. Others reported that they had discarded obsolete batteries. The RBRC also assumes at least 50 percent of batteries not in use but not yet recycled are being "hoarded" (C. Norman England, Rechargeable Battery Recycling Corporation, oral commun., 2006). Similarly, in a study conducted by Franklin Associates, Ltd., for the USEPA (U.S. Environmental Protection Agency, 2002a), it was assumed that 50 percent of NiCd rechargeable consumer batteries are discarded within the year purchased and 50 percent are retained for a period of up to 4 years. Therefore, for the purpose of estimating the quantity of batteries that are available for recycling in any year of the study period, it was assumed that up to 50 percent of the consumer batteries that become available for recycling in any given year do not immediately get recycled; a lag time of up to 4 years was assumed for this material.

The USEPA estimated that about 1,900 t of cadmium from household batteries was discarded as MSW in 2000 (U.S. Environmental Protection Agency, 2002a, p. 7, 157). Considering that this figure did not include industrial or military

Table 2. Estimated amount of contained cadmium in nickel-cadmium batteries available for recovery and recovery rates in the United States for 1996–2005.

[Units reported in metric tons of contained cadmium. Battery life estimated using data reported by selected manufacturers. Values may not total because of rounding. Amounts available for recycling derived from Kuck (2006), Plachy (2001, 2002, 2003a, 2004, 2005), and U.S. International Trade Commission (2006). Amounts recycled derived from Burchill (2000), Rechargeable Battery Recycling Corporation (2006), and Warren (2006). NA, Not available; --, Not applicable]

	Industrial batteries	Electric vehicle batteries[1]	Consumer batteries	Batteries in products	Total all battery types	Total cadmium recovery rate, in percent
Estimated battery life (years)	15	6	3	3	NA	--
Cadmium available for recycling in 1996	220	81	4,700	450	5,500	--
Cadmium in batteries collected for recycling in 1996[2]	NA	NA	NA	NA	200	4
Cadmium available for recycling in 1997	210	390	4,600	430	5,600	--
Cadmium in batteries collected for recycling in 1997[2]	NA	NA	NA	NA	210	4
Cadmium available for recycling in 1998	290	670	4,700	480	6,100	--
Cadmium in batteries collected for recycling in 1998[2]	NA	NA	NA	NA	270	4
Cadmium available for recycling in 1999	350	670	4,300	540	5,900	--
Cadmium in batteries collected for recycling in 1999[2]	NA	NA	NA	NA	190	3
Cadmium available for recycling in 2000	450	120	3,400	850	4,800	--
Cadmium in batteries collected for recycling in 2000[2]	NA	NA	NA	NA	210	4
Cadmium available for recycling in 2001	590	230	1,700	740	3,300	--
Cadmium in batteries collected for recycling in 2001[2]	NA	NA	NA	NA	230	7
Cadmium available for recycling in 2002	740	78	1,400	810	3,000	--
Cadmium in batteries collected for recycling in 2002[2]	NA	NA	NA	NA	250	8
Cadmium available for recycling in 2003	830	210	1,300	820	3,200	--
Cadmium in batteries collected for recycling in 2003[2]	NA	NA	NA	NA	330	10
Cadmium available for recycling in 2004	900	580	890	750	3,100	--
Cadmium in batteries recycled in 2004[3]	NA	NA	NA	NA	340	11
Cadmium available for recycling in 2005	970	530	880	880	3,300	--
Cadmium in batteries recycled in 2005[3]	NA	NA	NA	NA	340	10
Total cadmium available for recycling 1996-2005	5,600	3,600	28,000	6,700	44,000	--

[1] Assumed life of electric vehicle production battery is 6 years; for 1995-1997, however, a battery life of 3 years is assumed for prototype development batteries.

[2] Calculated on the basis of reported pounds of batteries collected for recycling x estimated contained cadmium percentage x assumed 95% refinery recovery rate.

[3] Calculated on the basis of battery recovery figures reported by Rechargeable Battery Recycling Corporation (2006) and unpublished data from International Metals Reclamation Company, Inc., oral commun., 2006.

batteries (assumed by Franklin Associates, Ltd., to account for about 25 percent of cadmium in batteries), this estimate is in general agreement with an estimate from this analysis for the same year (approximately 2,300 t of cadmium contained in consumer batteries that entered the MSW stream, assuming 50 percent of the batteries enter the MSW stream and 50 percent continue to be held by the consumer). Estimates of cadmium from batteries that become available for recycling, are recycled, or that enter MSW landfills on an annual basis for the period 1996 to 2005 are listed in table 3.

About 3,100 t of cadmium was contained in batteries available for recycling in 2004 (fig. 8). This material came from three principal sources: (1) waste from battery production in the United States, (2) battery discards, and (3) cadmium contained in spent batteries previously held in temporary storage. Approximately 340 t of this cadmium was recovered by recycling and about 2,800 t of cadmium in batteries entered MSW landfills. The USEPA reports that about 20 percent of the MSW material that was not recycled was incinerated and about 80 percent was sent to landfills (U.S. Environmental Protection Agency, 2003). About 540 t (98 percent) of metals is currently recovered from incineration by air pollution abatement devices; cadmium-bearing ash from the incineration process is collected and sent to MSW or hazardous waste landfills. In 2004, approximately 11 t of cadmium attributed to batteries entered the atmosphere from MSW incineration.

Summary

Because cadmium is toxic to humans and the environment under certain conditions, a thorough understanding of the use of products containing this metal and the pattern of use and disposal is warranted. In 2005, nickel-cadmium batteries accounted for more than 80 percent of the cadmium apparent consumption in the United States. The cadmium metal content of imported products (for all end uses) in 2004 was estimated at about 3,000 t, or about three times the reported production of cadmium metal from all primary and secondary sources in the United States. Since nickel-cadmium batteries began to be commercially recycled in 1995, the recycling rate has steadily increased to the 2004 level of about 11 percent, much of which comes from the recycling of industrial and commercial battery types. Although the market share of nickel-cadmium batteries has decreased since 1996, many of these batteries are still being produced domestically or are imported into the United States each year; others continue to be used, are being stored, or have been discarded. More than 40,000 t of cadmium contained in batteries are estimated either to have been discarded over the 10-year study period or remain temporarily in household storage. In 2004, about 90 percent of the cadmium contained in batteries potentially available for recycling ended up in municipal solid waste landfills. Incinerator losses account for about 11 t of cadmium in 2004.

