6 Powering Wireless Electronics: Rechargeable Batteries and Alternative Technologies

All wireless electronic devices need a portable power source. Currently, power is provided by rechargeable batteries, but technology is changing rapidly and other power sources – such as fuel cells – may soon make significant inroads into the market. This chapter looks at the waste issues raised by today's rechargeable batteries and at the potential impacts on waste of some of the alternative technologies now under development.

Rechargeable Battery Waste

The impact of batteries on the waste stream (like that of other products) depends on the amount of waste they generate and its toxicity. The amount of waste generated is a function of the length of a battery's life and its weight. Waste toxicity depends on a battery's material composition. Rechargeable batteries are preferable to single-use batteries because they have a much longer life. However, their toxicity is causing concern around the world. Sixty percent of the rechargeable batteries sold worldwide are used in cell phones.[1]

As noted in chapter 2, the number of cell phones retired per year in the US is likely to reach about 130 million by 2005, resulting in the generation of about 65,000 tons of waste. The batteries in these phones account for about half this weight, or 32,500 tons. However, a cell phone's batteries may be replaced (because they are no longer functional) at least once before the phone is retired. If every phone uses two sets of batteries before being retired, about 260 million batteries will be discarded per year, amounting to 65,000 tons of waste.

Rechargeable batteries generate less waste than single-use batteries because they can be recharged hundreds of times – some can even be recharged over 1000 times. But rechargeables have toxic constituents such as cadmium, nickel, zinc, and copper, which can pose problems in the municipal waste stream. Moreover, the adapters used to charge the batteries have toxic components of their own and are a major contributor to cell phone waste. These devices may weigh more than the handset and batteries combined, and they generally are not interchangeable among different makes and models of cell phone.

Rechargeable Battery Technologies

Market Share

Batteries are a weak link in the rapidly developing information technology sector. As cells phones and other wireless electronic devices take on new functions and processing speeds increase, their energy consumption rises. But while semiconductor processing capacity rose by 2600 percent over the past seven years, battery technology has improved by only 65 percent.[2] At the same time, the drive toward portability is augmenting the pressure to make these devices smaller and lighter. This has had a great impact on the battery industry, leading to the development of batteries that can deliver greater energy capacity with less weight. Concern about the environmental and health effects of cadmium and the prospect of landfill bans on nickel-cadmium (Ni-Cd) batteries have also contributed to the move toward other battery types.

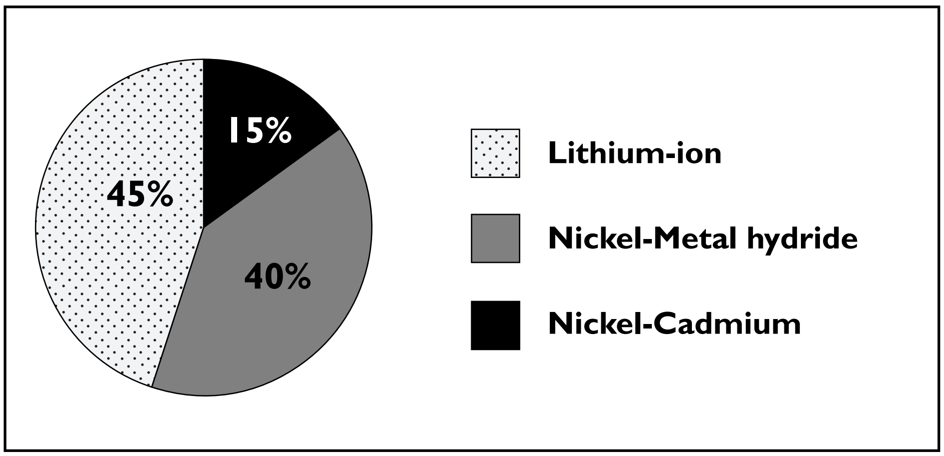
Until the mid-1990s, Ni-Cd batteries provided the power for most cell phones and other wireless devices.[3] In common use since the 1950s, Ni-Cds are the least expensive rechargeables. They have been used in a large number of electronic products but are now losing market share to newer, more efficient battery technologies. In particular, Ni-Cds have been replaced in recent years by nickel–metal hydride (Ni–MH) and lithium-ion (Li-ion) batteries, which have a higher energy density. This means they can provide the same amount of energy with less weight, or more energy with the same weight.

