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Strategies for a better environment

Waste in the Wireless World:
The Challenge of Cell Phones

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Introduction

At the start of the new millennium, the "wired" society of the 1990s has begun to give way to one that is wireless. Computing is getting legs, with people increasingly accessing the Internet and communicating with each other through small, hand-held electronic devices such as cell phones and personal digital assistants (PDAs). Freed from the plug, these devices provide access to information anytime, anywhere. As the writer James Gleick observed, "Two thousand and one is shaping up to be the year of the wireless device — the threshold year — just as 1994 was the year of the Internet and 1987 the year of the fax."[1] Former US Secretary of Labor Robert Reich predicts: "In another few years, we won't separate the Internet from all of these different devices. There is coming to be an integrated, almost seamless system for total connectivity."[2]

In addition to cell phones, PDAs, pagers, and pocket PCs, the wireless trend is spawning a wide array of other products, from e-mail devices (such as the BlackBerry) to MP3 music players, e-books, and simplified versions of many of these products intended for children. By 2005, 84 million people in the US are expected to access the Internet through such devices, up from 5 million in 2000.[3] And cell phones, besides providing voice communication, will be used increasingly for functions such as accessing one's e-mail, obtaining updated traffic and weather information, buying tickets, and getting the latest stock quotations and sports scores.

Today, over one billion cell phones are in use worldwide. In the US, their use has surged from 340,000 subscribers in 1985 to over 128 million in 2001. On average, these phones are used for only 18 months before being replaced.[4] Most are stored away in drawers or closets before eventually entering the municipal waste stream, where their management — whether by incineration or disposal in landfills — will ultimately be an increasing burden for local governments across the country.

This report examines the waste issues posed by wireless electronic products, with a focus on cell phones. It looks at the rapidly growing numbers of these products that are purchased and discarded and the toxic substances they contain. It also examines government policies and corporate initiatives addressing the end-of-life management of electronic products in the US and abroad. This report does not cover the multitude of environmental impacts associated with the manufacture of these products or with the huge communications infrastructure (e.g., transmission towers and switching and relay stations), nor does it look at energy use or the health risks associated with electromagnetic fields — all real issues in and of themselves.

The purpose of this report is to assess both the waste problems that cell phones and other wireless devices may pose in the future and the possibilities for eliminating those problems at their source, producing products that conform to a standard of true sustainability. Achieving this goal will necessitate designing producs that use as few toxic materials as possible and developing reuse and recycling programs that prevent these products from entering the waste stream. A closed-loop pattern of resource use — in which materials extracted from the earth are constantly reused and recycled in the production of new products — does not just reduce the environmental impacts of waste disposal. Even more important, it minimizes the amount of virgin materials that must be used to support our lifestyle and the far greater impacts of mining, drilling, logging, and materials processing.

So far, no existing program provides a satisfactory model, but that is likely to change with forthcoming initiatives in Europe and Japan. Meanwhile, both voluntary and mandatory approaches are moving forward in the US. While these currently focus on computers, they could be expanded to include cell phones and other electronic devices.

Electronic Waste Is Increasing Worldwide

Waste from electrical and electronic products is a subject of rising concern around the world. While this segment of the waste stream generally accounts for less than 5 percent of municipal waste in industrialized countries, it is growing much faster than the waste stream as a whole. Moreover, it contains many toxic substances, including arsenic, antimony, beryllium, cadmium, copper, lead, mercury, nickel, zinc, and brominated flame retardants, which can be released into the air and groundwater when burned in incinerators or disposed of in landfills, creating threats to human health and the environment. Finally, separating out the toxic materials in these products and disposing of them as hazardous waste is very costly.

At present, discarded TVs and computers are the main problem, with much attention focusing on their cathode-ray tubes, each of which contains 4 to 8 pounds of lead. However, given the enormous growth in wireless devices and their rapid obsolescence, it is only a matter of time before these products, too, start flooding into the waste stream, raising serious questions about the toxic substances they contain and how they will be managed.

Europe and Japan Lead in Addressing Electrical and Electronic Waste

Policies and programs abroad, particularly in Europe and Japan, aim at reducing the toxic materials in electrical and electronic waste and substantially increasing the amounts of these products that are reused and recycled after consumers discard them. These policies and programs are based on the principle of "extended producer responsibility," or EPR, which makes producers financially responsible for managing the waste generated by their products. (The terms "product stewardship" and "take-back" are also used to describe such programs.) The rationale underlying EPR is that, if producers must (1) pay to manage their products at end of life and (2) achieve high rates of reuse and recycling, they will design products that generate less waste and are easier to reuse and recycle in order to reduce their costs.

In Europe, the *Directive on Waste Electrical and Electronic Equipment* (the WEEE directive) and its companion *Directive on the Restriction of the Use of Certain Hazardous Substances* (the RoHS directive) are now being finalized. These far-reaching initiatives, which will be implemented in all European Union (EU) member states, specify that the waste from electrical and electronic equipment is of concern because:

- It accounts for over 4 percent of municipal solid waste (more than 6 million tons annually) in the European Union.
- It is growing at a rate three times faster than the EU municipal solid waste stream as a whole.
- It accounts for a major share of pollutants in the waste stream.

The WEEE and RoHS directives will require producers to take back their products at end of life free of charge, achieve ambitious reuse and recycling targets, and eliminate certain toxic substances from their products. The directives cover all electrical and electronic equipment sold in the EU. US producers will have to comply with the directives for products they sell in Europe but not for those they sell in the US.

In Japan, mandated producer take-back of electrical appliances has been in effect since 1998. Take-back is now being extended to electronic equipment, beginning with computers. There is intense competition among electronics producers in Japan to eliminate toxic substances and initiate design changes that facilitate reuse and recycling. These initiatives are seen as providing marketing advantages.

The US Begins to Tackle Electronic Waste

In the US, municipal solid waste managers are increasingly concerned about electronic products inundating their collection systems. In fact, surveys show this to be their primary concern.[5] While no federal legislation regarding end-of-life electronics is pending in the US, other initiatives that address the problem of electronic waste are under way. These range from state legislation requiring manufacturers to pay the end-of-life management costs for electronic products to take-back programs launched by individual companies. Meanwhile, the National Electronics Product Stewardship Initiative (NEPSI) aims at reaching a consensus among government, industry, and environmental organizations on the responsibility different stakeholders should have for managing electronic equipment at end of life, with a focus on computers.

But there is also a trend in the opposite direction, toward the development of throwaway electronic products. Much publicity has surrounded the introduction of throwaway cell phones, which could be followed by throwaway versions of computers and other products. In addition, new power sources for cell phones have disposable fuel cartridges that will also add to the waste stream if they are not taken back and refilled. The prospect of increased disposability raises serious concerns about the waste these products will generate, the toxic materials it will contain, and who should pay the costs of waste management. A useful alternative scenario may be found in the example of Kodak's throwaway camera. Under pressure from consumers, the company implemented a take-back program and redesigned the product to facilitate reuse and recycling. Besides achieving high recycling rates, these initiatives have generated significant profits for Kodak.

The Environmental Imperative

The world at the dawn of the 21st century is a very different place than the world of 100 years ago. Between 1900 and 2000, the earth's human population grew from 1.5 billion to 6 billion; over the next 50 years, it is expected to reach 10 billion. This surge in population, combined with generally rising standards of living around the world, is putting tremendous pressure on the global ecosystem. We simply cannot afford to be as profligate in our use of resources — and in our use of the planet as a dumping ground for our wastes — as we have been in the past.

The transition from an industrial to an information-based economy holds some promise for reducing our consumption of resources and our generation of waste. But it carries perils as well. By creating value from information, instead of from tons of coal and steel, we can decrease material inputs per unit of gross domestic product (GDP). In some cases, we can also reduce material inputs — that is, dematerialize — per unit of product. For example, a cell phone today is far lighter than its counterpart of 10 years ago. But as products get lighter they generally get cheaper as well, which means many more are sold. This, in turn, results in an increase in the total amount of materials used and ultimately discarded as waste.

Clearly, given the limited resources our planet can provide and the limited wastes it can absorb, what matters for the global environment is not material inputs per unit of GDP or material inputs per unit of product, but aggregate materials use. A recent study by the World Resources Institute estimates that over the next 50 years, economic activity worldwide is likely to increase fivefold, while materials consumption is likely to triple. Thus, even with certain products dematerialized and material inputs per unit of GDP reduced, the growth in materials use overall will present major problems for the global environment.[6]

The challenge in the coming decades will be to ensure continued economic growth while safeguarding the earth's resources and the public's health. This is not likely to occur without major changes in the way we use materials. An important strategy is to shift to a closed-loop pattern of materials use.

Product Design Is Key to Reduced Materials Use

The key to a closed-loop system is product design. For example, the recycling of plastics from discarded cell phones and other electronic equipment is today severely limited because of the brominated flame retardants these products contain. Instead, recycling can be facilitated by redesigning the products: removing these and other toxic constituents, using a smaller number of plastic resins, labeling the plastics, and using fasteners that allow for easy disassembly. These strategies lead to increased recycling rates and can, in many cases, make recycling profitable.

The main obstacle to implementing such strategies is the disconnect that currently exists between the design of products and their end-of-life management. When producers bear none of the costs for managing their products after consumers discard them, they have little incentive to create designs that facilitate reuse and recycling. If a company produces a disposable cell phone that generates much more waste than traditional phones, it is the taxpayer — not the producer or consumer of the actual product — who must pay the added waste costs. Thus, an unfunded mandate is imposed on local government.

EPR remedies this situation by transferring the financial responsibility for managing waste products to the producer and setting targets for reuse and recycling. With an EPR program in place, producers can no longer ignore their products' end-of-life management costs, because these will affect their bottom line. Instead, they have a powerful incentive to reduce those costs by coming up with products that generate less waste and whose parts and materials are cheaper and easier to reuse and recycle. Forging such links between product design and end-of-life management is therefore crucial to creating products that facilitate closed-loop materials use and avoid the need for costly waste treatment in the future.

Findings and Recommendations

Findings

The following findings of INFORM's research refer primarily to cell phones but are also applicable to most other hand-held wireless electronic devices, including personal digital assistants (such as the Palm Pilot), e-mail devices (such as the BlackBerry), pagers, e-books, MP3 music players, and pocket PCs. All of these devices are made of similar materials, have the same basic components — printed wiring board, display screen, case, power supply, and adapter — and present similar problems with respect to waste.

1. Waste from cell phones is increasing rapidly.

Cell phone use has grown dramatically in the US, from 340,000 subscribers in 1985 to over 128 million in 2001. Cell phones are typically used for only a year and a half before being replaced, even though they are often in good working order. By 2005, about 130 million cell phones weighing about 65,000 tons will be retired annually in the US. Most of these phones will be stored away in closets and drawers, creating a stockpile of about 500 million used phones weighing over 250,000 tons — material that will enter the waste stream at a later date. In future decades, the amount of waste generated by wireless electronic products could exceed that generated by wired computers.

- ***The small size of cell phones has both positive and negative implications for waste***. Because they are so small and lightweight, cell phones generate only a negligible quantity of waste per unit. However, their small size also makes them more likely to be thrown out in the trash, and ultimately to pose threats to the environment and public health after combustion in incinerators or disposal in landfills.
- ***In the US, the absence of a single cell phone standard increases the amount of cell phone waste***. Cell phones are typically dedicated to a specific service provider using one or another of several competing technical standards. Users therefore have to purchase a new phone when they change service provider or travel abroad, even when their current phone is still functional. As a result, more phones are purchased and more discarded. In contrast, phone systems in Europe all use a single standard, which is used in over 130 countries by two-thirds of the world's cell phone subscribers.
- ***If disposable cell phones become widely used, the amount of cell phone waste will increase substantially***. If cell phones designed to be thrown away after being used for about 60 minutes become commercial, they will produce large amounts of additional waste. Plans to market such phones have encountered delays, but the prospect of their introduction in the future remains a reality. If these products are not designed for reuse and recycling, with programs established to take them back after consumers discard them, the waste they generate will place additional burdens on municipal waste systems and the taxpayers who fund them.

2. Cell phones contain many toxic substances — including a number of persistent and bioaccumulative chemicals, called PBTs — that pose a threat to public health and the environment after incineration or disposal in landfills.

Cell phones contain substances on the US EPA's "Draft RCRA Waste Minimization List of Persistent, Bioaccumulative, and Toxic Chemicals," which comprises the "priority" PBTs regulated under the Resource Conservation and Recovery Act of 1976. PBTs are long-lived chemicals that can accumulate in the fatty tissues of animals, building up in the food chain to toxic levels even when released in very small quantities. They have been associated with cancer and a range of reproductive, neurological, and developmental disorders, and pose a particular threat to children, whose developing organ and immune systems are highly susceptible to toxic insult. PBTs in cell phones include antimony, arsenic, beryllium, cadmium, copper, lead, nickel, and zinc, which can be released to soil, groundwater, air, and waterways when disposed of in landfills, burned in incinerators, and, in some cases, processed in recycling facilities.

- ***Because plastics are highly flammable, the printed wiring board and housings of cell phones and other electronic products contain brominated flame retardants, a number of which are clearly damaging to human health and the environment.*** While the effects of some brominated flame retardants are still being evaluated, others have been associated with cancer, liver damage, neurological and immune system problems, thyroid dysfunction, and endocrine disruption. These substances can leach into soil and groundwater from landfills or form dioxins and furans — some of which are highly toxic — during incineration and recycling. Studies have found large increases in brominated flame retardants in fish and human breast milk; they have also been found in the blood of workers at an electronics recycling facility in Sweden. The use of brominated flame retardants is a major barrier to the recycling of plastics, one of the main components of cell phone waste.
- ***Lead, long recognized around the world as a threat to public health and the environment, is widely used in cell phone components and coatings.*** In a version of the US EPA's PBT list that ranked these substances as to degree of hazard, lead was ranked number one. Lead can contaminate drinking water by leaching into groundwater from landfills. It is suspected of being carcinogenic and has adverse impacts on the central nervous system, the immune system, and the kidneys. Lead has been linked to developmental abnormalities and can lead to impaired intelligence, hyperactivity, and aggressiveness in children. A primary application in electronic products is the tin-lead solder used to attach components to each other and to the printed wiring board. When the 500 million used cell phones that will be stockpiled in the US by 2005 enter the waste stream, they will put over 312,000 pounds of lead into the environment.

3. Cell phones are powered by any of several rechargeable battery types, all of which contain toxic substances that can contaminate the environment when burned in incinerators or disposed of in landfills.

Until the mid-'90s, nickel-cadmium (Ni-Cd) batteries provided the power for most cell phones. The dangers of cadmium are well known. In the version of the US EPA's PBT list that ranked these substances as to degree of hazard, cadmium was ranked number two (following lead). Cadmium is classified by the EPA as a probable human carcinogen, is toxic to wildlife, and can cause lung, liver, and kidney damage in humans. Ni-Cds have now lost much of their market share to lithium-ion and nickel–metal hydride batteries, which contain cobalt and substances on the US EPA's PBT list such as copper, nickel, and zinc — heavy metals that need to be kept out of disposal facilities. If each of the 130 million cell phones that will be discarded each year by 2005 uses two sets of batteries before being retired, 260 million of these batteries will enter the waste stream annually from cell phones alone.