Table 3. Estimates of cadmium metal attributed to rechargeable batteries in the United States, 1996–2005.

[Weight units are reported in metric tons. Values may not add because of rounding. Annual estimates of material available for recycling were developed using a schedule for the number of spent batteries that are placed in temporary storage in one year and either recycled or sent to Municipal Solid Waste (MSW) in a subsequent year. Data are derived from Kuck, 2006; U.S. International Trade Commission, 2006.]

Year	Cadmium metal attributed to domestic battery production	Cadmium metal in net battery trade	Cadmium metal in recycled batteries	Cadmium metal available for recycling	Cadmium metal entering MSW
1996	1,500	4,500	200	5,500	5,300
1997	1,700	3,800	210	5,600	5,400
1998	1,500	1,700	270	6,100	5,900
1999	1,400	1,700	190	5,900	5,700
2000	1,500	2,100	210	4,800	4,600
2001	800	1,800	230	3,300	3,000
2002	1,100	1,700	250	3,000	2,800
2003	500	1,400	330	3,200	2,900
2004	900	2,300	340	3,100	2,800
2005	500	2,500	340	3,300	2,900

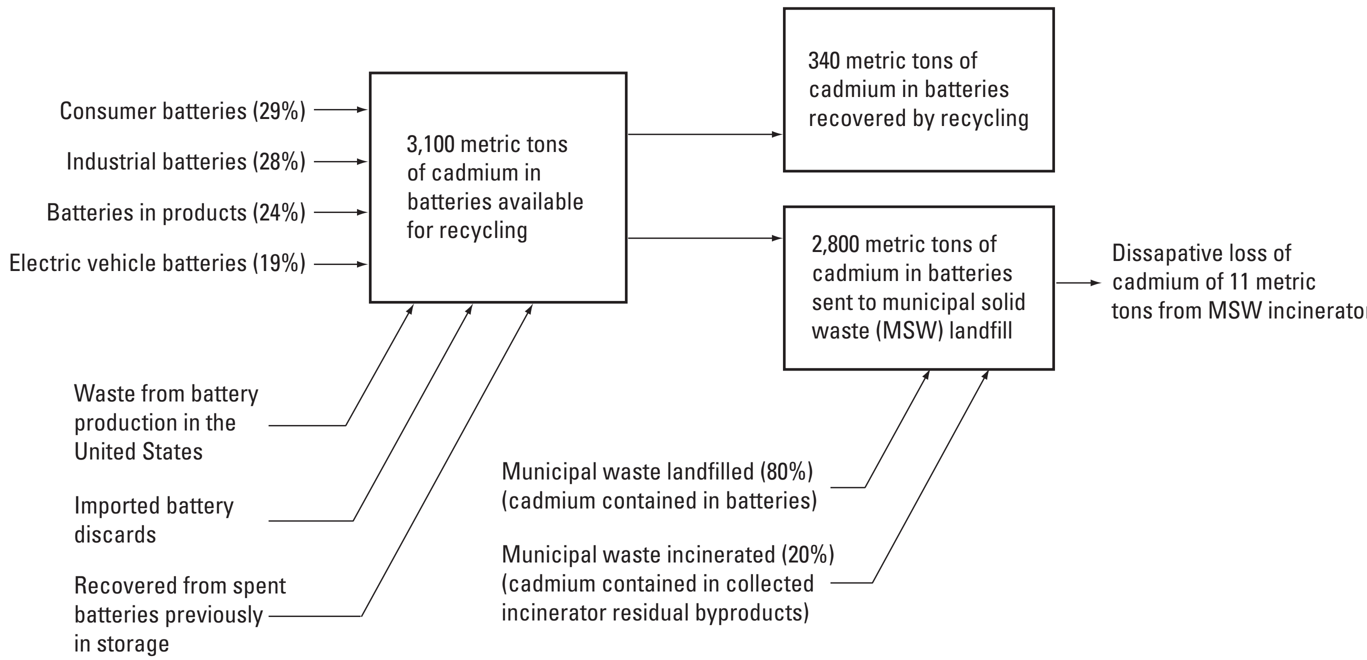


Figure 8. Estimates for cadmium municipal solid waste (MSW) generation in the United States for 2004 from nickel-cadmium batteries. [Units are expressed in metric tons and may not total owing to rounding. Estimates are based on the assumption that 50 percent of batteries spent in any given year remain in temporary storage for up to 4 years prior to entering the municipal solid waste stream (Rechargeable Battery Recycling Corporation, 2005) and that waste is split between incinerator (20%) and landfill disposition (80%) (U.S. Environmental Protection Agency, 2003). Values and percentages were found to vary from year to year.]

References Cited

Battery Association of Japan, 2006, Secondary battery sales statistics by volume: Tokyo, Japan, Japanese Ministry of Economy, Trade, and Industry, accessed May 5, 2006, at *http://www.baj.or.jp/e/statistics/index06.html*

Boehme, S.E., and Panero, M.A., 2003, Pollution prevention and management strategies for cadmium in the New York/New Jersey harbor: New York, New York Academy of Sciences, November, 64 p.

Burchill, Sean, 2000, Rechargeable Battery Recycling Corporation general overview: Rechargeable Battery recycling Corporation presentation at the 2000 Annual Meeting of the Municipal Waste Management Association, Seattle, WA, accessed June 6, 2006, at *http://www.usmayors.org/uscm/mwma/presentations/burchill.ppt#370*

INFORM, Inc., 2005, Rechargeable Battery Recycling Corporation fails to deliver on its promises: INFORM, Inc. press release, March 3, accessed June 6, 2006, at *http://infominc.org/RBRC520Release030305.pdf*

Klimasaukas, E.P., Kuck, P.H., and Plunkert, P.A., 2006, Cadmium, in Metals and minerals: U.S. Geological Survey Minerals Yearbook 2004, v. 1, p. 15.1-15.5. Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/cadmimyb04.pdf*

Kuck, P.H., 2006, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2006, p. 42–43. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/mcs/2006/mcs2006.pdf*)

Kuck, P.H., 2007, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2007, p. 38–39. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/mcs/2007/mcs2007.pdf*)