Figure 6.1 shows the cellular industry market share of these three rechargeable battery types as of November 2000. The market share of Ni-Cds, which formerly dominated the market, fell to only 15 percent.

Performance Characteristics

Table 6.1 compares some key characteristics of Ni-Cd, Ni–MH, and Li-ion batteries — the three primary rechargeables used in electronic products.* All of these (except for price) affect the length of a battery's life.

Figure 6.1 Cellular Industry Market Share of Three Types of Rechargeable Batteries (as of November 2000)



Source: Frost & Sullivan

It should be noted that the power consumption of an electronic device depends on how it is being used. For example, a cell phone operates in three modes — talk, standby, and off — each of which requires different amounts of power. The largest amount of power is consumed in the talk mode, when the phone is transmitting and receiving voice signals. Less power is used in the standby mode, when the phone is on and ready to receive calls. Some power is consumed even when the phone is "off"; this is the "discharge rate," described below. Other characteristics of rechargeable batteries include the following:

- **Energy density** is the amount of energy a battery can store per unit of its weight; it is expressed as watt-hours per kilogram (WH/kg). Li-ions are the best performers in this category. With twice the energy density of a Ni-Cd, a Li-ion battery can provide the same amount of energy at half a Ni-Cd's weight. In other words, a Li-ion battery weighing the same as a Ni-Cd can run for twice as long before needing to be recharged. And a battery that needs to be recharged less often will last longer, in addition to being more convenient.

- **Discharge rate** is the amount of energy a battery loses in a day when it is not in use. A discharge rate of 1 percent means that, after a day of nonuse, a fully charged battery will have 99 percent of the charge it had the day before. A high discharge rate leads to frequent recharging and a shorter battery life. Batteries with a high discharge rate are not suited to products that remain unused for long periods.

- **Cycle life** is the number of times a battery can be recharged. A battery that reaches the limit of its cycle life will no longer hold a charge and must be replaced.

* A new type of rechargeable battery, lithium polymer, was introduced in 1999. It is similar to lithium-ion but contains a plastic rather than a liquid electrolyte. Lithium-polymer batteries are slim, lightweight, and flexible, and could gain significant market share for cell phones in the future.

- **Memory effec**t is a gradual reduction in battery life caused by recharging a battery before it is completely drained. This causes the battery to "forget" the remaining energy it has stored, which eventually becomes unobtainable. The memory effect shortens the life of batteries, particularly Ni-Cds.

Table 6.1 refers to a typical battery of each type, but there is some variation among the characteristics within each category. Clearly, each type has its advantages and disadvantages. Ni-Cds are the cheapest and can be recharged the most, but they are also the heaviest and the most affected by the memory effect. Li-ions are the lightest and the least affected by the memory effect, but they can only be recharged 300 to 500 times; they are also the most expensive. Ni–MHs have by far the highest discharge rate, making them unsuited to devices that remain unused for long periods. In other respects, they tend to fall in between the other two battery types.

Regarding battery waste, the least amount will be generated by batteries that are not affected by the memory effect and have a high energy density, a high cycle life, and a low discharge rate. No battery has all these characteristics, however, so there are trade-offs with respect to the amount of waste each type generates. Users can help reduce waste by not recharging their batteries, particularly Ni-Cds, until they are completely spent.

Table 6.1 Characteristics of Three Types of Rechargeable Batteries

Battery Type	Energy Density (WH/Kg)	Discharge Rate	Cycle Life	Memory Effect	Typical Price*
Nickel-Cadmium	50	1% per day	1500	Strongly Affected	$27.95
Nickel–Metal-hydride	75	3%–10% per day	500	Slightly Affected	$33.95
Lithium-ion	100	1%–2% per month	300–500	Not Affected	$49.95

* Prices vary depending on specific battery characteristics. These are 2001 on-line prices for Motorola StarTAC phones.
Source: INFORM, Inc., based on MobileWorld Battery Information, http://www.mobileworld.org/info_battery.html; Motorola Consumer Catalogue Battery Information, http://commerce.motorola.com/consumer/QWhtml/battery_comp.html.

Material Composition

As noted in chapter 3, in November 1998, the US Environmental Protection Agency compiled its final list of persistent, bioaccumulative, toxic chemicals (PBTs) targeted for reduction in hazardous wastes. On a slightly earlier list, the agency assigned hazard ratings to these chemicals, with the lowest numbers signifying the materials of greatest concern (see Table 6.2). Cadmium was ranked number two on this list, following lead.