- ***Alternatives to rechargeable batteries have begun to be marketed, primarily as backup power sources. If these continue to be used in addition to batteries instead of as substitutes, waste from cell phones will only increase.*** Alternative power sources based on zinc-air technology, solar power, and muscle power are intended primarily for use where electric power is not readily available or the user does not want to wait for the phone to recharge. Since these devices — all of which contain toxic substances — are used in addition to existing batteries and chargers, they will increase the amount of waste generated by power sources for cell phones. For example, the Instant Power Charger from Electric Fuel Corp. can recharge a cell phone battery only three times and lasts only three months after being opened. Users needing continuous backup power would therefore buy several of these units each year, adding significantly to the waste stream unless these products are recovered for reuse or recycling.

4. The US electronics industry lags behind European and Japanese companies in eliminating both brominated flame retardants and lead from electronic equipment.

There is intense debate around the world on whether brominated flame retardants and lead should be eliminated from electronic products, including cell phones. Many US companies and the industry's main trade associations continue to lobby against bans on these substances, arguing that the substitutes being considered will not perform as well and may even be more damaging to the environment. US companies are researching alternatives but have made no commitments to eliminating brominated flame retardants or lead from their products. This will be required, however, by forthcoming European Union (EU) directives on electrical and electronic waste from products marketed in EU member states. In Japan, elimination of these substances is being driven by market forces.

- ***Manufacturers in Europe and Japan have announced plans to eliminate brominated flame retardants from their products.*** Ericsson, the giant Swedish cell phone producer, supports the bromine-free lobby and has banned two types of retardants (polybrominated biphenyls, or PBBs, and polybrominated diphenyl ethers, or PBDEs) from its products. Sony, based in Japan, plans to eliminate brominated flame retardants from its products worldwide by 2003.
- ***The Japanese electronics industry leads the world in eliminating lead from its products and is using this as a marketing strategy.*** Leading companies such as Sony, Panasonic, Hitachi, Mitsubishi, Toshiba, NEC, Sharp, and Seiko Epson plan to produce lead-free products for the Japanese market within two years and ultimately worldwide. This is the result of pressure from Japan's Ministry of Economy, Trade and Industry, which already requires manufactures to recycle lead-containing products and document their lead content. Companies have found that promoting lead-free products in Japan can increase their market share.

5. Sweeping directives soon to be adopted in the European Union will drive the reuse and recycling of electronic products around the world, as well as reductions in lead and other toxic components.

The *Directive on Waste Electrical and Electronic Equipment* (the WEEE directive) and *Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment* (the RoHS directive) will require producers to take back their waste electrical and electronic products from households free of charge. Collection targets of 4 to 6 kilograms (8.8 to 13.2 pounds) per person per year will be set, along with reuse/recycling targets ranging from 50 to 75 percent of the amount collected. The rates will vary by product type: cell phones will have to be reused/recycled at a rate of 65 percent, and there will be strict reporting requirements and enforcement mechanisms.

- ***The forthcoming directives are spurring innovation in recycling and disassembly technologies in Europe.*** The high recycling rates for electronic equipment that will be required in EU member states have created a powerful incentive to develop less costly methods of disassembly and recycling. For example, the ADSM (active disassembly using smart materials) project at Brunel University (UK), Stuttgart University (Germany), and Gaiker Technology Center (Spain) is developing smart materials that can disassemble themselves at specific triggering temperatures. Researchers have developed a phone that can disassemble itself in 1.5 seconds.
- ***The EU directives will require the phaseout of lead and other hazardous substances in products made or marketed in EU member states***. Mercury, cadmium, lead, hexavalent chromium, and certain brominated flame retardants will be phased out of all electrical and electronic products by specified dates. There may also be a specific requirement that printed wiring boards from cell phones be handled separately because of their high toxicity.

6. Some countries in Europe, as well as Japan and Australia, have already passed legislation establishing national take-back programs for electronic equipment that give manufacturers responsibility for managing the waste generated by their products. However, all of these have significant weaknesses.

In Europe, national electronic take-back programs are currently in effect in Sweden and the Netherlands (which belong to the EU) and Norway and Switzerland (which do not). In Japan, where producers have been required to take back refrigerators, air-conditioners, TVs, and washing machines since 1998, take-back will soon be implemented for computers and will eventually be extended to include other electronic products such as cell phones. Australia is unique in having a national take-back program exclusively for cell phones. Though all these programs give producers financial responsibility for their products at end of life, they fail to include many of the key criteria for an effective program.

- ***Existing European programs are weak with respect to recycling targets, reporting requirements, enforcement mechanisms, and guidelines for managing recovered equipment.*** Take-back programs in EU member states will have to be strengthened to comply with the forthcoming WEEE and RoHS directives.
- ***Japan's program discourages consumer participation***. In contrast to programs in Europe, take-back in Japan does not have to be free to the end user. Since consumers have to pay to return their used products, this approach creates a disincentive for them to do so. However, Japan's take-back program does provide strong incentives for manufacturers to design products that can be recycled at low cost, since companies must pay to recycle their own products. An advance disposal fee is being imposed on the sale of new computers to fund recycling. Consumers will have to pay take-back fees for computers currently in use.
- ***In Australia's take-back program for cell phones, no effort is made to reuse the phones or recover components for reuse***. This voluntary program, which is run by industry, sends all recovered eqquipment to smelters for metals recovery. Manufacturers and carriers pay a combined fee of 21 cents (US) for every cell phone put on the market. These fees fund the recycling program.

7. In the US, there is no federal program addressing the end-of-life management of electronic products. Voluntary take-back programs implemented by manufacturers have failed to recover significant amounts of electronic waste.

Voluntary take-back initiatives for cell phones and other electronic equipment indicate that US manufacturers are beginning to acknowledge some responsibility for their products after consumers discard them. However, all of these programs are weaker and narrower in scope than existing programs in Europe and Asia. Most lack collection and recycling targets, reporting requirements, and enforcement mechanisms — all crucial components of an effective program. In addition, since many of these programs are not free to the end user, they discourage consumers from returning their used equipment. A few promising initiatives involving the reuse of cell phones and the recovery and reuse of printed wiring boards are too small in scale to recover a significant percentage of cell phone waste.

- ***The only nationwide take-back initiative in the US — an industry-run program for rechargeable batteries — has not reported regularly on its recycling rates and has failed to meet its targets.*** The program run by the Rechargeable Battery Recycling Corp. (RBRC) represents a positive step for the US, since participating producers take full financial responsibility for managing their products at end of life. However, the program has not recovered a significant amount of battery waste and its voluntary structure provides no consequences for the shortfall.

- ***While there is no federal legislation addressing electronic waste in the US, there have been some fledgling efforts at the state level***. California, Massachusetts, and Minnesota are considering legislation that would make producers responsible for paying the costs of managing the waste generated by their electronic products. The legislative experience of several states indicates that banning certain electronic products from landfills is politically possible (this has been done in California and Massachusetts), but fees imposed on new products to fund take-back and recycling programs tend to be perceived as additional taxes, and none have been passed so far.

Recommendations

The following recommendations outline the components of a successful take-back program and other measures needed to stimulate the development of environmentally sustainable wireless devices through the implementation of a closed-loop pattern of materials use. By encouraging the design of products that can be recovered after consumers discard them and then reused or recycled, such a system can mitigate the substantial damage to the environment and public health caused by materials extraction and processing and, later on, by the disposal of toxic substances in incinerators and landfills. Programs to recover electronic products for reuse and recycling are essential because, by making manufacturers responsible for their products after consumers discard them, they provide a strong financial incentive to design products that can be easily and economically reused and recycled. There are several ways to implement such programs: they can be mandated by federal, state, or local government; they can be voluntarily initiated by industry; or they can result from negotiations between these stakeholders. The key is that they contain all the elements that can ensure the recovery and proper management of a substantial portion of the waste generated by used cell phones and other electronic devices.

1. To safeguard the environment and human health from wireless waste and the many toxic substances it contains, more effective programs are needed to ensure that cell phones and other small wireless electronic products are recovered and reused or recycled.

Given the huge increase in this waste stream that has already occurred, and the prospects for even larger increases as applications (based on data and image transmission) continue to grow, the need to divert these products from incinerators and landfills through reuse and recycling has become more urgent. Programs and policies that shift the costs of managing waste electronic products from taxpayers to producers — whether these are referred to as extended producer responsibility (EPR), product stewardship, or take-back programs — are an effective means of increasing rates of reuse and recycling. Such policies are already in place in Australia, Switzerland, Norway, the Netherlands, and Sweden, and will soon be mandated throughout the European Union. The forthcoming *Directive on Waste Electrical and Electronic Equipment* (WEEE directive) and *Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment* (RoHS directive) will require producers to pay to recover their products, thereby internalizing the costs of waste management into product prices. Since financial responsibility for managing end-of-life electrical and electronic products will be shifted to industry, municipal governments will be relieved of the burden of managing this waste.

2. An effective take-back program provides incentives for producers to design products that are less wasteful, contain fewer toxic components, and are easier to disassemble, reuse, and recycle.

The key to reducing waste and making reuse and recycling cost effective is product design. For example, products designed to last longer will generate less waste, and products that contain alternatives to toxic components will be cheaper to recycle. Similarly, if manufacturers make ease of disassembly a priority, designers will create products with parts that can be easily removed for repair or reuse and materials that can be easily separated for recycling. An effective program provides producers with the incentives they need to include such factors in their design decisions. For example, when producers are required to pay a fee based on the cost of reusing/recycling their own products, those with less wasteful products that are cheaper to reuse or recycle will have to pay less — an effective incentive to design for reuse/recycling. In contrast, uniform fees imposed on all products in a particular category (e.g., $1 each for cell phones of any brand) provide no such incentives.

3. An effective take-back program includes targets for collection and reuse/recycling, imposes reporting requirements and enforcement mechanisms, and does not charge consumers to collect their discarded products.

None of the take-back programs for electronic products run by manufacturers in the US includes these elements. Without them, however, a program — whether voluntary or mandatory — may look good on paper but end up collecting and reusing/recycling very little. For example, the take-back program for rechargeable batteries run by the Rechargeable Battery Recycling Corp. (RBRC) set a recycling target of 70 percent for 2001. RBRC failed to meet this goal, but because of the lack of reporting and enforcement mechanisms was not held accountable for the shortfall. In addition, producers such as IBM and Hewlett-Packard are charging consumers to take back used computers, which discourages participation in their programs. The EU directives, in contrast, will have clearly defined targets for collection and reuse/recycling, along with both reporting requirements and penalties for those failing to meet the targets. Take-back will be free to consumers.

In the US, voluntary efforts by individual producers, service providers (such as AT&T and Verizon), and retailers to take back used electronic products are commendable. But the test will be whether they can collectively recover a substantial proportion of this waste stream (including cell phones). If they fail to achieve the reuse/recycling rates necessary to protect the environment and public health, mandated programs will have to be implemented to accomplish these objectives.

4. Establishing a hierarchy of strategies for end-of-life product management would help to ensure that recovering maximum value from discarded products and minimizing environmental impacts are priorities.

Although costs must be taken into account when determining how end-of-life cell phones should be managed, the lowest-cost strategy is frequently not the optimal environmental solution. For example, recovering precious metals through smelting may be cheaper than component reuse or recycling, but the latter is more beneficial to the environment. Similarly, a clear definition of "recycling" is needed to distinguish it from technologies such as waste-to-energy recovery, in which materials are burned to produce energy. Finally, standards are needed to ensure that equipment exported at end of life is shipped only to destinations where it will be managed responsibly.

5. An effective take-back program includes financial incentives such as deposit/refund schemes to encourage consumers to return small electronic devices such as cell phones for collection and reuse/recycling.

Because cell phones are small and easily discarded with ordinary trash, financial incentives are needed to ensure their return by consumers. In the US, deposits/refunds on beverage containers have been very effective at encouraging the return and recycling of cans and bottles: recycling rates are three times higher in states with deposit/refund systems in place than in states without such systems. Providing discounts on new phones or phone service in exchange for returned equipment can also encourage consumer participation in take-back programs.

Other models applicable to cell phones may be found in the European experience with battery take-back — in Austria, for example, customers receive free lottery tickets when they return their spent batteries.

6. Bans may be needed to ensure that toxic substances are eliminated from cell phones and other wireless products in the future.

In order to sell their products in Europe and Japan, US companies will have to eliminate lead-based solder, some brominated flame retardants, and a number of other toxic materials in accordance with the EU's forthcoming WEEE and RoHS directives and Japan's forthcoming design guidelines. This may result in the elimination of such substances from products sold on the US market as well. There are several reasons for this: (1) it is often cheaper to create common designs for the global market; (2) pressure is likely to increase from government and environmentalists in the US to reduce the toxicity of products sold here to the level of those sold abroad; and (3) investments already made in the development of alternatives to toxic materials in products sold abroad may make the use of those alternatives in the US more economical.

If US producers do not voluntarily eliminate toxic materials from products sold in the US, regulations or legislation will be needed. Bans on toxic substances can take several forms. For example, substances such as polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) have been banned at the national level in the US, whereas some materials or products (such as cathode-ray tubes found in TVs and computers) are banned from disposal facilities in certain states. In the latter case, these materials may be present in products but must either be recovered for reuse/recycling or sent out of state for disposal. Vigilance is needed to ensure that environmental standards for products sold in the US are at least as stringent as those imposed abroad, and that developing countries are not used as dumping grounds for our toxic wastes.

7. Establishment of a uniform cell phone standard and standardized designs for cell phones and their accessories would substantially reduce cell phone waste.

In the US, replacing today's competing technical standards with a single standard (as was done in Europe in the 1980s) would permit the same phone to be used regardless of service provider, eliminating the waste that results from subscribers having to replace their existing phone — even when it is in good working order — when they choose to change provider. Global standardization would enable consumers to use the same phone in different countries, rather than purchase a new phone when they travel abroad.

Standardization of design elements would allow adapters and other accessories to be used with many makes and models of cell phone. At present, these are dedicated to specific devices, creating additional waste whenever consumers buy a new phone. In the US, standardized outlets provide access to power for all types of electrical equipment. A similar system for wireless products would enable all brands of cell phone, as well as other devices like pagers and personal digital assistants (e.g., the Palm Pilot), to recharge using the same adapter.

8. End-of life management should be a priority in the design of new power sources for cell phones.

Factoring waste issues into the design of alternative power sources such as fuel cells and zinc-air batteries would help to reduce the environmental impacts of these devices. For example, the fuel cartridges they contain should be designed to be recovered and refilled when the fuel is spent. And long-lasting fuel cells and solar cells should be designed to be used with many product makes and models so they can be recovered and reused. Finally, alternative power sources, like traditional batteries, contain many toxic substances, so it is crucial to recycle what is not reused.

9. If and when disposable cell phones become widely available, the need for recovery and reuse/recycling programs will be especially urgent. The less wasteful alternative of phone rental should be encouraged.

Like today's conventional cell phones, disposable phones will contain many toxic substances, but many more of them will be discarded each year. To prevent this waste from becoming an additional burden on municipalities and the taxpayers who fund them, it is critical that manufacturers implement programs to recover these products for reuse and recycling. Kodak's program to take back its throwaway camera provides a useful example of how factoring end-of-life management considerations into product design can result in high rates of reuse and recycling, as well as profits for producers.