Morrow, Hugh, 2005, Cadmium markets and trends: International Cadmium Association submission, United Nations Environment Programme, September, accessed June 6, 2006 at *http://www.chem.unep.ch/pb_and_cd/SR/Files?Submission%20NGO/ICdA/MARKET%20Review%20Sept2005-1.pdf*

Pillot, Christophe, 2004, The world rechargeable battery market 2003–2008: Paris, France, Avicenne Developpement, Batteries 2004, Brussels, Belgium, April, 35 p., accessed April 24, 2006, at *http://www.avicenne.com/download/batteries/The%20Worldwide%20Rechargeable%20Battery%20Market%202003-2008,%20Recharge%20Brussels,%20April%202004,%20C.%20Pillot.pdf*

Pillot, Christophe, 2005, Main trends for the rechargeable battery market worldwide 2004–2010: Paris, France, Avicenne Developpement, Batteries 2005, Paris, France, June 14-16, 26 p., Accessed April 24, 2006, at *http://www.avicenne.com/download/batteries/Main%20Trends%20for%20the%20Rechargeable%20Battery%20Market%20Worldwide%202004-2010,%20Batteries%202005,%20June%202005,%20C.%20Pillot.pdf*

Plachy, Jozef, 2001, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2001, p. 38-39. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/14030.pdf*)

Plachy, Jozef, 2002, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2002, p. 40-41. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/140302.pdf*)

Plachy, Jozef, 2003a, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2003, p. 42-43. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/140303.pdf*)

Plachy, Jozef, 2003b, Cadmium recycling in the United States in 2000: U.S. Geological Survey Circular 1196-O, accessed May 30, 2006, at *http://pubs.usgs.gov/circ/c1196o/*

Plachy, Jozef, 2004, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2004, p. 40-41. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/cadmimcs04.pdf*)

Plachy, Jozef, 2005, Cadmium: U.S. Geological Survey Mineral Commodity Summaries 2005, p. 40-41. (Also available online at *http://minerals.er.usgs.gov/minerals/pubs/commodity/cadmium/cadmimcs05.pdf*)

Rechargeable Battery Recycling Corporation, 2005, New survey reveals the ‘skinny’ on what Americans stockpile in their closets: Atlanta, GA, Rechargeable Battery Recycling Corporation, press release November 21, accessed April 20, 2006, at *http://www.rbrc.org/call2recycle/releases/PR_11_21_05.html*

Rechargeable Battery Recycling Corporation, 2006, Nearly 5 million pounds of rechargeable batteries collected in 2005: Rechargeable Battery Recycling Corporation January 5 press release, accessed June 6, 2006, at *http://www.rbrc.org/call2recycle/releases/PR_1_5_06.html*

Sanyo Energy (USA) Corporation, 2006, Engineering Handbook, Cadnica: Sanyo Energy (USA) Corporation, accessed August 24, 2006, at *http://www.sanyo.com/batteries/pdfs/cadnicaT_E.pdf*

Sheehan, Bill, 2003, Nickel-cadmium rechargeable batteries and EPR: Cotati, CA, Grassroots Recycling Network, July, accessed April 20, 2006, at *http://www.grrn.org/epr/skillshare/buffalo/battery_handout.pdf*

U.S. Environmental Protection Agency, 2000, Cadmium compounds—Hazard summary: U.S. Environmental Protection Agency Air Toxics Website, accessed June 7, 2006, at *http://www.epa.gov/ttn/atw/hlthef/cadmium.html*

U.S. Environmental Protection Agency, 2002a, Characterization of products containing lead and cadmium in municipal solid waste in the United States, 1970 to 2000: U.S. Environmental Protection Agency Office of Solid Waste document EPA-5S30-SW-015A, 220 p., accessed June 7, 2006, at *http://www.p2pays.org/ref/03/02062.pdf*

U.S. Environmental Protection Agency, 2002b, Enforcement alert—The Battery Act: U.S. Environmental Protection Agency enforcement and compliance assurance document 2248A, EPA-300-N-02-002, March, 4 p., accessed May 30, 2006, at *http://www.epa.gov/oeca/ore/enfalert/*

U.S. Environmental Protection Agency, 2003, Municipal solid waste generation, recycling, and disposal in the United States—Facts and figures for 2003: U.S. Environmental Protection Agency, accessed June 29, 2006, at *http://www.epa.gov/msw/msw99.htm*

U.S. Geological Survey, 2005, Cadmium end-use statistics, in Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States (ver. 1.1): U.S. Geological Survey Data Series 2005-140, accessed May 30, 2006, at *http://minerals.usgs.gov/ds/2005/140/cadmium-use.pdf*

U.S. International Trade Commission, 2006, ITC trade dataweb: U.S. International Trade Commission, accessed May 30, 2006, at *http://dataweb.usitc.gov*

Vangheluwe, Marnix, Verdonck, Frederik, and Versonnen, Bram, 2005, Contribution of spent batteries to the metal flows of municipal solid waste: Brussels, Belgium, European Academy of Standardization, October, 79 p., accessed April 24, 2006, at *http://www.rechargebatteries.org/RelDoc_Metals_flow_of_MSW__2005_FL.pdf*

Warren, Tim, 2006, Recycling rechargeable batteries: Rechargeable Battery Recycling Corporation presentation at a Kansas Department of Health and Environment conference, March 2006, in Great Bend, KS, accessed June 6, 2006, at *http://www.kdheks.gov/waste/works/06GreatBend/presentations/TimWarrenRBRC.pdf*

Zbattery, 2006, Camcorder batteries, cordless phone batteries, and digital camera batteries, accessed November 22, 2006 at *http://www.zbattery.com*

Appendix

The estimates used in this study related to cadmium content of various battery types are summarized in table A-1. The table includes batteries designated as representative types, assumed battery weights assigned for principle classifications, and cadmium content assumptions. For each classification, the percentage estimate of NiCd batteries contained within that classification also is reported. For some classifications, different allocations for the percentage of NiCd batteries are assumed for 2003, 2004, and 2005 on the basis of recent trend data (Pillot, 2004, 2005). Variations were necessary owing to changing market trends for some applications.