The dangers of cadmium are well known. It is classified by US EPA as a probable human carcinogen, it is toxic to wildlife, and it can pass through the food chain to humans, causing lung, liver, and kidney damage, and even death at high exposure levels.[4] Cadmium can leach into waterways from landfills and enter the atmosphere during incineration and recycling processes.[5] The European Union is moving to ban Ni-Cd batteries because of the toxicity of cadmium.[6]

Table 6.2 Hazardous Content of Three Types of Rechargeable Batteries

Toxic Chemical	Hazard Ranking*	Ni-Cd	Ni-MH (% of battery weight)**	Li-ion
Cadmium	2	6%–26%	-	-
Mercury	3	-	-	-
Chromium	9	-	-	-
Nickel/Nickel compounds	24	11%–30%	30%–50%	Yes†
Zinc	29	-	5%–20%	-
Copper	41	-	-	2%–15%
Cobalt/Cobalt compounds	63	0%–2%	2.5%–8%	<25%
Manganese	65	-	0%–2%	Some‡
Aluminum	82	-	0%–1%	2%–10%
Lithium compounds	-	<3%–10%	0%–1%	<25%
Steel	-	15%–25%	15%–25%	15%–30%
Polyvinylidene fluoride	-	-	-	0%–5%
Organic solvents	-	-	-	10%–20%
Carbon, graphite	-	-	-	3%–30%

*Listed according to ranking in US EPA, Office of Solid Waste, "Chemical Ranking Report for the RCRA PBT List Docket," Sept. 30, 1998, http://www.epa.gov.epaoswer/hazwaste/minimize/chemlist/rank.pdf. The lower the number, the higher the agency's level of concern. Unranked chemicals were not evaluated. **Percentage of total battery weight based on material safety data sheets (MSDSs). †The battery contains this chemical, but the amount is not disclosed on the MSDS. ‡Some versions of the battery contain this chemical, but the amount is not disclosed on the MSDS.
Source: INFORM, Inc.

Rechargeable batteries contain other PBTs in addition to cadmium, but their hazard ranking on the EPA's list is much lower. However, INFORM's research indicates that life-cycle studies comparing the toxicity of the three main types of rechargeable batteries are far from adequate. Clearly, Ni-Cds present a serious problem because of the cadmium they contain. But batteries that are replacing Ni-Cds contain zinc and copper — also on the EPA's PBT list — as well as cobalt, which is toxic and persistent. It is important to obtain sufficient information on all rechargeable battery technologies and not assume that any is environmentally preferable merely because its impacts have not been fully documented. Moreover, since all rechargeable batteries contain toxic materials, they should be recycled at end of life rather than sent to incinerators and landfills.

INFORM was not able to obtain material safety data sheet (MSDS) information on the composition of adapters. According to information supplied by Nokia and Motorola, these devices are made of steel and copper with plastic casing. Motorola indicated that they also include gold-covered copper.[7]

Alternative Power Sources

Hydrogen Fuel Cells

The demand for an alternative to batteries as a power source for wireless electronics is growing, for two reasons. First, battery technology has failed to keep up with the increased power needs of these devices. Second, the need to recharge can be an inconvenience. It can take many hours, the cell phone is inoperable during recharging, and an electrical outlet is not always available.

In the near future, portable electronic devices such as cell phones, personal digital assistants (e.g., Palm Pilots), and laptop computers may be powered by hydrogen fuel cells. Fuel cells have the potential to solve both of the problems driving the search for battery alternatives: they can provide more power with less weight (i.e., they have a high energy density), and the wireless product can be used immediately once new fuel is supplied. According to former US Secretary of Energy Federico R. Peña, "We're going to see fuel cells in homes, cars and other uses much sooner than we had predicted."[8]

A fuel cell combines the characteristics of a battery and an engine. Like a battery it produces electricity through chemical reactions, and like an engine it will run for as long as the fuel is supplied. Small fuel cells typically have a cartridge that supplies the fuel. Depending on the design, this can be discarded and replaced when the fuel runs out or it can be refilled. Usually the fuel used is hydrogen, either in its pure form or contained in a hydrocarbon fuel such as methanol.