An alternative to disposable phones is short-term phone rentals, currently aimed at international travelers. These phones generate less waste than disposables because they are continually being reused. The cost of phone rental is now very high but would likely come down if government, private industry, and other institutions encouraged its use by their employees who travel.

10. Government procurement policies favoring environmentally preferable products and vendors that offer product take-back for reuse/recycling would encourage producers to design such products and implement such programs.

Government is the largest customer in the US. The federal government accounts for 7 percent of this country's gross domestic product, and state and local government account for 13 percent. Because of its economic clout, government can drive design changes through its procurement guidelines. For example, General Motors recently eliminated mercury switches from its cars after Minnesota revised its procurement specifications to require mercury-free vehicles, and the Energy Star label became a standard feature on computers after the federal government began purchasing only these energy-efficient products. Similarly, government procurement guidelines can stipulate that cell phones purchased by government agencies must be free of specified toxic substances, must be taken back by producers, must come with a reuse/recycling guarantee.

I Cell Phones: An Overview

A cell phone is really a radio. Its predecessor was the radio telephone used in cars – primarily police and other emergency vehicles – beginning in the 1940s in the US. These were serviced by a central antenna in an area with only a few channels* and required high power transmission over long distances. Because of the limited number of channels available, callers typically had to wait – sometimes for long periods – in order to place a call. The equipment was extremely heavy and cumbersome.

The first commercial cell phone services were introduced in the US in 1983, and since then the use of cell phones has skyrocketed. In 1985, the country had 340,000 subscribers. That number increased to 5.3 million by 1990, to 33.8 million by 1995, and to close to 130 million by 2001.[1]

The genius of the cellular system is to divide geographic areas into a network of small cells, making hundreds of frequencies available and allowing millions of people to use the system simultaneously. And because only low power transmission is required, phone batteries can be small. These factors, and the continually shrinking size and weight of electronic components over the past three decades, combined to make widespread use of portable cell phones a reality by the 1990s.

The terminology relating to cell phones can be very confusing, partly because different terms are used in different countries. For example, what Americans call "cell phones" the British call "mobiles" and the French often call "portables." In this report, cell phone refers to both cellular phones and phones that are a component of systems technically distinct from conventional cellular, such as personal communications systems (PCS) in the US. It should also be noted that cell or mobile phones are different from cordless phones. The latter are used to extend wired phone systems over short distances (e.g., under 500 feet within a home) by sending signals between a dedicated base station and a handset. This report does not address cordless phones.

Cell Phone Market Share

The US cell phone market is very competitive. Table 1.1 shows the market share and number of subscribers of the major service providers. Verizon leads with 29 million subscribers. Table 1.2 shows the global market share of the top cell phone manufac-

Table 1.1 Market Share of US Wireless Service Providers, Dec. 31, 2001

	No. of Subscribers (millions)	Market Share (%)
Verizon	29.4	22.8
Cingular	21.6	16.7
AT&T	18.1	14.0
Sprint PCS	13.6	10.5
Nextel	8.6	6.7
VoiceStream	6.9	5.3
Other	31.0	23.9
TOTAL	**129.2**	**100.0**

Source: Strategy Analytics, *Wall Street Journal*, Feb. 12, 2002.

* A channel is a pair of radio frequencies – one to receive and one to transmit signals. The Federal Communications Commission (FCC) assigns commercial and noncommercial licenses giving the right to transmit over specific frequencies.

turers. Positions shift frequently, but in 2001 Nokia was the leader, with 36 percent.

Table 1.2 Global Market Share of Cell Phone Manufacturers, 2001

	No. of Shipments (millions)	Market Share (%)
Nokia	140.0	36
Motorola	58.6	15
Samsung	28.6	7
Siemens	28.4	7
Ericsson	27.9	7
Other	109.5	28
TOTAL	**393.4**	**100.0**

Source: Williams Capital Group, *Barron's*, Feb. 18, 2002.

Cell Phone Standards

All wireless services use a cellular-like network of base stations and antennas, along with mobile switches to manage the network. However, different systems may employ one of several cellular standards, which are not compatible. These standards dictate how a specific system works. They set the rules followed by the various elements of the system – base stations, mobile switches, cellular databases, etc. – in order to communicate with each other.[2]

In the early 1980s, European wireless companies and government officials, with leadership from Scandinavia, agreed to use a single technical standard known as GSM (Global System for Mobile Communications). GSM is now used by two-thirds of the world's cell phone subscribers in over 130 countries.[3] Because of this uniform standard, European users can operate their cell phones throughout Europe, regardless of provider network, and in other parts of the world where GSM has been adopted.

The US, on the other hand, has several competing standards: CDMA (code division multiple access) is used by Verizon and Sprint; TDMA (time division multiple access) is used by AT&T and Cingular; Nextel has its own proprietary standard; and GSM is used by VoiceStream. (In the US, GSM operates at a higher frequency than in Europe, so GSM phones sold in the US may not be compatible with European GSM phones, and vice versa.) With cell phones typically dedicated to a specific service provider using one or another of these competing standards, US users generally have to purchase a new phone when they change service provider, even when the old phone is still functional.

The percentage of customers who switch service providers to get a better deal is referred to as "churn." The financial magazine *Barron's* estimates churn at nearly 3 percent per month, or over 30 percent per year. This means that about 40 million users are switching service provider each year – and discarding their phones even though they may be in good working order.[4] Moreover, since US phones do not work in most other countries, travelers needing wireless services abroad must buy an additional phone. Thus, the net result of the lack of a single cell phone standard is more phones purchased and more discarded, with obvious implications for waste. (This is one impetus behind the development of a throwaway cell phone, discussed in chapter 7.)

Given the wide reach of the global economy and the huge volume of global travel, the need for a worldwide wireless communications system is clear. Such a system would be greatly facilitated by a single standard, and there have been numerous attempts to develop one. The International Telecommunications Union, a United Nations agency, tried but did not succeed. The Mobile Wireless Internet Forum, a new group that includes all the major companies in the industry, may meet with greater success. However, as the industry upgrades its technology and moves to the next generation of equipment, competition among supporters of the different standards is intense. The stakes are high — domination of worldwide wireless communication — and companies with the losing standards will be stuck with a lot of obsolete equipment.

A new technology now under development could render the standard issue moot. Software-defined radio (SDR) would shift many of the functions of hardware components to software, allowing for much greater flexibility. With SDR, the software could be reprogrammed to accommodate multiple standards or added applications, allowing cell phones and base stations to be upgraded without changing hardware. However, there are still technical problems to be solved before this technology becomes commercially viable.[5]

Makeup and Environmental Impacts of Cell Phones

Cell phones are complicated devices capable of processing millions of calculations per second. Their basic components are:

- The handset, including —
  - The printed wiring board (PWB).*
  - A liquid-crystal display panel (LCD).
  - The keypad, antenna, speaker, and microphone.
  - The carrying case.
- The power source/batteries.
- An adapter to charge the batteries.

A study done at Delft University of Technology in the Netherlands[6] indicates that the PWB and LCD together account for 98 percent of the handset's environmental impacts in production and recycling. This analysis excludes the impacts of the adapter and batteries, and is based on phones made between 1995 and 1998. The PWB and LCD, responsible for almost all of a handset's environmental impacts, account for only about half its weight.

According to TCO Development (a company owned by the Swedish Confederation of Professional Employers that aims to create good workplace environments through certification and eco-labeling programs), most of the environmental impacts of cell phones are due to the PWB, LCD, and batteries. For a phone to obtain the TCO label, it must be possible to open the unit's housing and separate these three parts using a single tool in a single operation.[7]

The Printed Wiring Board

The printed wiring board is the brains of the cell phone, controlling and coordinating all its functions, from signaling the base station to performing housekeeping chores for the keyboard and display. It is composed of electronic components such as integrated circuits and capacitors connected with circuitry (primarily made of copper) soldered to the board and secured with protective adhesives and coatings. The board itself is usually made of epoxy resins or fiberglass and is generally coated with gold plating.[8]

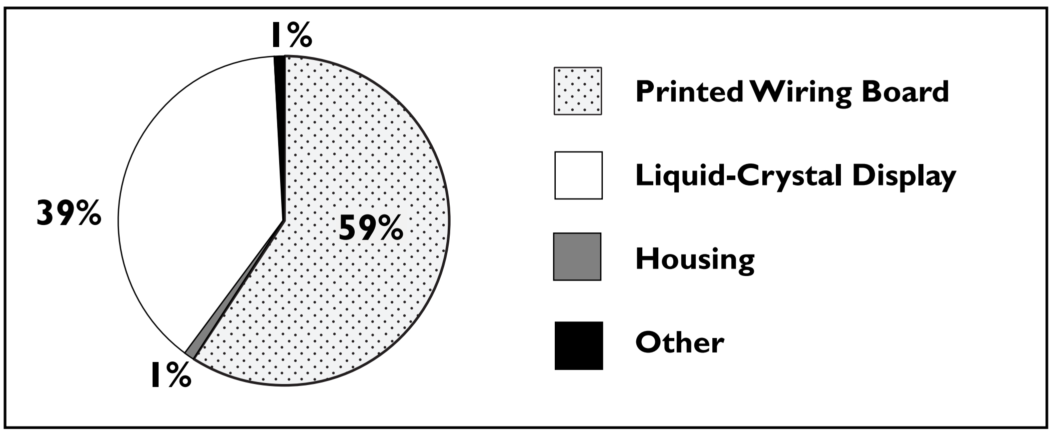
* Printed wiring boards are also known as printed circuit boards (PCBs). In the US, "printed wiring board" is generally used to avoid confusion with the toxic substances known as polychlorinated biphenyls, also called PCBs. Some sources define the PWB as the board to which the electronics are attached, and refer to this entire component as the printed wired assembly (PWA). In this report, PWB refers to the board and the attached electronic components.

The average composition of a printed wiring board, by weight, is one-third ceramics and glass, one-third plastics, and one-third metals.[9] In addition to copper and gold (the most valuable components of a cell phone[10]), the PWB contains a variety of other precious metals and hazardous substances, including arsenic (in chips made from gallium arsenide), antimony, beryllium, brominated flame retardants, cadmium, lead (used in the solder that joins the parts), nickel, palladium, silver, tantalum, and zinc.

Printed wiring boards contained in all electronic products (not just cell phones) are the second largest source of lead in the US municipal waste stream. According to the Silicon Valley Toxics Coalition, all PWBs fail the toxicity characteristics leaching procedure (TCLP) test, which the US Environmental Protection Agency uses to determine whether a material should be classified as a hazardous waste.[11] Studies at Delft University of Technology have found that, of all the materials contained in a printed wiring board, the lead and brominated flame retardants have the greatest environmental impact (see chapter 3).[12]

Based on the Delft study, Figure 1.1 shows the breakdown of a handset's environmental impacts by component: 59 percent from the printed wiring board and 39 percent from the liquid-crystal display. The Delft study also found that 64 percent of a PWB's environmental impact comes from the integrated circuits, which thus account for 23 percent of the impact of the handset.

Figure 1.1 Environmental Impacts of Cell Phones



Source: Casper Boks *et al*., "Combining Economical and Environmental Considerations in Cellular Phone Design," *Proceedings of the 2000 IEEE International Symposium on Electronics and the Environment*.

The Liquid-Crystal Display

The liquid-crystal display is a crucial component of almost all electronic devices, displaying information to users. It contains liquid crystals embedded between layers of glass, back lighting for illumination, and transistors to provide an electric charge. The liquid crystalline substances used in LCDs are of many types and levels of toxicity. Lamps for large LCDs generally contain mercury, but manufacturers claim that the small LCDs used in cell phones do not.[13]

A study done by Philips Consumer Electronics and the Fraunhofer Institute in Berlin concluded that, because LCDs contain toxic substances, they should be separated at end of life from the electronic equipment that contains them; otherwise, the entire product should be treated as hazardous waste and stored in underground dumps, at a cost of approximately $3000 per ton. The study also concluded that foil display systems now under development would make LCDs much more "environmentally friendly," especially in small products.[14]

Germany's Federal Environmental Agency (UBA) reached a different conclusion after assessing the risks posed by LCDs based on tests done by manufacturers. It concluded that no special requirements are needed to manage the disposal of LCDs. According to UBA, a cell phone contains a very small quantity of liquid crystals – about 5 milligrams, compared to .3 to .4 gram in a notebook computer. The European Union's forthcoming directives for dealing with electronic equipment waste require the removal and special treatment of LCDs larger than 100 square centimeters. Most cell phone LCDs are much smaller than this and so would not be subject to the removal requirements.

In a study comparing the environmental impacts of LCDs and cathode-ray tubes in computers, the US EPA found some environmental advantages in the use of LCDs.[15] However, the LCDs studied were far larger than those used in cell phones and may contain different substances, so this analysis does not shed much light on the impacts of cell phone LCDs.

Changes in technology could render the issue moot. A new type of display is being developed by a number of companies (including Kodak, Sanyo, Philips, DuPont, and NEC) based on organic light-emitting diodes. This much-simpler display technology has the potential to be cheaper, more lightweight, and less power intensive than LCDs. Motorola has already introduced a cell phone – the Timeport P8767 – based on these diodes. Some technical problems remain to be solved, but organic light-emitting diodes could become the screen of choice in the cell phones of the future.[16] However, it is not yet clear what materials will be used and what their environmental impacts will be.

Other Cell Phone Components

A cell phone's power source – the batteries – can contribute substantially to its environmental impacts. These are discussed in detail in chapter 6.

The adapter used to charge the batteries may weigh more that the handset itself and is a major contributor to cell phone waste. Little analysis has been performed on the composition and environmental impacts of this component. Adapters consist mainly of copper wires encased in plastic, but materials such as gold, cadmium, and brominated flame retardants may also be present.

Most of the other components of the handset are very small: the speaker is about the size of a dime and the microphone is no larger than a watch battery. But these, too, contain heavy metals and hazardous materials. The case is made of plastics – usually polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a combination of the two. Recycling of these plastics is hampered by additives, particularly brominated flame retardants. Studies so far indicate that the environmental impacts of these components are dwarfed by those of the printed wiring board and liquid-crystal display.

2 How Many Phones? How Much Waste?

Over the past decade, cell phones have been transformed from a gadget for the wealthy into a necessity for mainstream consumers. As shown in Table 2.1, the growth in the use of cell phones has been truly dramatic. In 1985, there were 340,000 cell phone subscribers in the US. By 1990, that number had risen to 5.3 million, and in 2001 the number of subscribers exceeded 128 million.[1] In 2000, 73 million cell phones were sold in the US.[2] Despite this remarkable growth, however, US cell phone use lags behind that of other industrialized countries. At the end of 2001, one billion phones were in use worldwide,[3] with about 400 million sold globally.[4]

Table 2.1 US Cell Phone Subscribers, 1985 to 2001

Year	Number of Subscribers (millions)
1985	0.34
1990	5.3
1991	7.6
1992	11.0
1993	16.0
1994	24.1
1995	33.8
1996	44.0
1997	55.3
1998	69.2
1999	86.0
2000	109.5
2001	128.7

Source: Cellular Telecommunications and Internet Association

To give an idea of the amount of waste generated by cell phones, this chapter provides information on the numbers of phones in use and their length of life, annual sales, and penetration rates. The goal is not to predict waste generation in a particular year, as this can vary considerably depending on economic conditions. Instead, we will make rough estimates of the average amount of waste these products may generate, and of the size of the stockpile of retired phones in storage that will eventually enter the waste stream.