In HTS code 8507308090, “nickel-cadmium storage batteries, not elsewhere specified”, multiple NiCd battery types are grouped into one category, so additional assumptions were needed regarding which batteries were included in this general category. Because specific information on batteries in this category is not available, a methodology using the average unit value, by country, as reported by the U.S. International Trade Commission was developed in order to estimate the relative distribution of batteries in this category into two general types, small consumer batteries with a relatively low unit value and large industrial batteries with a higher average unit value. It was assumed on the basis of the unit values for consumer and industrial batteries, as reported by selected manufacturers, that the price of a typical industrial battery/battery pack is greater than $300/unit and the typical price of a consumer battery/battery pack is less than $15/unit. Then the percent distribution of consumer and industrial battery imports by country was estimated using the unit value attributed to each importing country, which was based on the reported customs values and total number of batteries imported. The sliding scale of percentages allocated to industrial batteries, based on the reported unit value for each specified category, is shown in table A-2. Values, quantities, and percentages used are listed, by country, in table A-3. In order to obtain the most reliable estimate, the data were evaluated by country, rather than as a whole. For example, if the reported $/unit value of a specified category, as determined by U.S. International Trade Commission data, fell within the range of $75 to $150 per unit, then it was assumed that 75 percent of the batteries reported for that category were of the industrial type. Because of the rough nature of these assumptions, no adjustments were made for inflation over time or variations in country costs of production.

The assumptions made for average battery life and battery recovery distribution for each of the four principal battery groups are shown in table A-4. A special distinction was made for electrically powered vehicle (EV) research batteries imported into the United States prior to 2000. Although an average life of 6 years was assumed for EV batteries, batteries used in EV research were assigned a life of 3 years because these batteries probably were used intensively over a short period of time while battery research was ongoing. For each battery group, it was assumed that 10 percent of the batteries in that group would be recoverable in the year following the last year of battery life. These estimates were developed from information derived from Sanyo Energy (USA) Corporation (2006) and discussions with C. Norman England, President, RBRC (C. Norman England, Rechargeable Battery Recycling Corporation, oral commun., 2006).

Table A–1. Selected material content assumptions and estimates for nickel-cadmium batteries used in this analysis to determine the flow of cadmium in the United States, 1996–2005.

[g, grams; NA, Not available; --, Not applicable]

Classification	Manufacturer and battery type assumed as representative[1]	Weight range[2] (g)	Average weight[2] (g)	Cadmium content[2] (percent)	Cadmium content/cell or pack[3] (g)	Cobalt content[2] (percent)	Cobalt content/cell or pack[3] (g)	Nickel content[2] (percent)	Nickel content/cell or pack[3] (g)	Nickel-cadmium, in percent of total estimate[4]
General nickel-cadmium storage battery[5]	NA	NA	NA	14	NA	0	NA	22	NA	NA
Storage batteries, separate	--	--	--	--	--	--	--	--	--	--
Electrically-powered vehicle batteries	Saft STM	12,900–17,000	14,400	16	2,300	1	100	22	3,200	100
Sealed consumer batteries	Saft VRE	19–150	60	10–15	8.4	0.4–1	0.4	20–28	13.2	100
	Sanyo Cadnica	NA	NA	11–26	NA	0	0	13–29	NA	100
Industrial batteries	Saft SLM	1,000–45,000	14,900	8	1,200	0.2	30	9	1,300	100
	Saft SPH	NA	NA	16	NA	1	0	22	NA	100
Batteries enclosed in products	--	--	--	--	--	--	--	--	--	--
Power tools	Saft VRE-C	NA	43	10–15	6	0.4–1	0.3	20–28	9.5	91
Cordless phones	Battery selection[6]	63–113	80	14	11.2	0.9	0.7	22	17.6	40
Camcorders	Battery selection[6]	59–376	160	14	22	0.9	1.4	22	35	(1996–2003) 30
	--	--	--	--	--	--	--	--	--	(2004) 18
	--	--	--	--	--	--	--	--	--	(2005) 6
Cameras	Battery selection[6]	20–318	130	14	19	0.5	0.5	22	29	(1996–2003) 30
	--	--	--	--	--	--	--	--	--	(2004) 18
	--	--	--	--	--	--	--	--	--	(2005) 6
Portable radios	Saft VRE-AA	14–32	21	10–15	2.9	0.4–1	0.1	20–28	4.6	6
	Sanyo Cadnica-AA	NA	NA	11–26	NA	0	0	13–29	NA	6
Shavers	Saft VRE-AA	14–32	21	10–15	2.9	0.4–1	0.1	20–28	4.6	(1996–2003) 45
	Sanyo Cadnica-AA	NA	NA	11–26	NA	0	0	13–29	NA	(2004) 34
	--	--	--	--	--	--	--	--	--	(2005) 22
Electric toothbrushes	Saft VRE-AA	14–32	21	10–15	2.9	0.4–1	0.1	20–28	4.6	(1996–2003) 45
	Sanyo Cadnica-AA	NA	NA	11–26	NA	0	0	13–29	NA	(2004) 34
	--	--	--	--	--	--	--	--	--	(2005) 22
Portable vacuum cleaners	Saft VRE-Cs	43–150	97	10–15	13.6	0.4–1	0.7	20–28	21.3	(1996–2003) 45
	Saft VRE-D	NA	NA	10–15	NA	0.4–1	NA	20–28	NA	(2004) 34
	--	--	--	--	--	--	--	--	--	(2005) 22
Flashlights	Sanyo Cadnica	19–145	49	11–26	6.9	0	0	13–29	10.8	(1996–2003) 4
	--	--	--	--	--	--	--	--	--	(2004) 3
	--	--	--	--	--	--	--	--	--	(2005) 2
	Energizer	NA	NA	13–22	NA	0.5–2	NA	20–32	NA	--
	Panasonic	26–51	40	NA	NA	NA	NA	NA	NA	--
Portable electric lamps	Saft VE	18–150	64	10–15	9	0.4–1	0.4	20–28	14	(1996–2003) 24
(bicycle, for example)	--	--	--	--	--	--	--	--	--	(2004) 18
	--	--	--	--	--	--	--	--	--	(2005) 12
Clock batteries, reported separately	Saft VRE-AA	14–32	21	10–15	2.9	0.4–1	0.1	20–28	4.6	(1996–2003) 4
	Sanyo Cadnica-AA	NA	NA	11–26	NA	0	0	13–29	NA	(2004) 3
	--	--	--	--	--	--	--	--	--	(2005) 2
Military batteries, reported separately	Saft VRE-AA	14–32	21	10–15	2.9	0.4–1	0.1	20–28	4.6	16
	Sanyo Cadnica-AA	NA	NA	11–26	NA	0	0	13–29	NA	16

[1]Manufacturer was selected on the basis of volume of production and availability of data. Battery selection was based on applicability to end-use category.