Fuel cells are by no means a new idea. They were invented over 150 years ago but were not capable of generating useful amounts of power until after World War II.[9] In the 1960s, NASA began using fuel cells to generate electricity for spacecraft.[10] Today, many companies are trying to bring fuel cell technology to vehicles and homes, and some predict that its first widespread application is likely to be in portable wireless electronic devices.[11] Charles Call, president and CEO of MesoSystems, expects "laptops powered by fuel cells no later than 2002."

Prototypes of working hydrogen fuel cells were shown at the Knowledge Foundation's International Symposium on Small Fuel Cells and Battery Technology in April 2001. Displayed at the conference were a laptop computer powered by a videocassette-sized fuel cell and a flashlight powered for 20 hours by a fuel cell about the same size as six D batteries.[12]

The US Army is testing hydrogen fuel cells specifically for phones.[13] Robert G. Hockaday, who holds a number of fuel cell patents, predicts that his technology will lead to the development of fuel cells that are half the weight of current Ni-Cd batteries but provide 50 times more power between refills than Ni-Cds provide between charges. He envisions cell phones running continuously for 40 days on standby while consuming less than 2 ounces of fuel.[14] Also in the future is the possibility of cell phones and other electronic devices powered by fuel cells using methanol.[15] Motorola is working with Los Alamos National Laboratory to develop these devices, which are expected to run ten times longer between refills than current batteries do between charges.[16]

One of the problems posed by hydrogen fuel cells is the expense of creating the infrastructure needed to produce hydrogen. While fuel cells may eventually be lighter and more powerful than rechargeable batteries, they will not be widely used unless they can be produced at a price that makes them economically competitive. Fuel storage also presents safety issues. Both hydrogen and methanol are flammable and could pose a risk in some locations where small electronic devices are used, such as airplane cabins.

Engineers argue that, because fuel cells can be refueled indefinitely, their cost can be amortized over a long lifetime.[17] In cell phones, however, this will only apply if the design of both fuel cell and cell phone is standardized, permitting the same type of fuel cell to be used in phones of many makes and models. Otherwise, users are likely to discard the fuel cell along with the phone — and the life of cell phones will probably continue to be short.

Zinc-Air Batteries

Unlike traditional batteries, zinc-air batteries do not store electricity generated by an outside source in the form of chemical energy. Instead, they consume oxygen from the air, which oxidizes the zinc to create energy. Like hydrogen fuel cells, zinc-airs have a much higher energy density than traditional rechargeables. Electric Fuel Corp. is marketing these devices as a power source for cell phones and personal digital assistants (PDAs).* Electric Fuel claims that its products, unlike most zinc-air batteries, do not contain mercury.[18]

Electric Fuel's products are meant to serve as backup batteries and rechargers rather than substitutes for traditional rechargeable batteries. The Instant Power disposable cell phone battery weighs under 4 ounces, can provide 16 hours of talk time and up to 25 hours of standby time, and sells for about $17. It comes fully charged and is aimed at users concerned that their batteries could run out when they do not have access to an electrical outlet or cannot wait for the phone to recharge. According to Electric Fuel, its batteries are currently available for "many" Nokia, Samsung, Ericsson, and Motorola phones.[19]

Electric Fuel now plans to phase out these backup batteries — each phone requires a different design, and it is hard to keep up with new models.[20] Instead, the company will focus on its Instant Power Chargers, portable units that can recharge the battery in a cell phone or PDA without being plugged into an electrical outlet. The charger consists of a disposable "power cartridge" (which is the zinc-air power source), a "smart cord" that connects the cartridge to the phone (and can be used by many different phone models), and an airtight pouch for storing the cartridge between uses. The complete charger weighs about 3.5 ounces — 2.7 ounces for the cartridge alone.[21]

This product provides a complete charge within two hours but begins delivering power within a minute; the phone can be used during the charging process. The power cartridge can fully recharge a cell phone battery about three times. It lasts for about three months after being opened and must be stored in the airtight pouch between uses to preserve power for the next recharge. Instant Power Chargers sell for about $20 (replacement cartridges cost $10 apiece) and are available for Nokia, Motorola, Ericsson, Panasonic, and Siemens cell phones. Chargers for other brands will be available soon.[22]

The company describes its Instant Power products as "environmentally friendly," noting that the batteries are mercury-free.[23] However, both products have disposable components that could add significantly to the waste stream. Of course, many consumers will have no interest in using these products, but those who do are likely to use many of them. The resulting waste could be reduced by programs to take back and refill the cartridges, as is done with toner cartridges for computer printers.