Forecasting is always difficult and is particularly problematic when technological change is involved. It is difficult to predict the new technologies that might be developed or the degree to which consumers will accept them. As a starting point, INFORM arrived at some conservative estimates based on existing technologies and current trends — for example, the types of cell phones in use today and patterns in their use over the past decade.

These estimates do not take into account the possibility that, within the next three years, disposable cell phones will become widely used or that cell phones will substantially increase in weight because of added functions (such as data and photo transmission). Such changes could substantially increase the amount of waste generated by cell phones and similar products (see chapter 7 for a look at some of the new applications for cell phones that could become common in future years).

As noted in the previous chapter, cell phones are frequently replaced when they are still in good working order, whether because the user travels abroad, changes service provider, or simply wants a different product. These phones are often referred to as "obsolete," despite the fact that devices of the same make and model often remain in widespread use. Nor are they properly described as "discarded," since most replaced phones do not immediately enter the waste stream.

In place of either of these terms, this report uses the word "retired" to refer to phones that have been taken out of service. Most of these products are stored away in drawers, closets, and basements, and will enter the waste stream at a later date. Any phone for which the owner is not paying a service subscription is considered retired.

According to INFORM's conservative estimates:
- By 2005, about 200 million cell phones will be in use in the US.
- By 2005, about 130 million phones will be retired each year in the US.
- By 2005, over 500 million phones will be stockpiled in the US — that is, stored and destined to enter the waste stream at some later date.

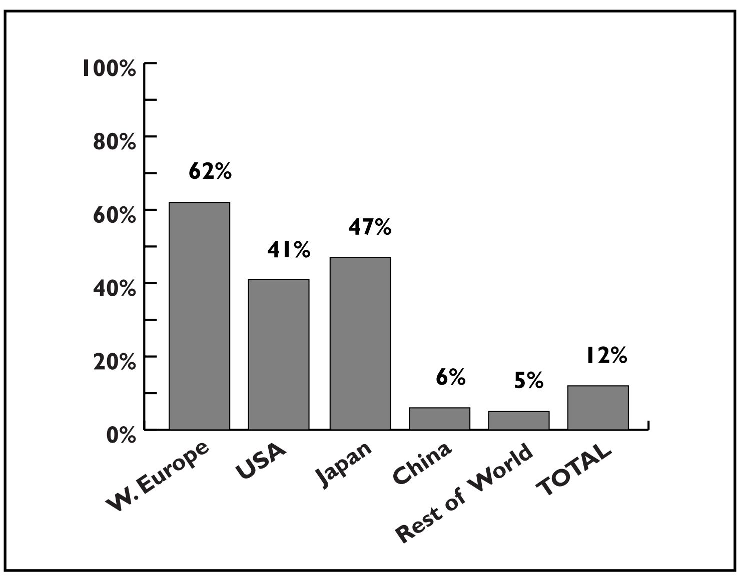
Cell Phone Penetration

Because of inconsistent data and variations in the definition of terms used to describe cell phone use, it is important to clarify some additional terms used in this report:*

- **Subscribers** is the total number of subscriptions for cell phone service. Thus, an individual with one cell phone subscription for work and a different subscription for personal use would count as two subscribers.
- **Penetration** measures subscribers as a percentage of the total population. Because an individual may have more than one subscription, penetration can exceed 100 percent. Penetration does not measure the percentage of the population that uses cell phones but rather the total number of phones in use as a percentage of population.

Figure 2.1 compares estimates of cell phone penetration in the US and other parts of the world, based on a detailed study conducted in 2000 at the Research Centre of Bornholm (Denmark).[5] This study concluded that the theoretical maximum percentage of a nation's population that would ever become cell phone users is 75 to 80 percent. In some countries, however, such as Japan, Finland, and Norway, penetration will exceed 100 percent within the next few years.[6]

Figure 2.1 Worldwide Cell Phone Penetration, as of year-end 2000



Source: Carl. H. Marcussen, Research Centre of Bornholm, Denmark.

As of the end of 2000, according to the Bornholm study, the highest cell phone penetration in Western Europe was about 75 percent, in Finland, Iceland, and Austria, followed by about 72 percent in Norway and Italy. The average for Western Europe was estimated at 62 percent, compared to only 41 percent in the US. This indicates that there is considerable potential for growth in cell phone use in the US. (It should be noted that while the US lags in cell phone

* Data in Table 2.1, Table 2.2, and Figure 2.1 is based on these definitions.

use, it leads the world in the percentage of the population that uses a computer and accesses the Internet.[7])

Estimating Cell Phone Penetration and Numbers of Phones in Use

The US population is expected to reach 294 million by 2005, up from 281 million in 2000.* If cell phone penetration in the US reaches 75 percent, comparable to the highest levels in Western Europe, there will be 220 million cell phones in use in this country by 2005. If it reaches 100 percent (meaning more people using multiple phones), the number of phones in use will be 294 million. We can take this as the extreme upper limit for cell phone penetration in the US.

A reasonable lower limit might be based on a cell phone penetration of 50 percent, slightly higher than the actual number for 2000, or 147 million cell phones in use in 2005. As shown in Table 2.2, the estimated number of phones in use in 2005, based on different penetration rates, ranges from roughly 150 to 300 million. A conservative estimate would be 200 million.

Estimating Cell Phone Sales and Numbers of Phones Retired

Table 2.3 shows the estimates of cell phone sales in the US made by Gartner Dataquest, a technology consulting firm. Estimated sales for 2004 are 152 million, with cumulative sales of 720 million from 1995 to 2004. These figures are consistent with the subscriber estimates discussed above.

When estimating the number of retired cell phones, an important factor is the average economic life of a phone. This is the age at which the owner chooses to replace it, which may be shorter than the phone's technical life. Worldwide, the average economic life of a cell phone is currently about 1.5 years, down from about three years in 1995. In the US, the economic

Table 2.2 Estimated Cell Phones in Use in the US, 2005*

Penetration (%)	Phones in Use/ Subscribers (millions)
50	147
55	162
60	176
65	191
70	206
75	220
100	294

*Figures based on a total population of 294 million.
Source: INFORM, Inc.

Table 2.3 US Cell Phone Sales, 1995 to 2004

Year	Cell Phone Shipments/Year (millions of units)
1995	14.5
1996	16.6
1997	22.2
1998	30.6
1999	49.3
2000	72.9
2001	100.1
2002	122.3
2003	140.0
2004	151.9
TOTAL	720.4

Source: INFORM, Inc. Calculations are based on Gartner Dataquest, "Mobile Terminals: North America, 1995 through 2004," August 7, 2000.

* Projections based on the 2000 census are not yet available. This estimate is based on the 1990 census projections, which were adjusted upward using the actual population figure for 2000 from the 2000 census.

life of a cell phone is the same as the world average. In poorer countries like China, where people cannot afford to replace phones as often, it is 2.5 years. In Japan, cell phones have an economic life of only one year, despite that nation's weak economy.[8]

Table 2.4 Estimated Number of Cell Phones Retired Per Year in the US

PHONE LIFE (YEARS)	NUMBER RETIRED PER YEAR (MILLIONS)					
	Per 300 million in use	Per 220 million in use	Per 200 million in use	Per 175 million in use	Per 160 million in use	Per 150 million in use
1.0	300	220	200	175	160	150
1.5	200	147	133	117	107	100
2.0	150	110	100	88	80	75

Source: INFORM, Inc.

Table 2.4 shows the estimated number of cell phones retired per year in the US given different lengths of phone life. Assuming 200 million phones in use and an economic life of 1.5 years, the number retired would be about 130 million per year.

Stockpiled Cell Phones

According to INFORM's estimates, the US stockpile of retired cell phones could exceed 500 million by the end of 2005. This assumes that over 700 million phones will be retired in the US by 2005,* of which about 75 percent will be placed in storage.

There is no good data on the disposition of retired phones. However, research and pilot electronics collection projects indicate that most retired phones are stored. For example, the European ECTEL project (described in chapter 5) found that only 14 percent of cell phones wind up in landfills,[9] and in Minnesota's electronics collection project (described in chapter 4), very few phones were brought to the collection sites. According to the Silicon Valley Toxics Coalition, about 75 percent of all the computers sold in the US have been stockpiled.[10] On the basis of such evidence, INFORM concludes that the number of stored phones is about 75 percent of the number retired.

How Much Waste?

Cell phone weight has decreased dramatically. According to a study published by the government of Canada, the weight of the typical phone dropped from 10.5 ounces in the early 1990s to 7.7 ounces by the end of the decade.[11]

Weights provided by cell phone manufacturers generally refer to the handset plus batteries. According to INFORM's own measurements of a sampling of typical phones in use today, the combined weight of these

* Stockpile of phones retired based on estimates of cumulative sales up to 2005.

components ranges from 3.45 to 10.15 ounces. In addition, however, the adapter often weighs more than the handset and batteries combined. Since each phone comes with its own adapter, which generally cannot be used with other makes and models, this device can add substantially to the waste generated by discarded cell phones.

Given these weights, the average retired phone — including the handset, batteries, and adapter — will generate about one pound of waste. Thus, the 130 million phones that, according to INFORM's estimates, will be retired each year by 2005 will, along with their adapters, weigh 130 million pounds, or 65,000 tons. Moreover, significant additional waste will be generated by replacement batteries and accessories such as car chargers, headsets, carrying cases, and extra face plates and adapters, most of which are designed for specific models of cell phone.

Wireless Waste in Perspective

Reliable data on the amount of waste generated by electronic equipment in the US does not exist. In its report entitled *Municipal Solid Waste in the United States: 1999 Facts and Figures*, the US Environmental Protection Agency included, for the first time, a separate subcategory for consumer electronics. At the same time, however, the agency acknowledged the problem of unavailable data. Previously, consumer electronics were grouped under the heading "miscellaneous durables," which also included such products as dishes and luggage.

According to the EPA's data, the US generated 230 million tons of municipal solid waste in 1999.[12] In the new subcategory of consumer electronics, the EPA reported that 1.8 million tons of waste were generated, or under 1 percent of municipal solid waste.[13] Also in 1999, a study performed in Minnesota on the composition of that state's waste stream concluded that 2 percent was electronic products.[14] The European Union estimates that electrical and electronic equipment accounts for 4 percent of municipal solid waste.[15] Given the disparities among these estimates, more work is clearly needed to define consumer electronics and collect reliable data on the amount of waste generated by these products.

Of course, no single product accounts for a large portion of the waste stream, and cell phones are only a small subcategory of electronic waste. Thus, the 65,000 tons of cell phone waste that, according to INFORM's estimates, will be generated in 2005 are far less than one-tenth of 1 percent of the 240 million tons of municipal solid waste projected for that year.[16] Moreover, the waste generated by cell phones and other wireless products is dwarfed by the amount generated by wired computer equipment. For example, it is estimated that over 20 million computers are retired each year[17] — products that, once discarded, will generate over 400,000 tons of waste.*

It is important to recognize that these estimates are based on current technologies and current patterns of use, which could change very rapidly. For example, in a recent interview, Nokia's vice president in charge of design predicted that "within a few years having just one cell phone will seem as odd to most people as owning a single pair of shoes."[18] Today, cell phones in the US are primarily used for voice communication. New applications based on data and image transmission could greatly increase the amount of waste generated, since the devices would likely be heavier than current models and users might buy different devices for different functions. The proliferation of accessories and backup power supplies (discussed in chapter 6) likewise carries the potential for increased waste.

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* This figure is based on a weighted average of 42 pounds: 50 pounds per PC and 7.5 pounds per laptop. See H. Scott Matthews *et al*., "Disposition and End-of-Life Options for Personal Computers," Green Design Initiative Technical Report No. 97-10, Carnegie Mellon University, Pittsburgh, July 7, 1997.

Conceivably, the waste stream from cell phones and other wireless electronic devices, including pocket computers, pagers, personal digital assistants, e-books, medical monitors, and locator devices, will reach hundreds of thousands of tons per year. At the same time, the waste generated by computers may decrease considerably. Apple's new iMac desktop computer weighs only 21 pounds, compared to 50 pounds for traditional computers with cathode-ray tube monitors. If this represents a trend toward much lighter computers, the waste from wireless products could eventually exceed the waste from wired computers. Contributing to this scenario is the prospect of disposable cell phones and new applications leading to wireless devices that are as yet unknown.

3 The Toxic Content of Cell Phones and Other Electronic Devices

Cell phones and other small electronic devices contain a large number of hazardous substances. Some of these, such as cadmium, have long been known to have serious impacts on the environment and public health. This chapter will focus on two substances at the center of the current policy debate on the hazardous content of electronic products, brominated flame retardants and lead solder, as well as on several less well-known materials found in these products.

It should be noted that these substances are not known to pose threats to the environment or public health while the devices are being used. Rather, their hazardous effects occur upstream – during materials extraction and processing – and at end of life, when cell phones and other wireless products are incinerated or disposed of in landfills, and during recycling processes such as shredding, grinding, melting, plastics extrusion, and metals processing.[1] This chapter will focus on cell phones, but the toxic materials discussed are contained in components of wireless devices in general.

Persistent, Bioaccumulative Toxins: A US EPA Target

Many of the substances discussed in this chapter are on the US Environmental Protection Agency's "Draft RCRA Waste Minimization List of Persistent, Bioaccumulative, and Toxic Chemicals" (PBTs). This list (see Appendix A), published in November 1998, comprises the "priority" PBTs that may be found in hazardous wastes regulated under the Resource Conservation and Recovery Act of 1976. US EPA has set a national goal of reducing the quantity of these PBTs present in waste by at least half by 2005.[2]

The EPA's PBT list is a product of politics as well as science. There has been intense lobbying over what substances should be included, with some being omitted because their impacts have not yet been thoroughly documented. Nevertheless, the list is a good starting point for gaining insight into the problems posed by the toxic content of cell phones and other wireless electronic products. Finally, the hazard ratings referred to in this chapter are from a slightly earlier version of the EPA's PBT list;[3] the final list did not rank the chemicals as to degree of hazard.

Dangers of PBTs

PBTs are persistent in that they linger in the environment for a long time without degrading, increasing the risk of exposure to human beings. They can also spread over large areas, moving easily between air, water, and soil, and have been found far from the areas in which they were generated. PBTs accumulate in the fatty tissues of human beings and other animals, increasing in concentration as they move up the food chain. As a result, they can reach toxic levels over time, even when released in very small quantities.[4]

According to the EPA, "PBTs are associated with a range of adverse human health effects, including damage to the nervous system, reproductive and developmental problems, cancer and genetic impacts."[5] Children are particularly susceptible because they weigh less than adults and their immune systems are less developed. Some PBT-containing products, such as lead-based paints, have been banned in the US, but many PBTs continue to be used in electronic products.

PBTs found in cell phones include arsenic, antimony, beryllium, cadmium, copper, lead, nickel, and zinc. (Cell phones also contain toxic substances not included on the EPA's list of PBTs, such as brominated flame retardants.) The amount of PBTs contained in a single cell phone or similar product is small, but the number of such devices entering the waste stream is increasing rapidly. Indeed, the small size of these products increases the likelihood that they will be thrown in the trash and sent to incinerators and landfills, where environmental contamination can occur from combustion and leaching into soil and groundwater. For this reason, reducing the PBT content of cell phones and other electronic products, and managing them properly at end of life, are essential to preventing damage to the environment and public health.