[2]Based on reported weights given by manufacturer for all batteries in that classification. Data obtained from specified manufacturer's website.

[3]Calculated using (average weight) x (selected commodity content). When a percent range is shown, the average percent, reported by Vangheluwe, Verdonck, and Versonnen, 2005, was used for calculations.

[4]Percent allocation of the number of batteries attributed as nickel-cadmium batteries, based on end–use distributions reported by Pillot, 2004, 2005a. In some cases, the 2004 and 2005 percentages were reported to be lower than the percentages of prior years. Where no years are reported, value applies to entire study period.

[5]Vangheluwe, Verdonck, and Versonnen (2005).

[6]Based on a random selection of batteries used for each of these applications, as reported by Zbattery, 2006, accessed November 22, 2006, at *http://www.zbattery.com*.

Table A-2. Industrial battery allocation, by percent.

[Allocations were based on the premise that the typical price of an industrial battery is greater than $300/unit, while the typical price of a consumer battery is less than $15/unit. An allocation of the percentage of industrial batteries was assigned using the average unit value of batteries imported, by country, as shown in table A-3.]

Reported unit value	Percent attributed to industrial batteries
$0-$15	0
$15-$25	25
$25-75	50
$75-150	75
$150-$300	90
>$300	100

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Antigua/Barbuda	Customs value	0	0	0	0	0	2,600	0	0	0	0
	Units of quantity	0	0	0	0	0	400	0	0	0	0
	Unit value ($/unit)	0	0	0	0	0	6.50	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Australia	Customs value	5,973	8,198	0	0	75,000	0	3,337	0	0	17,758
	Units of quantity	94	1,145	0	0	320,000	0	9	0	0	6
	Unit value ($/unit)	63.54	7.16	0	0	0.23	0	370.78	0	0	2,959.67
	% to industrial	50	0	0	0	0	0	100	0	0	100
	Industrial units	47	0	0	0	0	0	9	0	0	6
Austria	Customs value	0	0	0	0	0	0	0	7,848	0	0
	Units of quantity	0	0	0	0	0	0	0	255	0	0
	Unit value ($/unit)	0	0	0	0	0	0	0	30.78	0	0
	% to industrial	0	0	0	0	0	0	0	25	0	0
	Industrial units	0	0	0	0	0	0	0	64	0	0
Belgium	Customs value	18,795	1,546	213,847	4,203	119,909	191,519	187,367	0	5,774	0
	Units of quantity	895	50	736,140	900	36,050	35,715	44,077	0	41	0
	Unit value ($/unit)	21.00	30.92	0.29	4.67	3.33	5.36	4.25	0	140.83	0
	% to industrial	25	50	0	0	0	0	0	0	75	0
	Industrial units	224	25	0	0	0	0	0	0	31	0
Br Virgin Is	Customs value	0	0	0	0	0	30,570	0	0	0	0
	Units of quantity	0	0	0	0	0	2,150	0	0	0	0
	Unit value ($/unit)	0	0	0	0	0	14.22	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Brazil	Customs value	0	0	0	63,354	3,389	2,054	27,360	0	407,060	0
	Units of quantity	0	0	0	810	579	277	7,817	0	127,423	0
	Unit value ($/unit)	0	0	0	78.21	5.85	7.42	3.50	0	3.19	0
	% to industrial	0	0	0	75	0	0	0	0	0	0
	Industrial units	0	0	0	608	0	0	0	0	0	0
Bulgaria	Customs value	0	0	0	0	0	0	0	2,043	0	0
	Units of quantity	0	0	0	0	0	0	0	250	0	0
	Unit value ($/unit)	0	0	0	0	0	0	0	8.17	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Canada	Customs value	120,876	210,990	646,616	199,068	2,851,275	3,032,152	142,217	287,706	872,966	134,321
	Units of quantity	5,890	4,693	20,895	3,455	46,390	36,950	3,133	2,601	19,263	9,000
	Unit value ($/unit)	20.52	44.96	30.95	57.62	61.46	82.06	45.39	110.61	45.32	14.92
	% to industrial	25	50	50	50	50	75	50	75	50	0
	Industrial units	1,473	2,347	10,448	1,728	23,195	27,713	1,567	1,951	9,632	0
China	Customs value	6,988,651	6,365,376	7,495,091	13,990,978	23,569,804	6,922,996	8,905,977	9,704,339	9,326,632	14,628,192
	Units of quantity	2,547,016	3,454,307	3,831,207	5,827,274	5,326,195	3,935,637	3,745,607	5,622,212	4,965,911	5,453,973
	Unit value ($/unit)	2.74	1.84	1.96	2.40	4.43	1.76	2.38	1.73	1.88	2.68
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Colombia	Customs value	0	27,500	0	0	0	0	0	0	0	3,530
	Units of quantity	0	5,000	0	0	0	0	0	0	0	2
	Unit value ($/unit)	0	5.50	0	0	0	0	0	0	0	1,765.00
	% to industrial	0	0	0	0	0	0	0	0	0	100
	Industrial units	0	0	0	0	0	0	0	0	0	2
Cote d'Ivoire	Customs value	0	23,395	0	0	0	0	0	0	0	0
	Units of quantity	0	42,000	0	0	0	0	0	0	0	0
	Unit value ($/unit)	0	0.56	0	0	0	0	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Czech Republic	Customs value	0	31,548	101,139	967,815	1,963,941	1,552,973	1,905,401	663,038	754,218	414,440
	Units of quantity	0	1,900	3,311	8,034	15,006	20,161	36,151	17,393	5,430	4,133
	Unit value ($/unit)	0	16.60	30.55	120.46	130.88	77.03	52.71	38.12	138.90	100.28
	% to industrial	0	25	50	75	75	75	50	50	75	75
	Industrial units	0	475	1,656	6,026	11,255	15,121	18,076	8,697	4,073	3,100
Denmark	Customs value	0	37,719	73,728	10,615	11,186	6,166	19,434	7,728	4,070	10,800
	Units of quantity	0	320	7,347	213	186	52	111	155	100	69
	Unit value ($/unit)	0	117.87	10.04	49.84	60.14	118.58	175.08	49.86	40.70	156.52
	% to industrial	0	75	0	50	50	75	90	50	50	90
	Industrial units	0	240	0	107	93	39	100	78	50	62
Ecuador	Customs value	0	0	0	0	14,213	0	0	0	0	0
	Units of quantity	0	0	0	0	56	0	0	0	0	0
	Unit value ($/unit)	0	0	0	0	253.80	0	0	0	0	0
	% to industrial	0	0	0	0	90	0	0	0	0	0
	Industrial units	0	0	0	0	50	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Finland	Customs value	11,756	465,419	29,031	21,992	103,610	82,840	10,348	23,690	22,635	47,214
	Units of quantity	110	46,268	2,353	1,705	1,076	560	198	347	375	686
	Unit value ($/unit)	106.87	10.06	12.34	12.90	96.29	147.93	52.26	68.27	60.36	68.83
	% to industrial	75	0	0	0	75	75	50	50	50	50
	Industrial units	83	0	0	0	807	420	99	174	188	343
France	Customs value	1,514,669	3,935,401	5,918,306	7,058,477	26,856,840	19,252,086	12,255,051	10,378,255	12,263,256	11,852,367
	Units of quantity	62,115	87,273	805,423	91,063	295,348	3,218,145	3,529,610	1,783,711	137,497	45,810
	Unit value ($/unit)	24.38	45.09	7.35	77.51	90.93	5.98	3.47	5.82	89.19	258.73
	% to industrial	25	50	0	75	75	0	0	0	75	90
	Industrial units	15,529	43,637	0	68,297	221,511	0	0	0	103,123	41,229
Germany	Customs value	2,254,880	2,055,418	2,644,362	2,743,955	3,160,506	1,653,064	2,017,050	2,450,481	2,397,520	1,950,102
	Units of quantity	667,388	679,016	3,815,368	607,048	554,707	48,033	74,240	164,383	83,907	103,746
	Unit value ($/unit)	3.38	3.03	0.69	4.52	5.70	34.42	27.17	14.91	28.57	18.80
	% to industrial	0	0	0	0	0	50	50	0	50	25
	Industrial units	0	0	0	0	0	24,017	37,120	0	41,954	25,937
Hong Kong	Customs value	5,361,647	4,314,125	3,282,865	2,682,463	1,931,103	2,128,550	2,891,720	1,573,809	2,360,376	1,630,512
	Units of quantity	1,605,326	1,204,278	1,680,758	548,078	518,444	580,003	559,835	348,333	869,614	650,997
	Unit value ($/unit)	3.34	3.58	1.95	4.89	3.72	3.67	5.17	4.52	2.71	2.50
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Hungary	Customs value	0	0	0	0	0	0	46,672	59,054	0	0
	Units of quantity	0	0	0	0	0	0	15,000	1,104	0	0
	Unit value ($/unit)	0	0	0	0	0	0	3.11	53.49	0	0
	% to industrial	0	0	0	0	0	0	0	50	0	0
	Industrial units	0	0	0	0	0	0	0	552	0	0
Iceland	Customs value	3,825	5,641	0	0	0	0	0	0	0	0
	Units of quantity	15	24	0	0	0	0	0	0	0	0
	Unit value ($/unit)	255.00	235.04	0	0	0	0	0	0	0	0
	% to industrial	90	90	0	0	0	0	0	0	0	0
	Industrial units	14	22	0	0	0	0	0	0	0	0
India	Customs value	0	0	0	0	0	61,787	0	58,668	250,488	56,584
	Units of quantity	0	0	0	0	0	100,880	0	343	206	52
	Unit value ($/unit)	0	0	0	0	0	0.61	0.00	171.04	1,215.96	1,088.15
	% to industrial	0	0	0	0	0	0	0	90	100	100
	Industrial units	0	0	0	0	0	0	0	309	206	52