Solar-Powered Batteries

Batteries that are rechargeable by sunlight could have a positive effect on the environment by reducing the electricity or fuel needed to recharge batteries in electronic devices. Like fuel cells, these batteries could also reduce

* Electric Fuel Corp. describes these products as fuel cells, but according to many experts, this term applies only to power sources fueled by hydrogen, which Electric Fuel's products are not.

waste by eliminating the need for adapters. However, used as a backup instead of a substitute for conventional rechargeable batteries and adapters, solar-powered batteries will only add to the waste stream.

An example of this technology is the Power Booster cell phone battery from Sunpower Systems Inc., which can be used in most Nokia, Ericsson, and Motorola phones. The device is actually a standard lithium-ion battery, but solar cells mounted on the back of the phone allow it to be charged by sunlight. A conventional recharger plugged into an electrical outlet can also be used.

The company claims that a drained Power Booster battery left in the sun for 15 to 20 minutes will gain enough power to make an emergency call and can be completely charged in five hours. The battery can also be charged in artificial light, but not nearly as quickly as in sunlight. According to Sunpower Systems, recharging the Power Booster under a lamp for one hour provides enough power for a one- or two-minute call, while leaving it in the sun for an hour provides enough power for nearly ten minutes of calling time. The battery costs $49.95 and lasts about two years, though this varies with usage.[24]

The Power Booster is being marketed as an “ancillary charger” intended for use where electric power is not available, rather than as a replacement for conventional chargers. Sunpower Systems plans to create similar solar-powered batteries for other wireless products, such as PDAs, beepers, cordless phones, and laptop computers.

The Power Booster weighs 4 to 5 ounces and lasts between one and two years. The solar cells themselves, however, can last 20 to 30 years. The company is interested in exploring the possibility of recovering these cells — which are made of silicon or gallium arsenide, an arsenic derivative — for reuse.[25]

Muscle Power

One new technology for powering cell phones may be described as “retro” in that it is based on human muscle power. Several wind-up and pump devices are now available or are soon to be marketed.

Motorola, in association with the Freeplay Energy Group, plans to distribute a hand-cranked device called FreeCharge in the US in 2002. Forty-five seconds of cranking will provide three to six minutes of calling time and several hours of standby time. The product has its own internal nickel–metal hydride battery and functions as a backup recharger. It weighs about 9 ounces and will cost about $65.[26] Although a battery could theoretically be fully charged using this device, the companies expect FreeCharge to be used as a backup charger in situations where electricity is not readily available.

Several cables will be available to make FreeCharge compatible with a number of phones made by Motorola and other manufacturers.[27] Freeplay Energy, headquartered in London, describes itself as “the world’s leading developer of self-sufficient energy technology.” It has developed other devices based on muscle power and has sold over three million of its hand-cranked flashlights and radios over the past five years.[28]

Already on the market is a hand-held device from AlladinPower, Inc. (of Tampa, Florida), that generates power when squeezed. It can be used to recharge batteries in cell phones and other electronic devices. Three minutes of squeezing will provide 20 minutes of calling time. AladdinPower is also introducing a foot pump: three minutes of pumping for an hour of calling time.[29]

Environmental Impacts of Alternative Power Sources

Whether a new product will have a beneficial or a detrimental effect on the environment depends in large part on how it is used. If it is used as a supplement to existing products that continue to be used, it will result in the increased consumption of energy and raw materials, increased pollution from product manufacture, and increased waste from discarded products. If it serves as a one-to-one substitute for an existing product, all of these environmental impacts may be reduced, depending on what the new product replaces.

Fuel cells. In the case of fuel cells, for example, research conducted by INFORM and others has documented the significant environmental advantages of this technology as a power source for vehicles. Fuel cells generate no harmful emissions and in vehicles can substitute for gasoline and the traditional combustion engine, which are major sources of carbon dioxide and other air pollutants.

As a substitute for rechargeable batteries, however, fuel cells would not provide such advantages, because batteries do not generate emissions during use. Instead, the environmental impacts of fuel cells in electronic products will depend largely on how their toxic content and weight compare with the toxic content and weight of the batteries and adapters they replace. Although some manufacturers claim that fuel cells will have no toxic constituents, this is not yet clear, because the technology is still being developed. Another factor with effects on waste generation is the type of cartridges used to store the fuel and whether these are refillable.