Toxic Substances Targeted by Companies

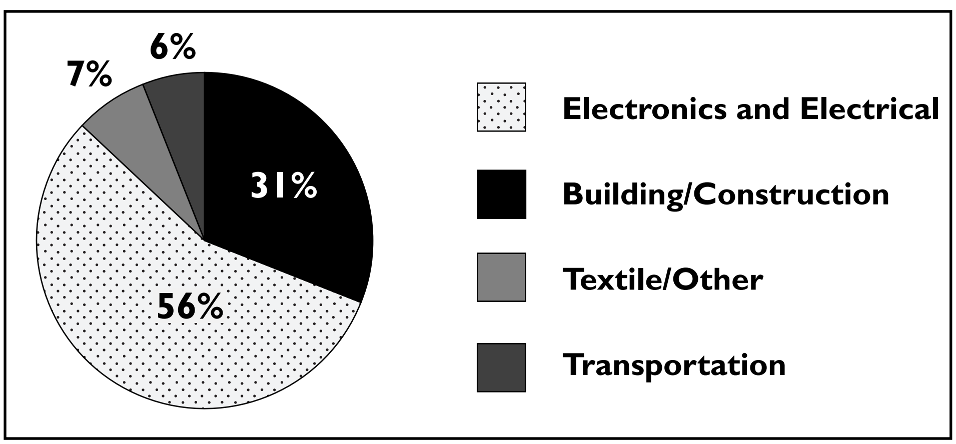
In Scandinavia, two companies have compiled lists of toxic substances of concern in cell phones and other electronic devices.

Denmark S/D, the country's largest telecommunications service provider, has undertaken a project that aims to develop "green" procurement guidelines for manufacturers of cell phones and other telecommunications products, and a system for providing product information to consumers. A questionnaire developed by the company for its vendors (see Appendix B) indicates the materials of concern and the components that need to be easily separated for disposal. Almost all the chemicals included in this questionnaire are on the EPA's PBT list.

In Sweden, the large cell phone producer Ericsson has posted on its website a list of substances that are restricted or banned from its products and from products it purchases from other suppliers (see Appendix C). While lead solder is merely restricted and not banned at present, Ericsson expects 80 percent of its new products to be lead-free, 80 percent of its printed wiring boards to be halogen-free, and all of its products to be beryllium-free by 2002.[6] Two categories of brominated flame retardants, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), are already on Ericsson's list of banned substances.

Brominated Flame Retardants

Figure 3.1 Uses of Brominated Flame Retardants

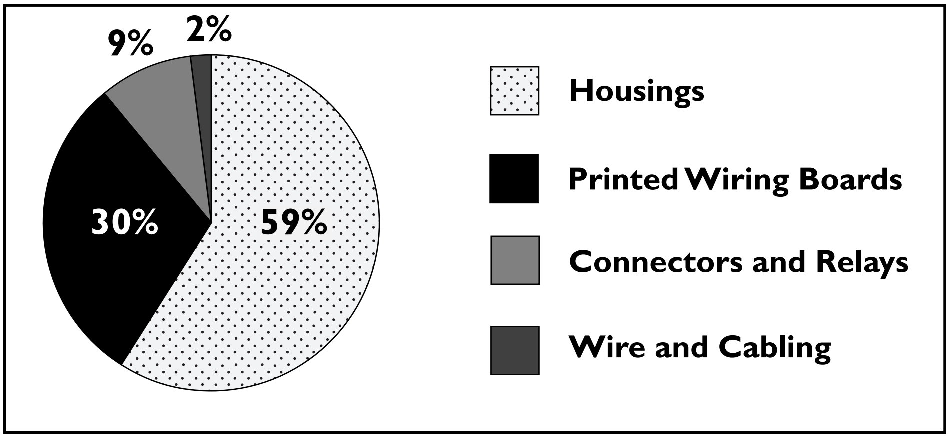


Source: Bromine Science and Environmental Forum

In electronic products such as cell phones, plastics are used in the printed wiring board and in cables, housings, and connectors. Because plastics are highly flammable, a flame retardant is typically added to reduce the risk of fire. According to the Bromine Science and Environmental Forum (BSEF), an industry trade association, 39 percent of all flame retardants are brominated.[7] Others are based on chlorine, phosphorous, nitrogen, or inorganic materials.

Figure 3.1 shows the various uses of brominated flame retardants. Electrical and electronic products are by far the largest application, at 56 percent.[8] In the past, electrical and electronic products contained either chlorinated or brominated flame retardants, both of which are known as halogenated flame retardants.* When they were found to have damaging effects on the environment, chlorinated retardants were replaced by the brominated variety.

Figure 3.2 Consumption of Brominated Flame Retardants in Electronic and Electrical Products



Source: Bromine Science and Environmental Forum

Environmental and Health Impacts

Brominated flame retardants in electrical and electronic products are primarily used in printed wiring boards and plastic housings (Figure 3.2).[9] There are a number of different types of brominated flame retardants (see box), some of which are clearly damaging to the environment and human health; the impacts of others are still being evaluated. Research indicates that brominated flame retardants can be persistent, bioaccumulative, and toxic, and that they can leach into soil and groundwater from landfills.[10] The presence of copper, widely used in printed wiring boards, increases the risk that brominated flame retardants will form dioxins and furans during incineration. (Dioxins and furans are polychlorinated organic compounds, some of which are known to be highly toxic to animals.) This risk is further exacerbated by incomplete combustion when incinerators operate at too-low temperatures.[11]

Brominated Flame Retardants

Hexabromocyclododecane (HBCD)
Polybrominated biphenyls (PBBs)
Polybrominated diphenyl ethers (PBDEs)

- Decabromodiphenyl ether (Deca-BDE)
- Octabromodiphenyl ether (Octa-BDE)
- Pentabromodiphenyl ether (Penta-BDE)

Tetrabromobisphenol (TBBP-A)

Source: Bromine Science and Environmental Forum, "An Introduction to Brominated Flame Retardants," October 19, 2000, 4.

Brominated flame retardants can also generate dioxins and furans during recycling and smelting, thereby creating an obstacle to the recycling of plastics from electronic products. According to a study published by Environment Canada, most recyclers do not process plastics from electronic equipment, because they are unable to determine which ones contain brominated flame retardants.[12]

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* The word halogenated derives from the Greek for "salt former." These substances commonly react in nature with metals to form salts.

Table 3.1 Total Market Demand for the Major Brominated Flame Retardants, 1999 (metric tons)

Type of Brominated Flame Retardant	Europe	Americas	Asia	Total
Tetrabromobisphenol (TBBP-A)	13,000	21,600	85,900	121,300
Hexabromocyclododecane (HBCD)	8900	3100	3900	15,900
Decabromodiphenyl ether (Deca-BDE)	7500	24,300	23,000	54,800
Octabromodiphenyl ether (Octa-BDE)	450	1375	2000	3825
Pentabromodiphenyl ether (Penta-BDE)	210	8290	--	8500
Total	30,860	58,665	114,000	204,325
	15.1%	28.7%	56.2%	100%

Source: Bromine Science and Environmental Forum, July 2000.

Polybrominated biphenyls. PBBs are persistent and insoluble in water. They can enter aquatic systems from manufacturing facilities and landfills, spread widely, and become a part of the food chain after consumption by fish (they have been found in the Arctic in the tissues of seals). PBBs can form dioxins and furans during recycling or incineration, and are associated with increased risk of cancer, disruption of the endocrine system, and illnesses of the digestive and lymphatic systems.[13]

Production of PBBs has been banned in the US since 1977. According to BSEF, PBBs are no longer produced anywhere in the world and there is no market for them.[14] They are still a concern, however, because of their presence in old electronic products, which will continue to enter the waste stream for many years. In addition, the possibility exists that production of these substances could resume in the future.

Polybrominated diphenyl ethers. PBDEs are associated with cancer, liver damage, neurological and immune system problems, thyroid dysfunction, and endocrine disruption.[15] Like PBBs, they can create dioxins and furans when burned or during recycling.[16]

Concern over PBDEs is on the rise, particularly since Swedish studies found a 50-fold increase in their concentration in human breast milk between 1972 and 1997. PBDEs have also been found in the blood of workers at a Swedish electronics recycling facility and in breast milk and fish in Japan.[17] In 2001, high levels of PBDEs were found in salmon in Lake Michigan, prompting a new study of the impacts of these chemicals.[18] They have also been found in fish in Virginia.[19] A study released in December 2001 by Environment Canada found extremely high levels of PBDEs in the breast milk of North American women — 40 times higher than the highest levels found in Sweden.[20]

Regulating the Use of Brominated Flame Retardants

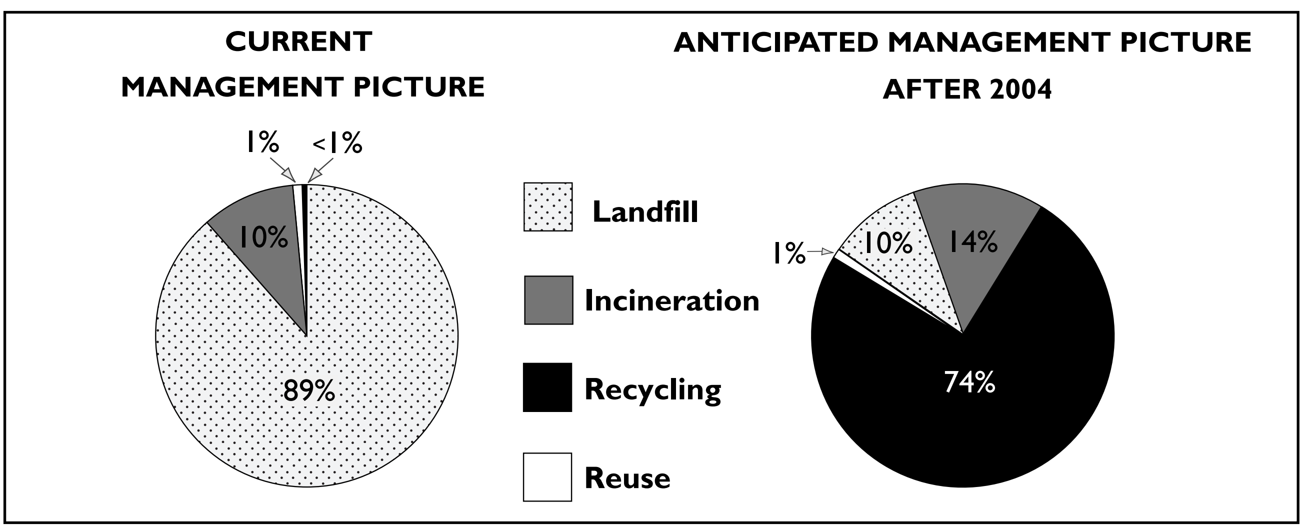
Certification programs. In Europe, popular eco-labeling programs such as the German Blue Angel and the Scandinavian White Swan do not award their labels to products that contain PBBs or PBDEs. In Sweden, the TCO eco-label program has established specific criteria for cell phones covering a broad range of issues, from ergonomics to electromagnetic fields. Cell phones receiving this label may not contain any chlorinated or brominated flame retardants in plastic components weighing over 10 grams or in plastic laminates.[21]

Companies that obtain certification of their products by an eco-label program do so voluntarily. Thus, these programs do not carry the same weight as regulations that impose outright bans or limitations on the use of brominated flame retardants and other hazardous substances.

Government regulations. There have been moves to phase out or limit the use of PBDEs in a number of European countries, including Germany, the Netherlands, and Sweden. In 1995, the Organisation for Economic Cooperation and Development (OECD) reached a voluntary agreement with industry to reduce the use of PBBs and PBDEs. In September 2001, the European Parliament took a tough stance on PBDEs, voting to phase out penta-, octa-, and deca-PBDEs in electrical and electronic products as part of the European Union's (EU's) forthcoming *Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment*, or RoHS directive (discussed in chapter 5). This decision was strongly opposed by industry and was made despite the fact that risk assessments being conducted by the EU were not yet complete.[22] The RoHS directive, along with the EU's forthcoming *Directive on Waste Electrical and Electronic Equipment*, or WEEE directive (also discussed in chapter 5), are expected to have a major effect on the design, production, and end-of-life management of electronic products.

Figure 3.3 looks at the ways in which plastic wastes containing brominated flame retardants are currently managed in Europe versus their anticipated management after the WEEE and RoHS directives take effect. Recycling of these plastics is expected to increase from less than 1 percent to 74 percent,* while landfilling is expected to

Figure 3.3 Management of Plastic Wastes Containing Brominated Flame Retardants in Europe



Source: INFORM, Inc., based on data from Bromine Science and Environmental Forum.

* Energy recovery is expected to account for 4 percent of this recycling.

drop from 89 percent to 10 percent and incineration is expected to increase from 10 percent to 14 percent. Reuse is expected to remain at 1 percent. After 2004, however, BSEF expects less than 25 percent of plastic wastes containing brominated flame retardants to end up in disposal facilities — a dramatic change in these materials' end-of-life management.[23]

Industry opposition. The bromine industry vigorously opposes a blanket ban on brominated flame retardants. The Bromine Science and Environmental Forum claims that bromine is not a toxic substance — that in fact it is used in cough medicine. It argues that flame retardants based on bromine are the most effective type with respect to both performance and cost because they provide the highest level of fire protection for the smallest quantity used. BSEF also says it is not clear that alternatives to brominated flame retardants are less harmful to the environment and human health. Consistent with this position, the bromine industry is studying the feasibility of recovering bromine from waste plastics for use in a "closed-loop" system of bromine manufacture.[24]

With respect to specific types of brominated flame retardants, BSEF claims that octa- and deca-BDE are not dangerous and do not bioaccumulate. Contrary to the view of many government officials and environmentalists, the trade group insists that the PBDEs found in breast milk and in the blood of electronics recycling workers present no health risks.[25] BSEF also claims that dioxins and furans are not a concern with new incinerator technologies, that brominated flame retardants do not hamper the recycling of plastics, and that waste-to-energy conversion of plastics containing these substances is safe (in waste-to-energy conversion, materials are burned to recover energy). Further, the group claims that the trend toward increased quantities of PBDEs in breast milk, evident since the early '70s, has been reversed, with concentrations dropping 30 percent from 1997 to 2000.[26]

The issue of tetrabromobisphenol (TBBP-A). A ban on all brominated flame retardants would also include TBBP-A, which is used in 96 percent of printed wiring boards and accounts for over half the total market volume of brominated flame retardants. While there are suspicions that TBBP-A has damaging environmental effects similar to those of PBBs and PBDEs, this has not been demonstrated. Its phaseout under the EU's forthcoming regulations is under debate.

In a publication on brominated flame retardants, BSEF cites a World Health Organization assessment that TBBP-A has little potential to bioaccumulate and that "the risk for the general population is considered to be insignificant."[27] US EPA, however, recently added TBBP-A to its Toxics Release Inventory,* citing the chemical's properties of persistence, bioaccumulation, and toxicity.[28] Finally, an Environment Canada study states that TBBP-A is persistent, highly toxic to aquatic life, and suspected to bioaccumulate.[29]

Industry Efforts to Eliminate Brominated Flame Retardants

Leadership in eliminating brominated flame retardants is coming from companies in Europe and Japan. The Swedish phone giant Ericsson backs the bromine-free lobby and plans to eliminate bromine from 80 percent of the printed wiring boards in new products.[30] Sony's Green Management Plan calls for the elimination of brominated flame retardants from its products by 2003.[31] Other major electronics producers, such as Phillips and NEC, are also working to replace brominated flame retardants in their products. The majority of these efforts involve the use of flame retardants based on phosphorus, which does not contribute to the creation of dioxins and furans when products are incinerated or recycled.