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Indonesia	Customs value	4,243,040	5,282,748	6,002,549	4,330,341	4,143,484	1,613,919	397,662	183,385	140,894	36,784
	Units of quantity	2,244,072	2,790,075	2,939,889	2,771,510	2,581,526	1,074,387	780,242	145,524	237,101	64,800
	Unit value ($/unit)	1.89	1.89	2.04	1.56	1.61	1.50	0.51	1.26	0.59	0.57
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Ireland	Customs value	2,338,872	228,562	483,248	120,382	972,366	1,321,618	124,045	12,159	0	0
	Units of quantity	125,029	8,210	16,956	4,133	76,747	29,156	73,234	579	0	0
	Unit value ($/unit)	18.71	27.84	28.50	29.13	12.67	45.33	1.69	21.00	0	0
	% to industrial	25	50	50	50	0	50	0	25	0	0
	Industrial units	31,257	4,105	8,478	2,067	0	14,578	0	145	0	0
Israel	Customs value	630,497	146,800	374,353	423,548	111,181	90,008	90,000	2,070	0	0
	Units of quantity	10,664	8,960	29,000	25,350	10,630	6,422	90	43	0	0
	Unit value ($/unit)	59.12	16.38	12.91	16.71	10.46	14.02	1,000.00	48.14	0	0
	% to industrial	50	25	0	25	0	0	100	50	0	0
	Industrial units	5,332	2,240	0	6,338	0	0	90	22	0	0
Italy	Customs value	27,077	3,201	20,986	0	7,127	209,728	606,271	316,158	669,179	946,284
	Units of quantity	4,866	415	104	0	500	714	295	11,642	787	22,165
	Unit value ($/unit)	5.56	7.71	201.79	0.00	14.25	293.74	2,055.16	27.16	850.29	42.69
	% to industrial	0	0	90	0	0	90	100	50	100	50
	Industrial units	0	0	94	0	0	643	295	5,821	787	11,083
Japan	Customs value	64,137,101	39,717,506	29,890,272	17,886,592	16,846,744	11,350,615	12,231,392	8,420,501	5,161,582	3,829,577
	Units of quantity	26,031,781	21,497,001	19,061,711	10,185,179	7,473,877	5,842,002	5,425,699	3,085,315	1,067,129	361,213
	Unit value ($/unit)	2.46	1.85	1.57	1.76	2.25	1.94	2.25	2.73	4.84	10.60
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Korea	Customs value	1,100,749	1,712,919	1,531,293	1,962,190	2,046,271	1,051,063	290,031	216,172	353,265	204,242
	Units of quantity	1,085,316	191,788	79,232	1,158,414	960,340	329,921	92,361	15,083	24,819	13,433
	Unit value ($/unit)	1.01	8.93	19.33	1.69	2.13	3.19	3.14	14.33	14.23	15.20
	% to industrial	0	0	25	0	0	0	0	0	0	25
	Industrial units	0	0	19,808	0	0	0	0	0	0	3,358
Macao	Customs value	98,477	3,451,393	2,451,451	173,090	0	20,010	6,270	12,540	13,200	0
	Units of quantity	10,742	363,286	166,803	18,976	0	18,000	9,500	19,000	20,000	0
	Unit value ($/unit)	9.17	9.50	14.70	9.12	0	1.11	0.66	0.66	0.66	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Malaysia	Customs value	506,188	1,398,293	1,419,265	692,960	598,569	617,004	316,044	873,364	1,315,722	68,926
	Units of quantity	329,670	494,077	616,792	405,800	618,062	203,551	40,276	90,162	115,882	5,072
	Unit value ($/unit)	1.54	2.83	2.30	1.71	0.97	3.03	7.85	9.69	11.35	13.59
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Mali	Customs value	0	0	2,678	0	0	0	0	0	0	0
	Units of quantity	0	0	450	0	0	0	0	0	0	0
	Unit value ($/unit)	0	0	5.95	0	0	0	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Mexico	Customs value	1,200,213	1,561,435	837,718	1,169,393	1,363,013	8,693,746	2,277,300	699,458	1,399,204	104,723
	Units of quantity	173,691	330,669	251,708	386,502	382,323	1,468,185	441,745	111,856	177,136	12,025
	Unit value ($/unit)	6.91	4.72	3.33	3.03	3.57	5.92	5.16	6.25	7.90	8.71
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Morocco	Customs value	0	0	68,933	0	0	0	0	0	0	0
	Units of quantity	0	0	8,364	0	0	0	0	0	0	0
	Unit value ($/unit)	0	0	8.24	0	0	0	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Netherlands	Customs value	43,321	47,019	73,797	2,425	38,556	35,591	63,762	28,093	26,101	48,880
	Units of quantity	2,845	2,035	4,330	6	5,342	3,112	18	32	71	13
	Unit value ($/unit)	15.23	23.11	17.04	404.17	7.22	11.44	3,542.33	877.91	367.62	3,760.00
	% to industrial	25	25	25	100	0	0	100	100	100	100
	Industrial units	711	509	1,083	6	0	0	18	32	71	13
New Zealand	Customs value	5,087	15,000	0	0	8,000	189,309	136,112	328,612	64,378	157,856
	Units of quantity	168	151	0	0	40,000	5,397	4,267	13,650	2,282	6,774
	Unit value ($/unit)	30.28	99.34	0	0	0.20	35.08	31.90	24.07	28.21	23.30
	% to industrial	50	75	0	0	0	50	50	25	50	25
	Industrial units	84	113	0	0	0	2,699	2,134	3,413	1,141	1,694
Nigeria	Customs value	0	0	6,000	0	0	0	0	0	0	0
	Units of quantity	0	0	10	0	0	0	0	0	0	0