The ability of fuel cells to be refueled indefinitely could offer the benefit of long life, but this will have no practical effect unless the devices can be used interchangeably in many different makes and models of cell phone. Otherwise, they will wind up being discarded along with the phone or other product to which they are dedicated. Finally, the environmental benefits of fuel cells will also depend on how the impacts of producing the hydrogen fuel compare with the impacts of producing the electricity used to recharge batteries.

Solar and muscle power. Currently, devices based on solar and muscle power are being used as backup rechargers rather than substitutes for batteries and adapters. As such, they are adding to the waste stream rather than reducing it.

It is hard to imagine that human muscle power will ever be widely used to power electronic devices in the US — a society so dedicated to convenience that people use electric power to sharpen their pencils and brush their teeth. Solar batteries, however, if used as a substitute for rechargeables and adapters, could offer some environmental benefits. Assuming they are similar to conventional rechargeable batteries, their benefits would lie in the elimination of the need for adapters. They would also reduce air pollution by reducing the need for electricity. On the negative side, solar-powered batteries contain gallium arsenide, which, in turn, contains small amounts of arsenic — a persistent, bioaccumulative, toxic chemical.

All of the alternative power sources on the market today (these do not include fuel cells) are being used as backups — supplements — to existing products, and they all contain their own batteries. As a result, users of these devices will increase the amount of waste generated by power sources for cell phones and other wireless electronic devices. Moreover, all these new products contain toxic substances, so it is crucial that they be recycled. Factoring waste issues into design decisions would help to reduce the environmental impacts of these devices. Design strategies that would result in more economically recyclable power sources that generate less waste include reducing toxic constituents, extending product life, making fuel containers refillable, and standardizing designs so power sources can be used with many different phones.

End-of-Life Management of Rechargeable Batteries in the US

Although industry has strongly resisted the implementation of extended producer responsibility (EPR) policies in the US, there is one nationwide, industrywide EPR program operating in this country. This is the program to take back and recycle rechargeable batteries operated by the Rechargeable Battery Recycling Corp. (RBRC).

RBRC's program came about when eight states, concerned about the environmental impacts of nickel-cadmium batteries, passed legislation specifying that these products could not be sold in their states unless manufacturers established a system to take them back and recycle or properly dispose of them. The battery industry, faced with different provisions in each state and the threat of additional legislation in other states, decided to launch a national take-back program. Its first step was to press for federal legislation that would ease the stringent hazardous waste regulations that made battery take-back very expensive. Congress passed this legislation in 1996.[30] Industry then created a nonprofit company, the RBRC, to operate its collection and recycling program.

The program operates as follows: for a fee, RBRC licenses its logo to manufacturers of batteries and battery-containing products. The revenues, about $9 million in 2000, are used to fund the take-back program.[31] (Companies that choose not to become licensees must implement their own programs in states mandating the take-back of batteries.) There are now over 300 licensees, accounting for over 90 percent of the Ni-Cd-powered portable product industry.[32]

At first, RBRC took back only Ni-Cd batteries, but in 2001 the program was expanded to include other rechargeables, such as nickel–metal-hydride and lithium-ion batteries. It also expanded its operations into Canada. RBRC established four separate systems to manage the collection of batteries from retailers, communities, businesses and public agencies, and federal installations. Collected batteries are sent to the International Metals Company (INMETCO) in Pennsylvania for recycling.

Initially, RBRC's system resulted in significant progress. INMETCO, under its contract with RBRC, built a recycling facility to reclaim cadmium for use in the manufacture of new Ni-Cd batteries. (The company was already recycling nickel into products such as stainless steel sinks.) RBRC's goal was to recover 70 percent of Ni-Cds by 2001, and it reported that recycling rates had risen from 2 percent in 1993 to 22 percent in 1997 (see Table 6.3). In 1998, however, RBRC deferred its 70 percent goal until 2004.

Since 1998, RBRC has provided no data on the number of Ni-Cd batteries entering the waste stream or the recycling rates achieved by its collection and recycling program. Legislation in Minnesota and New Jersey requires such information to be reported, but RBRC has not met its obligations and the states have not moved to enforce them. Recently, a spokesperson for RBRC made the following claim: "Last year, the industry recycled over 3.5 million pounds of Ni-Cd batteries and has recycled over 20 million pounds since the RBRC program began. RBRC had an increase of 10 percent in the number of pounds collected in the year 2000 versus the prior year."[33]

A comparison of these numbers with those in Table 6.3 indicates that the amounts recycled in 1999 and 2000 are far below the amounts projected by RBRC.