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* The federal Toxics Release Inventory (TRI) program collects data on the quantities of nearly 650 toxic chemicals released by industrial plants into the air and water, and incinerated, recycled, treated, and disposed of on-site and elsewhere.

US companies are also developing alternatives to brominated flame retardants, but they are moving more slowly and have not made any explicit commitments to eliminate specific amounts from their products. Rather, they are including reduction of hazardous substances as a general goal in their environmental programs and are eliminating brominated flame retardants from selected products. For example, one of Motorola's phones is now free of brominated flame retardants. Intel, a major supplier of integrated circuits and printed wiring boards, reports that most plastics in its products no longer contain brominated flame retardants, and none have PBBs or PBDEs.[32] On the other hand, the American Electronics Association has joined the bromine industry in opposing restrictions on brominated flame retardants.

Other Efforts

An alternative to finding substitutes for flame retardants is to redesign products so that flame retardants are not required. Researchers at Delft University of Technology in the Netherlands have found that the environmental impacts of printed wiring boards could be substantially reduced if brominated flame retardants were eliminated. They suggest using printed wiring boards on a base of polyimide (plastic) foil, which would have such a high flaming point that no retardants would be needed. Moreover, these components would be no more expensive than the currently used boards made of fiberglass and epoxy resins.[33]

Elimination of brominated flame retardants from electrical and electronic equipment is a goal of a number of environmental groups in the US and abroad. Michael Bender, a consultant to the Silicon Valley Toxics Coalition, has circulated a resolution calling on the US Congress to expand monitoring of brominated flame retardants in human beings, require their phaseout by 2006, and, in the interim, require labeling of products containing these substances.[34] Friends of the Earth, based in Europe, has launched a campaign to boycott products containing brominated flame retardants. In 2002, US EPA, Region IX (in California), will convene a multi-stakeholder roundtable focused on brominated flame retardants and their alternatives in electronic products. One issue to be addressed is whether PBDEs should be included on the EPA's list of persistent, bioaccumulative, and toxic chemicals targeted for waste minimization.

Lead

As noted earlier, US EPA's original list of persistent, bioaccumulative toxins ranked these chemicals as to degree of hazard. On this list, lead was ranked number one.

Lead is ubiquitous in electronic products, including cell phones, and is used in various components and coatings. An important application is in tin-lead solder — the primary means of attaching electronic components to each other and to the printed wiring board. An estimated 100,000 to 125,000 tons of lead solder are produced globally for the electronics industry each year.[35]

Lead in Municipal Solid Waste

In a study performed for US EPA in 1988, 40 percent of the lead in US landfills was found to be from discarded electrical and electronic products, principally the picture tubes of TVs. Apart from TVs, electrical and electronic products accounted for 4.4 percent of the lead found in municipal solid waste.[36]

Like brominated flame retardants, the quantity of lead contained in small electronic devices such as cell phones is small. Compared to a single TV picture tube, which may contain 4 to 8 pounds of lead, the printed wiring board of a cell phone contains about 50 grams per square meter,[37]or about .01 ounce of lead. However, the short life of cell phones means that large numbers are discarded each year, and because they are small, they are more likely than larger devices to be thrown in the trash and sent to incinerators and landfills, where environmental contamination can occur from combustion and leaching into soil and groundwater. Lead can also be released into the environment during recycling.

In the US, the lead solder contained in the printed wiring boards of the 130 million cell phones estimated to be retired in 2005 (see chapter 2) will generate approximately 1.3 million ounces, or 81,250 pounds, of lead waste. And printed wiring boards contained in the estimated stockpile of 500 million retired cell phones, once discarded, will put 312,500 pounds of lead into the environment.

Environmental and Health Impacts

A heavy metal found in food, soil, and dust, lead enters the food chain through atmospheric deposits on plants and absorption from the soil. It can also contaminate drinking water by leaching into groundwater from sources such as landfills. Lead is suspected of being carcinogenic, has adverse impacts on the central nervous system, the immune system, and the kidneys, and has been linked to developmental abnormalities. Lead poisoning in children can lead to impaired intelligence, hyperactivity, and aggressiveness.

Lead is regarded as a problem material throughout the world. According to the United Nations Environment Programme, it is "a substance that requires regulation on a global level with binding conventions."[38] The forthcoming EU directive on electrical and electronic waste, which requires the phaseout of lead solder, states that lead "accumulates in the environment and has acute chronic toxic effects on plants, animals, and microorganisms."[39] In the US, the EPA has slashed the threshold reporting levels for lead under the Toxics Release Inventory from 25,000 to 100 pounds per year because of concern over its environmental and health impacts.

Replacing the Lead in Solder

Replacing the lead in solder can be complicated and costly. Among the metals being considered are various combinations of tin, copper, silver, bismuth, antimony, indium, germanium, and zinc. Different materials are being used in different applications, but the most frequently used substitute is a tin-silver-copper alloy.[40] Almost all these alternatives have significantly higher melting temperatures than lead, requiring higher processing temperatures during manufacturing (Table 3.2). This, in turn, may mean that printed wiring boards will have to be redesigned so that the materials they contain can withstand higher temperatures.

Table 3.2 Melting Temperature of Different Types of Solder

Alloy	Melting Point (° C)
Tin-Lead	183
Tin-Bismuth	138
Tin-Zinc	198.5
Tin-Copper	227
Tin-Silver	221
Tin-Silver-Copper	217
Tin-Silver-Copper-Antimony	213–218
Tin-Silver-Bismuth	205–210
Tin-Silver-Bismuth-Copper	217–218
Tin-Silver-Bismuth-Copper-Germanium	210–217
Tin-Silver-Indium	179–218

Source: Adapted from Laura J. Turbini *et al.*, "Examining the Environmental Impacts of Lead-Free Soldering Alternatives," *Proceedings of the 2000 IEEE International Symposium on Electronics and the Environment*, 48.

There are questions as to whether lead-free solders will compromise the performance of electronic components. They may also have the effect of reducing the recycling value of cell phones and other devices if the high temperatures involved in separating the components cause some to be destroyed in the process. Another trade-off is energy use: higher melting points mean more energy used in manufacturing, which increases costs and is detrimental to the environment. Despite these concerns, however, there is strong momentum around the world toward a transition to lead-free solder. (An interesting alternative to finding substitutes to lead in solder is eliminating solders from printed wiring boards altogether, and replacing them with adhesives.[41])

Industry Efforts to Eliminate Lead from Solder

The three largest semiconductor manufacturers in Europe — Philips (Netherlands), Infineon (Germany), and ST Microelectronics (Switzerland) — have called for international standards for eliminating lead from solder. Noting that lead is found in nature with other metals and not all traces can be removed, they have agreed to define "lead-free" as less than 0.1 percent of a single material.[42] In the US, the world's largest semiconductor manufacturer, Intel, defines a lead-free product as one "to which lead or lead compounds have not been intentionally added."[43] Clearly, there is a need for a uniform, global definition of lead-free.

Japan. The Japanese electronics industry is the world leader in the use of alternatives to lead in solder. A requirement to phase out lead in electronic products is expected soon,[44] and a mandate from the Ministry of Economy, Trade, and Industry (METI, which was formerly the Ministry of International Trade and Industry, or MITI) requires that manufacturers recycle lead-containing appliances and document their lead content.[45] Market pressures, too, have generated competition among the large electronics manufacturers to introduce lead-free products as soon as possible. Sony has actually been able to increase its market share in Japan by offering such products.[46]

Meanwhile, Fujitsu has announced plans to eliminate lead solder from all its printed wiring boards by December 2002.[47] Other leading companies, including Sony, Panasonic, Hitachi, Mitsubishi, Toshiba, NEC, Sharp, and Seiko Epson, have plans to produce lead-free products within the next two years for the Japanese market and ultimately worldwide.[48]

Europe. Additional pressure to eliminate lead is coming from Europe, where the focus has been on regulation. The EU's forthcoming RoHS directive will require elimination of lead from electrical and electronic products sometime between 2006 and 2008 (the date is still under discussion).

Philips, Infineon, and ST Microelectronics are working together to set the ground rules for lead-free solder (including a consistent definition of lead-free). These companies anticipate introducing their lead-free products well in advance of the EU deadline.[49] The Global Environment Coordination Initiative (GECI), an alliance of electronics assembly firms formed in Brussels in July 2001, also says it can convert to lead-free solder long before the EU deadline. It targeted the end of 2001 for consumer electronics and cell phones, 2002 for laptop computers, and 2003 for desktop computers.[50]

In Sweden, the TCO eco-labeling program requires that, in cell phones, "the batteries, paint, lacquer and plastic components...shall not contain any lead."[51] This means that a product with lead solder can still receive the TCO label, although the organization expects to add lead-free solder to its labeling requirements in the next few years.[52] Both Nokia (Finland) and Ericsson (Sweden), two of the world's top five cell phone producers, plan to eliminate lead from their products by 2002.[53]

North America. In Canada, Nortel has developed a lead-free phone that it claims performs better than those made with lead-based solder.[54] In the US, Motorola has developed a phone with 95 percent less lead than its conventional phones but has not yet marketed it.[55]

The electronics industry in the US is moving much more slowly than industry in Europe and Japan, although developments abroad are having a significant impact. Since most electronic products are globally designed — that is, if they have to be lead-free in Europe and Japan, they will probably be made lead-free throughout the world — US companies are making substantial investments in research on substitutes for lead.

A major concern of the US electronics industry is the business risk involved in offering lead-free products when the replacement materials may themselves turn out to have detrimental health and environmental impacts. The Electronics Industry Alliance (EIA) — a major US trade association — opposes the forthcoming lead ban in Europe, but acknowledges that lead is damaging to the environment and public health. However, the group claims that "there has never been a scientific study to assess the environmental risks posed by the various lead-free solders under consideration and study as substitutes for lead solder."[56] The EIA is participating in a partnership with the EPA to perform life-cycle analyses of lead-based solder and its alternatives.

A recent report from Hewlett-Packard provides some insight into the views of an important US electronics manufacturer on this issue. HP acknowledges that its efforts to phase out lead have been driven by the EU's forthcoming directives and by market forces in Japan. It describes removing lead as a "daunting challenge" similar to the hypothetical task of changing a person's blood type. This is because lead solder is such an important factor in the design and manufacture of electronics products and the entire electronics supply chain.[57]

HP is concerned about the effects on costs and product performance of the high melting temperatures of lead-free solders. It notes that silver (a component of many potential substitutes) is toxic, has an exposure limit only three times greater than that of lead, and can more readily enter the water supply — all of which raise questions about its suitability as a substitute. (Silver was originally on the EPA's list of persistent, bioaccumulative, and toxic chemicals but was removed because of incomplete information.) HP is particularly interested in an alloy of tin, bismuth, and copper that has a lower melting point than tin-lead solder. The company cautions, however, that the supply of bismuth is limited, which could pose problems if its use in solders became widespread.* (It should also be noted that copper is on the EPA's Draft RCRA list of PBTs.)

HP believes there is "a shortage of compelling and credible scientific evidence that alternatives to lead in solder for electronics are better for the environment than the original tin-lead solder."[58] It is especially concerned about the possibility that replacements for lead could themselves be banned in the future. HP is urging the industry to work together on the issue and find a standardized solution that minimizes costs and keeps manufacturing complexity to a minimum. While a single substitute for lead may not be found for all products, the company believes that a small number of alternatives (preferably two) may be feasible.[59]

Intel, meanwhile, describes the transition to lead-free electronic products as "a massive undertaking." The company is particularly concerned about the impacts that lead-free solder may have on the compatibility of

* Other concerns about bismuth relate to its incompatibility with lead, which is likely to continue being used in coatings for several years. Also, the recycling process for bismuth is incompatible with the processes used for other metals, making it difficult to recover. See Cynthia Murphy and Gregory Pitts, "Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants," *Proceedings of the 2001 IEEE International Symposium on Electronics and the Environment*, Institute of Electrical and Electronics Engineers, New York, 2001.

manufacturing processes across the supply chain, and is emphasizing the importance of establishing standards, identifying compatible technologies, and developing a conversion timetable. Intel also notes that the reliability of plastic components is affected by the high processing temperatures required by most lead-free solders, and that the costs of the replacement materials are higher than those of lead (Table 3.3).[60] On its website, Intel cites estimates that the material costs of eliminating lead in the US will be $140 to $900 million, with total supply chain costs likely to reach tens of billions of dollars.[61]

Debate Continues on Lead-Free Solder

Many US companies continue to oppose lead-free requirements through their trade associations. As already noted, the Electronics Industry Alliance opposes the EU's prospective ban but acknowledges that lead is a problem material. Another group, the Surface Mount Council, has argued that lead-free solders are no more friendly to the environment than lead, and that the focus should be on recovery and recycling rather than eliminating lead from products.[62] The US Chamber of Commerce has been pressing the European Parliament for exemptions to the EU's forthcoming ban.[63]

Table 3.3 Relative Costs of Lead Substitutes in Solder

Replacement Material	Relative Cost
Lead	1
Zinc	1.3
Antimony	2.2
Copper	2.5
Tin	6.4
Bismuth	7.1
Indium	194
Silver	212

Source: Todd A. Brady *et al.*, "Product Ecology at Intel," *Proceedings of the 2001 IEEE International Symposium on Electronics and the Environment*.

The industry's opposition to shifting to lead-free solder centers on three generic arguments often raised in connection with requirements to replace specific materials in products: 1) the change is too costly; 2) product performance will suffer; 3) the substitutes may be more damaging to the environment and public health than the original material.

Some researchers have rejected these arguments. For example, in a paper presented in 2001 at the Institute of Electrical and Electronics Engineers' annual symposium on electronics and the environment, researchers from the University of Tokyo and the Fraunhofer Institute in Berlin argued that eliminating lead, while posing some problems, will improve the environmental performance of electronic products. The researchers used "eco-indicator" systems developed in the Netherlands and Switzerland to compare lead and lead-free solders. They found that the substitute materials require increases in energy use of 15 to 50 percent, but saw the decreased toxicity benefits of the alternative materials as outweighing their negative energy impacts.

The University of Tokyo/Fraunhofer study also found that new production equipment can substantially reduce energy use, and that switching to alternative materials will lead to more new equipment being used. The researchers noted that eliminating lead from electronics products will increase their recycling value, since lead is a major contaminant and substitutes such as silver have considerable value. Despite the higher costs of the alternatives, they claimed that switching to lead-free solder will not increase the cost of printed wiring boards, because solder accounts for such a small percentage of total costs. Finally, the study pointed to one potential problem: switching to silver solders could consume 6 to 9 percent of the world's total output of silver, putting pressure on silver supplies. The researchers recommended the use of silver but emphasized the need for high rates of take-back and recycling.[64]

Other Hazardous Materials

Cell phones and other wireless electronic devices also contain cadmium and hexavalent chromium. It is well known that these substances — soon to be banned under the EU's forthcoming directives — are toxic and can have seriously harmful effects on public health. Cell phones also contain valuable materials such as gold, silver, palladium, and platinum, which should be recovered, reused, or recycled.