	Unit value ($/unit)	0	0	600.00	0	0	0	0	0	0	0
	% to industrial	0	0	100	0	0	0	0	0	0	0
	Industrial units	0	0	10	0	0	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Norway	Customs value	49,391	42,677	4,648	18,422	3,212	19,563	9,704	38,074	0	3,034
	Units of quantity	1,210	698	105	168	59	41	36	173	0	60
	Unit value ($/unit)	40.82	61.14	44.27	109.65	54.44	477.15	269.56	220.08	0	50.57
	% to industrial	50	50	50	75	50	100	90	90	0	50
	Industrial units	605	349	53	126	30	41	32	156	0	30
Philippines	Customs value	56,763	3,365	0	227,643	45,256	60,265	82,247	3,553,420	36,813	14,815
	Units of quantity	7,759	71	0	416,445	2,504	13,434	3,125	3,359,090	666	1,164
	Unit value ($/unit)	7.32	47.39	0	0.55	18.07	4.49	26.32	1.06	55.27	12.73
	% to industrial	0	50	0	0	25	0	25	0	50	0
	Industrial units	0	36	0	0	626	0	781	0	333	0
Poland	Customs value	0	0	0	0	172,056	0	0	0	0	0
	Units of quantity	0	0	0	0	261,480	0	0	0	0	0
	Unit value ($/unit)	0	0	0	0	0.66	0	0	0	0	0
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Russia	Customs value	0	0	0	0	0	2,500	0	0	0	0
	Units of quantity	0	0	0	0	0	4	0	0	0	0
	Unit value ($/unit)	0	0	0	0	0	625.00	0	0	0	0
	% to industrial	0	0	0	0	0	100	0	0	0	0
	Industrial units	0	0	0	0	0	4	0	0	0	0
Singapore	Customs value	4,412,071	5,294,243	1,704,182	1,264,525	650,623	480,169	64,590	245,121	309,137	391,377
	Units of quantity	2,617,317	3,203,871	1,001,404	1,076,409	532,851	397,183	154,432	305,682	379,353	580,346
	Unit value ($/unit)	1.69	1.65	1.70	1.17	1.22	1.21	0.42	0.80	0.81	0.67
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Slovak Republic	Customs value	0	0	0	0	0	0	0	0	0	53,900
	Units of quantity	0	0	0	0	0	0	0	0	0	350
	Unit value ($/unit)	0	0	0	0	0	0	0	0	0	154.00
	% to industrial	0	0	0	0	0	0	0	0	0	90
	Industrial units	0	0	0	0	0	0	0	0	0	315
South Africa	Customs value	0	0	0	0	0	48,583	0	0	30,757	90,112
	Units of quantity	0	0	0	0	0	8,100	0	0	2,718	8,513
	Unit value ($/unit)	0	0	0	0	0	6.00	0	0	11.32	10.59
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Spain	Customs value	210,344	17,393	4,000	96,592	25,109	0	14,318	2,634	17,291	0
	Units of quantity	5,153	93	2	2,659	999	0	455	37	3,130	0
	Unit value ($/unit)	40.82	187.02	2,000.00	36.33	25.13	0	31.47	71.19	5.52	0
	% to industrial	50	90	100	50	50	0	50	50	0	0
	Industrial units	2,577	84	2	1,330	500	0	228	19	0	0
Sweden	Customs value	3,687,107	1,589,409	3,071,771	4,418,025	5,650,717	5,746,256	6,868,659	9,892,231	9,137,391	10,453,593
	Units of quantity	58,644	22,241	35,195	48,957	56,594	47,643	64,612	62,283	62,263	77,513
	Unit value ($/unit)	62.87	71.46	87.28	90.24	99.85	120.61	106.31	158.83	146.75	134.86
	% to industrial	50	50	75	75	75	75	75	90	75	75
	Industrial units	29,322	11,121	26,396	36,718	42,446	35,732	48,459	56,055	46,697	58,135
Switzerland	Customs value	187,649	179,252	554,812	1,498,424	1,043,832	614,673	661,137	515,328	192,455	187,218
	Units of quantity	28,336	44,010	78,889	34,282	20,462	35,899	14,025	26,652	3,756	18,410
	Unit value ($/unit)	6.62	4.07	7.03	43.71	51.01	17.12	47.14	19.34	51.24	10.17
	% to industrial	0	0	0	50	50	25	50	25	50	0
	Industrial units	0	0	0	17,141	10,231	8,975	7,013	6,663	1,878	0
Taiwan	Customs value	7,177,082	10,087,416	6,837,650	3,818,209	5,810,493	5,109,717	2,722,901	1,883,387	1,982,487	1,307,003
	Units of quantity	712,290	877,151	1,243,919	839,195	1,354,331	2,135,725	693,325	313,046	312,300	209,383
	Unit value ($/unit)	10.08	11.50	5.50	4.55	4.29	2.39	3.93	6.02	6.35	6.24
	% to industrial	0	0	0	0	0	0	0	0	0	0
	Industrial units	0	0	0	0	0	0	0	0	0	0
Thailand	Customs value	44,647	823,215	10,944	23,060	53,465	23,157	43,827	2,175	2,700	10,125
	Units of quantity	53,872	142,092	1,824	4,000	6,684	13,555	11,564	118	200	750
	Unit value ($/unit)	0.83	5.79	6.00	5.77	8.00	1.71	3.79	18.43	13.50	13.50
	% to industrial	0	0	0	0	0	0	0	25	0	0
	Industrial units	0	0	0	0	0	0	0	30	0	0
Turkey	Customs value	0	0	0	0	0	0	0	0	0	11,000
	Units of quantity	0	0	0	0	0	0	0	0	0	100
	Unit value ($/unit)	0	0	0	0	0	0	0	0	0	110.00
	% to industrial	0	0	0	0	0	0	0	0	0	75
	Industrial units	0	0	0	0	0	0	0	0	0	75
United Arab Emirates	Customs value	0	0	0	4,525	0	0	0	2,233	0	0
	Units of quantity	0	0	0	1	0	0	0	950	0	0
	Unit value ($/unit)	0	0	0	4,525.00	0	0	0	2.35	0	0
	% to industrial	0	0	0	100	0	0	0	0	0	0
	Industrial units	0	0	0	1	0	0	0	0	0	0