There are lessons to be learned from RBRC's program. First, as a voluntary initiative, it has no recycling targets other than those it sets — and can readily change — itself. Second, there are no reporting requirements, which means there is little accountability. Yet the battery industry has been able to use the program to fend off regulations and possible bans on Ni-Cds. Expansion of the program to include all rechargeable batteries is a positive step, but the recycling rates that have actually been achieved have not been documented. Finally, INFORM's research indicates that, despite RBRC's publicity campaign, few consumers are aware of the program.

Table 6.3 Ni-Cd Battery Recycling in the United States and Canada

Calendar Year*	Total Recyclable Pounds Entering Waste Stream	RBRC Market Penetration	RBRC Program Pounds Entering Waste Stream	RBRC Program Pounds Recycled	RBRC Program Recycling Rate
1993	14,221,000	-	14,221,000	284,000	2%
1994	15,760,000	-	15,760,000	630,000	4%
1995	17,921,000	-	17,921,000	2,703,000	15%
1996	20,542,000	-	20,542,000	3,078,000	15%
1997	22,454,000	75%	16,840,500	3,782,000	22%
1998	23,231,000	80%	18,584,800	4,646,200	25%
1999	26,330,000	81%	21,327,300	6,398,190	30%
2000	27,917,000	82%	22,891,940	8,012,179	35%
2001	28,242,000	83%	23,440,860	9,376,344	40%
2002	28,199,000	84%	23,687,160	11,843,580	50%
2003	28,032,000	85%	23,827,200	14,296,320	60%
2004	28,035,000	86%	24,110,100	16,877,070	70%
2005	28,027,000	87%	24,383,490	19,506,792	80%

* Numbers for 1998 to 2005 are projected.
Source: Rechargeable Battery Recycling Corp., "Charge Up to Recycle," Fall 1998.

End-of-Life Management of Rechargeable Batteries Abroad

EU Directives

The European Union (EU) adopted its principal battery directive in 1991. This is not based on EPR, that is, it does not make industry responsible for take-back and recycling. (The first EU directive based on EPR was its packaging directive, adopted in 1994.) Instead, the focus is on reducing the heavy-metal content of batteries, promoting the use of batteries with less hazardous content, and separating batteries from other waste during collection and recycling. Two follow-up directives focus on banning mercury from batteries and labeling batteries as to their content.

Proposed amendments to these battery directives are now being circulated. Among the controversial provisions are a ban on Ni-Cds by January 1, 2008, and a recovery target for consumer batteries of about 75 percent.[34] Industry opposes these provisions, claiming they would increase battery prices by 30 percent.[35] An alternative being discussed is the imposition of a deposit/refund system on cadmium-containing batteries, which could ensure high recovery rates and perhaps avoid the need for a cadmium ban.[36]

National Legislation in Europe

Battery laws have proliferated throughout Europe. In Austria, Belgium, Germany, the Netherlands, and Switzerland, this legislation has included mandates for EPR.[37]

In most of the European programs, retailers collect batteries for free and manufacturers and importers pay for their transport and recycling. Many countries have set up producer responsibility organizations that run the programs and determine the fees each manufacturer or importer must pay. Some countries have created incentives for consumers to bring back spent batteries. For example, Austria gives out free lottery tickets and provides households with battery bags to encourage battery return. In Italy, there is a voluntary deposit system for Ni-Cds and a discount is provided on new cell phone batteries when spent batteries are returned. Switzerland now requires an advance disposal fee on Ni-Cds; if 80 percent of these batteries are not recovered, deposit fees are to be imposed.[38]

Asia

Asian nations are also acting on battery waste. In Japan, battery legislation was passed when industry failed to meet its voluntary recovery goals. The law specifies that manufacturers and importers of rechargeable batteries and the products that contain them must pay for battery collection and recycling. The following recycling targets must be met by 2003: 60 percent recovery of Ni-Cds; 55 percent recovery of Ni–MHs; 30 percent recovery of Li-ions.

Elsewhere, Korea has imposed deposits on batteries, and Taiwan has a mandated take-back program. The latter is run by a producer responsibility organization that sets the fees to be paid by manufacturers and importers. Recovery targets depend on battery type and range from 40 to 75 percent.[39]