Other materials present in cell phones that pose threats to human health and the environment include beryllium, tantalum, arsenic, and copper.

Beryllium

In beryllium-copper alloys, the metal beryllium contributes hardness, strength, conductivity, and corrosion resistance. Beryllium-copper alloys usually contain about 2 percent beryllium.[65] In cell phones, they are used in springs and contacts that need to expand and contract.

Beryllium-copper has a worldwide market of 50 million pounds per year, with cell phones accounting for the largest share, at 15 million pounds. The US is the largest producer, processor, and consumer of beryllium. With the increased popularity of cell phones, production has soared.[66]

Beryllium can be a serious health hazard in manufacturing and recycling facilities. In the form of dust or fumes, it is one of the most toxic metals to inhale. Small particles of the metal can break off when products are shredded or heated and spread through the air. Workers who become sensitized to beryllium can suffer irreversible and sometimes fatal scarring of the lungs.[67]

Because of the serious dangers it poses to workers, the presence of beryllium in cell phones can be a significant barrier to recycling. For example, at Noranda Inc., a large Canadian metals producer that also recycles electronic products, a number of workers were diagnosed with chronic beryllium disease. As a result, the company has set a beryllium limit on used electronic products entering its recycling facilities. The limit is 200 parts per million in solid scrap and 50 parts per million in powdered scrap. Loads that exceed these limits are rejected.[68]

Tantalum

The precious metal tantalum has been a key factor in reducing the size of cell phones and other small electronic devices. Highly resistant to heat and corrosion, it is used in capacitors that control the flow of current inside small circuit boards. About 35 percent of the tantalum capacitors produced are used in cell phones. With cell phone use soaring, the price of tantalum rose from $20 per pound in the early 1990s to about $350 per pound in January 2001.[69]

The health effects of tantalum are not known, because little toxicity testing has been done. However, Malaysia's Environment Ministry has found tantalum dumps to be radioactive and has voiced concern that miners could suffer lung disease from exposure to the metal.[70] Recently, some impacts were documented in an article in *The New York Times Magazine*, which described how tantalum mining in Congo has overrun a national park and devastated its population of wildlife.[71] The article also cited a United Nations claim that tantalum mining is perpetuating Congo's civil war, with factions battling over control of this valuable metal.[72] To mitigate devastating environmental and social effects such as these in the future, reusing and recycling hazardous materials such as tantalum are essential.

Arsenic

Arsenic can cause damage to the nerves, skin, and digestive system, and can even cause death when ingested at high levels.[73]

The average cell phone contains five gallium-arsenic semiconductors, which are superior to silicon chips in these devices because of their ability to reduce static. These chips are harmless during use but create a toxic compound when cell phones are incinerated. In Japan, where an estimated 610 million cell phones will be disposed of by the end of 2010, there is some concern over the 93 kilograms (205 pounds) of potentially toxic arsenic contained in this waste.[74] In the US, the 500 million retired cell phones estimated to be stockpiled by 2005 will put 169 pounds of arsenic into the environment once discarded.

Copper

On the EPA's original list of persistent, bioaccumulative toxins, copper was ranked 41. Copper is used as an herbicide to kill algae in swimming pools and lakes. It is toxic to fish and bioaccumulates in marine organisms. Ingestion by humans can cause diarrhea, liver damage, and death. It is used extensively in cell phones and causes dioxins and furans to form when materials containing brominated flame retardants (such as printed wiring boards) are incinerated.

4 End-of-Life Management of Electronics in the US

Concern about electronic waste is rising in the United States, driven by two major factors. First, municipal waste systems are being overwhelmed by rapidly growing quantities of discarded electronic equipment that is expensive to manage because of its toxic constituents. Second, regulations are being implemented in Europe and Asia that require producers to take back and reuse or recycle their electronic equipment at end of life, raising the question of whether such regulations should be implemented in the US as well.

In this chapter, we look at how the electronic waste management problem is being addressed in the US. (Chapter 5 describes policies and programs for end-of-life management of electronics abroad.) While some of the programs described involve a wide range of electronic products, including cell phones and other wireless devices, the focus at present is on computers. However, the same issues pertain to all discarded electronics, so even those programs that do not specifically address waste from wireless devices provide insights into how these products might be managed at end of life. It is also important to note that wireless products are distinctive in one way that could have significant implications for their end-of-life management: because they are so small, they may require different types of collection systems than those used to manage heavy products that contain CRTs.

According to INFORM's estimates, about 130 million cell phones will be retired each year in the US by 2005 and over 500 million cell phones will be stockpiled — that is, stored away in drawers, closets, and attics. Ultimately, all this equipment will enter the municipal waste stream.

Cell phones and other wireless devices are a particular problem because, like personal computers, they contain precious metals and many toxic components. These products should not be disposed of in landfills or burned in incinerators, but because they are so small, it is difficult to prevent them from being thrown out in the trash. The challenge is to develop systems that recover the highest possible value from these products after they are discarded, and that reduce the risk of damage to the environment and public health resulting from their end-of-life management. At present, retired cell phones do have some value. Hobi International, Inc., an electronics recycler, pays to take back old phones mainly because of the high percentage that can be sold for reuse.[1]

Before considering end-of-life options, it is useful to point out that cell phones are retired and replaced primarily because of marketing factors. Since phones are dedicated to a particular service provider, users who change providers usually must get a new phone even if the old one works perfectly well. Service contracts typically last one year, and even users who renew with the same provider often have an incentive to replace their current phone. For example, in the summer of 2001, AT&T offered a free Nokia phone and $80 worth of rebates along with its standard service contract — thus, choosing to get a new phone actually earned customers $80. As a result, many phones are being discarded that are in good working order and suitable for reuse.

Programs to Refurbish and Reuse Cell Phones

A number of programs in the US promote the refurbishment and reuse of cell phones. These terms are used as follows throughout this chapter:

- **Refurbishment**: the cleaning, reprogramming, and/or repair of a product.
- **Reuse**: the reapplication of a product that retains its original form or identity.

Refurbishment and reuse extend the utility of products and prevent functional products from being disposed of as waste. Some examples of programs in the US include the following:

- **CAP Inc.** (Computers Assisting People Inc.) CAP has been collecting used cell phones throughout Ohio since February 2001. The program grew out of the group's success collecting used computer equipment, parts, and software and donating them to nonprofit organizations. It primarily targets businesses (where CAP's phone collection containers are located), but has also begun to target community social groups in order to promote individual phone donations. Collected phones are sent to Motorola and are either recycled or refurbished, depending on the item's condition. Refurbished phones are preprogrammed to dial 911 and several other numbers, and are given to victims of domestic violence and to "families at risk" (determined by local police agencies and shelters). CAP has collected almost 1000 cell phones since the program's inception.[2] For more information, see http://www.capinc.org/capfone.htm.

- **CollectiveGood International**. Participants in this program donate their used phones to charities, which sell them to CollectiveGood. The organization then refurbishes and sells them at 33 to 50 percent below the cost of a new phone. It targets developing countries where the average per capita income is under $3000 per year (particularly in Latin America, where networks use the same cellular standards as in the US). CollectiveGood partners with charities such as CARE, and also with entities such as the Rechargeable Battery Recycling Corp. and Waste Management Inc.'s Asset Recovery Group, which respectively recycle batteries and phones that cannot be reused.[3] Launched in December 2000, CollectiveGood has collected 10,000 to 11,000 phones to date.[4] For more information, see http://www.collectivegood.com.

- **Donate a Phone — Call to Protect**. These programs, run by the Wireless Foundation, have collected approximately 800,000 cell phones since September 1999. In Call to Protect, which began in 1996 (Motorola was the sponsor), phones and airtime are donated to victims of domestic abuse. Donate a Phone was established as an adjunct to Call to Protect to obtain more phones. Of the 800,000 phones collected so far, approximately one-third have been recycled. Approximately 60,000 usable phones have been given new batteries and sent to shelters for victims of domestic violence. The remaining phones have been refurbished and sold through ReCellular Inc. (described below). Revenues generated from phone sales are used to acquire new phones and refurbish used phones, and in program support and development.[5] For more information, see http://www.wirelessfoundation.org.

- **HopeLine**. Since its inception in 2001, this community service program, run by Verizon Wireless, has collected thousands of previously owned cell phones at the company's 1200-plus stores nationwide.[6] Verizon collects all brands of used phones, which are then refurbished, recycled, and/or sold, depending on the unit's condition.[7] Phones that can be refurbished are preprogrammed to dial 911 and one other number, generally a community police station or shelter, and provided to people in need of emergency services, such as domestic violence victims, crossing guards, and the elderly.[8] Proceeds from phone sales are donated to nonprofit domestic violence advocacy organizations and are used to purchase wireless handsets for abuse victims. A 10-week trial of the program in Georgia and on the company's website during the summer of 2001 resulted in 8000 collected cell phones.[9] For more information, call 1-800-426-2790.

- **New York City P.H.O.N.E.S**. (People Helping Others Needing Emergency Services). During a three-month period in 2000, the city collected over 22,000 cell phones at 300 sites for distribution to people in need of access to emergency services, such as victims of domestic violence, senior citizens, the homebound, livery cab drivers, school crossing guards, and neighborhood watch groups. The program was sponsored by Bell Atlantic (now part of Verizon Wireless), which preprogrammed the phones to call 911 only.[10] For more information, see http://www.nyc.gov/html/ccfv/html/phones.html.

- **ReCellular Inc**. Established in 1991, ReCellular buys and sells thousands of cell phones and accessories per day, refurbishes them, and lists them for sale on its website. Phones range in price from $29.95 to $129.95 and include major brands such as Nokia, Ericsson, and Motorola. ReCellular buys phones only in bulk — its primary customers are wireless carriers (e.g., Bell South Mobility, GTE Wireless, MCI Worldcom Wireless, Nokia Mobile Phones, and SBC Communications) and their authorized retailers, dealers, and agents. The company provides a 90-day warranty on all phones sold.[11] For more information, see http://www.recellular.com.

- **Phones Under Warranty**. Most service contracts provide a warranty on cell phones for the duration of the contract, which is usually one year. If the phone breaks during this period, the subscriber can send it back to the service provider, which replaces it free of charge with a refurbished phone. Broken phones are repaired when possible and subsequently used as replacement units.

- **New Every Two** (Verizon Wireless). This program enables customers to trade in their old phone for a new one every two years. At the end of the two-year contract, Verizon provides customers with $100 toward the purchase of a new phone. The customer must send back the old phone and renew the service contract with Verizon for another two years. In response to criticism that the program is wasteful, Verizon responds that the average wireless customer gets a new phone every 18 months anyway, and its program actually encourages people to keep their phones longer. Verizon refurbishes hundreds of thousands of returned phones each year and puts them back into service as replacement units.[12] For more information, see http://www.verizonwireless.com/special_offers/new_every_two/index.html.

Recycling of Cell Phones and Other Wireless Devices

In this chapter, the term "recycling" is used as follows:

- **Recycling**: the disassembly and processing of a product into raw materials that are used to make new products.*

Recycling of cell phones is in its infancy. Some electronics recyclers are beginning to process cell phones, but they accept bulk shipments only — not single phones from individual consumers. Communities or producers that collect used phones can consolidate them and use these recyclers' facilities.

United Recycling of Franklin Park, Illinois, was established in the 1950s to recover precious metals. The company now has three units: United Recycling Services, which disassembles the equipment; Universal Integrated Circuits, which recovers and resells the usable chips; and United Refining and Smelting Co., which recovers the precious metals.

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* The distinction between recycling and remanufacture — the cleaning, repair, replacement, and reassembly of parts into a product in sound working condition — is often hazy. In the context of electronic products, remanufacturing would include removing the circuit boards from used equipment and using them in new products. In this report, remanufacture is included under recycling.

United processes a wide variety of electronic equipment, including cell phones. All electronic waste received is evaluated to maximize recovered value. Items that can be reused and sold are identified and marketed. However, the company will destroy products at the request of customers, who may wish to protect proprietary design features, prevent damage to their brands' reputation from lower-quality products, or protect the market for new products. United will also recover parts for customers' spare parts inventories.

All materials containing integrated circuits (ICs) are sent to Universal Integrated Circuits for recovery. There is a substantial market for ICs, which are generally sold abroad to small manufacturers of lower-value products such as off-brand computers and electronic games and toys. The remaining materials go to United Refining and Smelting for recovery of precious metals such as gold, silver, platinum, palladium, and copper. Base metals, plastics, cardboard, and other materials are sold on the commodities market.

United also operates a take-back program for computer and fax equipment, available to consumers in Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin, at a cost of $27.99 per unit. Compaq Computer gives participants in this program a discount of 6 to 9 percent off the purchase price of a new computer.[13] For more information, go to http://www.unitedrecycling.com.

Fox Electronics of San Jose, California, was established in 1984 to recover integrated circuits from printed wiring boards for redistribution back into electronics manufacturing. It now offers a range of recycling services, including precious metals recovery. Like United, Fox will destroy materials at the request of customers, and provides a certificate guaranteeing that these items will never "resurface." Fox will also set up and operate take-back services, because the company believes it is only a matter of time before take-back mandates similar to those in Europe are proposed in the US.

Fox claims to be the world's largest processor of used integrated circuits, removing, refurbishing, repackaging, and reselling over two million per month. According to Fox, it can provide a higher return on scrap printed wiring boards than can precious metal refineries because the value of the component ICs is far greater than that of the precious metals. Its IC inventory is posted on the Internet, and its used chips come with a "100% unconditional guarantee for form, fit and function,"[14] while selling for 20 to 30 percent less than new.[15] Fox returns to its customers 60 to 70 percent of the revenues generated from the resale of ICs.[16]

To date, Fox has primarily recycled computer equipment. It is not currently recycling cell phones but may do so in the future. The company has recycled personal digital assistants (e.g., Palm Pilots). For more information, go to http://www.foxelectronics.com.

As the examples of United Recycling and Fox Electronics indicate, the materials recovered from cell phones and other wireless devices at end of life are the precious metals and integrated circuits they contain. Plastics, however, which account for about one-third the weight of a cell phone handset,[17] are not being recycled. This is because they contain additives (including brominated flame retardants, discussed in detail in chapter 3) that can contaminate the recycled materials and destroy their value. Debate on plastics recycling has gone on for years, with recyclers calling for manufacturers to facilitate recycling by standardizing and labeling the resins used, and manufacturers arguing that recyclers should develop better separation methods and that standardization of materials will impede their ability to "meet the needs of tomorrow."[18]

Voluntary Manufacturer Take-Back Initiatives

US companies are well aware that they will soon have to take back their electronic products in Japan and Europe, and that this will create strong pressures for them to take similar action in the US. Spurred by the EU's forthcoming *Directive on Waste Electrical and Electronic Equipment* (see chapter 5 for a discussion of the WEEE directive), and by the threat of state legislation in the US, some companies are voluntarily initiating take-back programs in hopes of staving off similar mandates here. While these programs tend to focus on computers, some include cell phones and all are instructive in providing potential models for the end-of-life management of small, wireless electronic devices.

In evaluating these initiatives, it is useful to consider how they address some key issues that have been at the heart of the debate on take-back in Europe. These include:

- Who pays to collect the materials and transport them to recyclers?
- Who pays for recycling?
- Are there any recycling targets?
- Are there any reporting requirements?
- Is take-back free to the end user?