Table A-3. Values, quantities, and percentages used in the development of Harmonized Tariff Schedule (HTS) code 8507308090, by country, for industrial and non-industrial batteries.—Continued

[By applying average cadmium content values for both industrial and non-industrial batteries (table A-1) to the number of industrial and non-industrial units reported here, the amount of cadmium attributable to this HTS category was determined.]

Country		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
United Kingdom	Customs value	1,857,653	1,289,584	1,450,539	2,933,499	2,073,712	2,025,592	1,122,864	511,215	1,085,856	568,029
	Units of quantity	84,189	94,051	497,748	67,913	22,878	70,971	18,528	20,348	423,346	24,481
	Unit value ($/unit)	22.07	13.71	2.91	43.19	90.64	28.54	60.60	25.12	2.56	23.20
	% to industrial	25	0	0	50	75	50	50	50	0	25
	Industrial units	21,047	0	0	33,957	17,159	35,486	9,264	10,174	0	6,120
Venezuela	Customs value	0	0	0	0	0	0	4,800	0	0	0
	Units of quantity	0	0	0	0	0	0	12	0	0	0
	Unit value ($/unit)	0	0	0	0	0	0	400.00	0	0	0
	% to industrial	0	0	0	0	0	0	100	0	0	0
	Industrial units	0	0	0	0	0	0	12	0	0	0
Vietnam	Customs value	0	0	0	0	0	0	0	0	0	9,673
	Units of quantity	0	0	0	0	0	0	0	0	0	2
	Unit value ($/unit)	0	0	0	0	0	0	0	0	0	4,836.50
	% to industrial	0	0	0	0	0	0	0	0	0	100
	Industrial units	0	0	0	0	0	0	0	0	0	2
Total industrial units		**108,303**	**65,300**	**68,026**	**174,446**	**327,901**	**165,465**	**125,295**	**94,350**	**210,162**	**151,555**
Total units imported		38,476,463	35,597,219	36,937,237	24,534,479	21,522,226	19,682,365	15,843,629	15,522,352	9,042,706	7,675,041
Non industrial units		**38,368,160**	**35,531,919**	**36,869,211**	**24,360,033**	**21,194,325**	**19,516,900**	**15,718,334**	**15,428,002**	**8,832,544**	**7,523,486**

Table A-4. Assumptions related to battery service life and battery recovery distribution.

[Data are derived from Sanyo Energy (USA) Corporation, 2006 and C. Norman England, Rechargeable Battery Recycling Corporation, oral commun., 2006. Values for years 1 to 16 are expressed in percent.]

Battery recovery distribution assumptions	Battery life (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Industrial batteries	15	8	1	1	1	1	1	1	1
Electrically powered vehicle (EV) batteries	6	10	1	1	1	20	57	10	
EV research batteries	3	10	20	60	10				
Consumer batteries	3	10	20	60	10				
Batteries enclosed in products	3	10	20	60	10				

Battery recovery distribution assumptions	Battery life (years)	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
Industrial batteries	15	1	1	1	1	1	20	50	10
Electrically powered vehicle (EV) batteries	6								
EV research batteries	3								
Consumer batteries	3								
Batteries enclosed in products	3								

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