Computer Take-Back by Manufacturers

IBM unveiled its take-back program in November 2000. For a fee of $29.99 per unit, the company will take back computers made by any manufacturer from individuals and small businesses. IBM provides a prepaid shipping label, but owners must pack the equipment themselves and bring it to a UPS location. Computers are shipped to Envirocycle, an electronics recycling company in Pennsylvania, which donates working units through the nonprofit Gifts in Kind International and recycles the remainder. This program has not met with great success: only 1000 computers were returned during the first six months of the program's operation.[19] Packing and shipping the equipment is inconvenient, and consumers are reluctant to pay IBM's fee when localities will generally pick up discarded computers for free. For more information, go to http://www.ibm.com/ibm/environment/products/prp.phtml.

Hewlett-Packard launched its take-back program, which is very similar to IBM's, in May 2001. The company will take back equipment made by any manufacturer for a fee ranging from $13 to $34, depending on the component. Consumers must box the equipment, but FedEx will pick it up at their door. Equipment is shipped to HP facilities in California and Tennessee for recycling by MicroMetallics. HP has not released any data on the amount of equipment it is getting back through this program. For more information, go to https://warp1.external.hp.com/recycle.

Compaq has partnered with United Recycling on its take-back program. For $27.99, consumers receive a shipping label and must then pack up and drop off the equipment at a UPS location. UPS delivers the used equipment to United Recycling. The program operates only in seven midwestern states: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin.[20]

Gateway has taken a different approach. Purchasers of a new Gateway computer can either trade in their old equipment (as long as it has value) or donate it to a charitable organization and receive a rebate of up to $50. It is the consumer's responsibility to identify a charity that will take the used equipment. Thus, Gateway provides an incentive to keep old computers out of storage or disposal facilities, but is not itself involved in their end-of-life management. The problem with this system is that charities are becoming reluctant to take used computers. For example, in May 2001, Goodwill Industries in California announced it would no longer accept donations of computers, TVs, and cell phones, citing the prohibitive costs of repair, recycling, and disposal.[21]

Dell has a number of programs that recover used computer equipment:

- **Trade-ups**: consumers can redeem the value of used computers and peripherals of any brand and use the redemption amount to offset the price of a new Dell computer.[22] For more information, go to http://www.delltradeups.com.

- **Auction**: Dell runs an on-line auction similar to eBay for buying and selling used computer equipment of any brand.[23] For more information, go to http://www.dellauction.com.

- **Exchange**: in partnership with the National Christina Foundation, Dell accepts used computer equipment and provides it to the economically disadvantaged, students at risk, and people with disabilities.[24] For more information, go to http://www.cristina.org/dsf/dell.ncf.

Intel, which is not a computer maker but rather a major supplier of parts to manufacturers of electronic products, will arrange for students to refurbish used computers, which are then given to schools and nonprofit organizations. This program, called StRUT (students recycling used technology), has refurbished over 24,000 computers.[25] For more information, go to http://www.strut.org.

Take-Back by Manufacturers of Other Electronic Equipment

In October 2000, Sony launched a take-back program for all its branded products, including cell phones.[26] The company described its "We Make It, We Take It" initiative as a five-year program that would begin in Minnesota, expand to five other states during 2001, and go national by 2004. (The program is an outgrowth of government initiatives in Minnesota to involve manufacturers in the management of electronic waste. See "Government Action on End-of-Life Electronics" in this chapter.) Sony would initially subsidize the program but expected it to become profitable by 2005. However, budget constraints led the company to put the program on hold in 2001 and not to expand it as planned.

Sony's Minnesota program, which was in operation as of November 2001, is based on a partnership with the state and Waste Management Inc. (WMI). Individual municipalities run the collection program (which is free to end users), separate the products, and ship them to WMI facilities, where they are sorted into glass, plastics, and metals. Sony reuses the glass and WMI sells the plastics and metals.[27]

In March 2001, Sony joined Panasonic and Sharp in a recycling program in Connecticut and New Jersey. Each manufacturer pays to recycle its own products, while the states pay the costs of collection, sorting, and transport to designated recyclers. This program, too, is free to the end user.

Analysis of Manufacturer Take-Back Schemes

INFORM's research indicates that making producers responsible for their products at end of life can result in products designed to be less wasteful and more recyclable. To be effective, such "extended producer responsibility" (EPR) programs must:

1. Focus specifically on the waste generated by end-of-life products.
2. Clearly define what financial responsibility producers have for the collection, transport, and recycling of their products at end of life.
3. Set meaningful targets for collection and recycling.
4. Differentiate recycling from technologies such as waste-to-energy conversion, in which materials are burned to recover energy.
5. Include reporting requirements and enforcement mechanisms.
6. Provide producers with incentives to design for reuse/recycling.
7. Provide consumers with incentives to return their used products.

All the programs described above specifically address waste, and in all of them producers are taking some financial responsibility for the end of life of their products. However, these are voluntary programs and none of them includes targets for collection and recycling. Nor do they define what counts as recycling, and they do not include reporting requirements or enforcement mechanisms. While some producers will pay the costs of recycling, most show no willingness to pay for the collection of used products and their transport to recyclers. In all of these programs, this is paid for either directly by consumers or by local government. In the few cases where the manufacturer collects used equipment, consumers are charged for the service.

Another problem relates to the export of electronic equipment collected for recycling. Much of this is being shipped to developing countries, where it is polluting the environment and damaging public health. The US in unique among the industrialized nations of the world in not having signed the Basel Convention — a United Nations treaty that limits the export of hazardous waste.[28]

On the positive side, these programs indicate that manufacturers are beginning to address the fate of their products after consumers discard them. This is an important step forward. However, the absence of targets and reporting requirements means that companies can establish such programs and end up taking back very little. The danger is that, while not really contributing significantly to the management of their products at end of life, manufacturers will be able to use these initiatives to bolster the argument that no take-back legislation is needed in the US.

In Europe, mandated take-back programs usually require that take-back be free to the end user. Any fees imposed at end of life are considered a disincentive for consumers to return their used products. In this country, where IBM, Hewlett-Packard, and Compaq all charge consumers to participate in their programs, it may well turn out that little equipment is actually returned. Japan's mandated take-back program does permit manufacturers to impose end-of-life fees on consumers, and it will be interesting to see what impact these have on recovery rates.

Table 4.1 End-of-Life Electronics Management: US Manufacturer Programs vs. the EU's WEEE Directive*

	Who Pays Collection Costs?**	Who Pays Transport Costs?**	Who Pays Recycling Costs?**	Collection/ Recycling Targets?	Free to End User?	Brands Included	Reporting/ Enforcement Mechanisms?
IBM	Consumer	Consumer	Industry	No	No	All	No
Hewlett-Packard	Consumer	Consumer	Industry	No	No	All	No
Compaq	Consumer	Consumer	Industry	No	No	Own	No
Sharp/ Panasonic/ Sony	Government	Government	Industry	No	Yes	Own	No
Europe (WEEE Directive)	Industry	Industry	Industry	Yes	Yes	All	Yes

* This table refers to mandated take-back programs under the EU's forthcoming *Directive on Waste Electrical and Electronic Equipment* (WEEE). Also note that Gateway and Dell provide incentives for reuse in the US but do not operate take-back programs.
** This column refers to direct payment of these costs only.
Source: INFORM, Inc.

In none of the voluntary take-back programs initiated by manufacturers in the US do producers assume the full costs of collection, transport, and recycling. In some of them consumers pay directly for getting materials to recyclers, in others local government pays. Thus, the companies initiating these programs have taken financial responsibility for recycling only.

This is an improvement over the prevailing system, in which government pays all the end-of-life management costs for used electronics. But since companies may soon be able to profit from recycling, the arrangement could mean that government — if it pays to collect and deliver materials to recyclers — will in effect be subsidizing those profits. A key goal of EPR is to give producers incentives, such as any financial benefits that might be gained from take-back, to design products that are more recyclable. But such profits will be problematic if government winds up paying a substantial portion of end-of-life management costs by supplying companies with free feedstock for their manufacturing operations.

Clearly, companies that pay to recycle their own products have the greatest incentive to design for recycling. Design strategies resulting in products that are more economically recyclable and that generate less waste include using fewer plastic resins, labeling the resins, using fasteners that are easier to take apart, and reducing toxic constituents. Sony, which is working to make the recycling of its products profitable, is pursuing all of these strategies.[29]

Results of the joint initiative undertaken by Sony, Sharp, and Panasonic, in which each company pays the cost of recycling its own products, will provide important information on the economic feasibility of managing end-of-life products by brand. If this proves too expensive, companies may decide to pool their efforts and form producer responsibility organizations that recycle products of any brand. In that case, the major challenge will be to devise a fee system that rewards companies that design for recyclability. In Europe, fees to fund the recycling of packaging waste have been based on material composition and weight. Such fees closely approximate the actual costs of recycling a particular package. But electronic equipment is far more complex, with each product containing hundreds of materials, and will require a more complex solution.

Retailer Take-Back

A number of retailers are participating in local take-back programs for electronic equipment. Best Buy Co., a large electronics retail chain, is the first to undertake such a voluntary initiative nationally.

The program, announced in April 2001, involves drop-off programs at selected Best Buy stores across the country. The company will accept almost all electronic products, irrespective of brand (See Appendix D. Best Buy describes its initiative as a take-back program for electronics, but some electrical products are also included.) Best Buy's goal is to hold a drop-off event at each site at least once a year.[30]

Best Buy generally charges a fee for computer monitors ($10 per unit) and TVs ($15 to $25 per unit), but all other items are accepted free of charge. At one event, no fees were charged; at another, each car used to transport returned equipment was charged an additional $5.00. Best Buy is seeking partners in this program and has already lined up Panasonic, which expects to carry one quarter of the program costs.[31] Toshiba and Compaq have each sponsored collection events at Best Buy stores.[32]

As of November 2001, Best Buy had held collection events in ten stores in seven states. Most of the equipment collected so far has been computers and TVs, with consumers dropping off fewer than 100 cell phones. These were sent to CollectiveGood International (see "Programs to Reuse and Refurbish Cell Phones" in this chapter), which agreed to have the phones reused or recycled domestically. The Rechargeable Battery Recycling Corp. (see chapter 6) provided collection boxes at each event, so consumers could return spent batteries from their cell phones and other electronic devices. Batteries were sent to recyclers.[33]

As noted above, manufacturers seem more willing to pay to recycle electronics than to collect and transport the materials to recyclers. The Best Buy program illustrates the role that retailers could play in bearing those costs. However, environmentalists (such as the Western Electronics Product Stewardship Initiative [WEPSI] and the GrassRoots Recycling Network) are concerned about the program's take-back fees and the infrequency of collection. They argue that take-back should be free, with any costs incorporated into the product purchase price, and that programs should offer more than one drop-off event at each site per year. Best Buy has certainly taken the lead with its voluntary collection program, but other retailers will have to play a role as well if the retail sector is to be a significant player in the collection of used electronic equipment.

Trade Association Involvement in End-of-Life Electronics

In addition to launching take-back programs of their own, electronics manufacturers are working collectively through the Electronics Industry Alliance (EIA), a trade association, to address the problem of end-of-life electronics. The EIA comprises over 2100 high-tech companies, including manufacturers of computers, semiconductors, circuit boards, telecommunications equipment, and consumer electronic products, and represents 80 percent of the $550 billion US electronics industry.[34]

In January 2001, the EIA launched its web-based Consumer Electronics Initiative, which provides information on charities and government programs that accept used electronic equipment from consumers. This program provides information only – it does not involve any financial contribution by industry to the end-of-life management of electronic products. For more information, go to http://www.eiae.org.

In October 2001, the EIA announced grants totaling $100,000 for the implementation and study of different collection models for electronics from household sources. The companies funding this project are Canon, Hewlett-Packard, JVC, Kodak, Nokia, Panasonic, Philips Consumer Electronics North America, Sharp, Sony, and Thomson – almost all Japanese or European companies. Notably missing from the project are large US computer-makers such as IBM, Dell, Compaq, and Gateway.

The three grant recipients in the EIA project are the US Environmental Protection Agency, Region III (comprising Delaware, Pennsylvania, Maryland, Virginia, West Virginia, and the District of Columbia), the state of Florida, and the Northeast Recycling Council (comprising solid waste officials from Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont). The one-year pilot projects will involve implementing collection programs and evaluating data from government-funded curbside and drop-off collection programs and various retail collection models.[35]

Corporate Give-Back

AT&T's "take-back" program is more accurately described as a give-back program. Instead of taking anything back itself, the company requires suppliers to take back the products they sell to AT&T. So far, this has included carpet, cables, switches, and cell phone batteries (but not cell phones themselves). AT&T's 500 wireless retail outlets also encourage customers to bring their used batteries back to the stores instead of throwing them away. The stores then mail the batteries to recyclers. AT&T believes that "the costs for this procedure are outweighed by the environmental benefit."[36]

National Electronics Product Stewardship Initiative

The National Electronics Product Stewardship Initiative (NEPSI) is a national multi-stakeholder dialogue begun in April 2000. In the face of threatened legislation in a number of states and abroad, its goal is to reach agreement on how end-of-life electronic equipment should be managed in the US. Industry favors a voluntary approach and is working to achieve this through the NEPSI dialogue. The initiative involves over 40 participants representing industry (including the Electronics Industry Alliance), government (including Massachusetts' Product Stewardship Institute, described in "Government Action on End-of-Life Electronics" in this chapter), nongovernmental organizations (including INFORM), and academia. (See Appendix E for a complete list of participants and their affiliations.)

NEPSI is focusing on computer equipment and TVs and is addressing such questions as:

- What mechanisms (such as advance disposal fees) can be used to pay the end-of-life management costs of these products?
- Who should pay the costs of collection, transport, and recycling?
- What collection, transport, and recycling infrastructure is required?
- What regulatory changes are needed (e.g., to remove barriers to recycling)?

NEPSI plans to hold six meetings ending in September 2002. Ideally, the end result will include a consensus on what responsibility industry should have for managing electronic equipment at end of life. If this effort fails, more initiatives can be expected at the state level to require manufacturers to pay the end-of-life management costs for these products.

Government Action on End-of-Life Electronics

No legislation dealing with end-of-life electronics has so far been passed at the federal level in the US. However, there have been numerous initiatives at the state and local levels. This is not surprising, since it is here that government is struggling with the financial burden of managing the fast-growing and toxic electronics waste stream.

Minnesota

The state that has taken the lead in promoting product stewardship and EPR is Minnesota. In 1991, Minnesota adopted legislation making the producers of nickel-cadmium batteries responsible for collecting and responsibly managing them at end of life. This, along with action in several other states, ultimately led to a national take-back and recycling program for these batteries that is fully funded by industry (see chapter 6 for a discussion of this program).

More recently, the Minnesota Office of Environmental Assistance (OEA) launched its Product Stewardship Initiative in 1999, resulting in the creation of multi-stakeholder task forces to address three priority waste streams: paint, carpet, and electronic products with cathode-ray tubes (CRTs). Progress made by these task forces and the pilot projects they spawned led to many of the voluntary electronic take-back programs that exist today, and also to the National Electronics Product Stewardship Initiative described above.

Minnesota includes in its definition of product stewardship the shifting of the responsibility and costs of managing end-of-life products from the general taxpayer to the manufacturer and consumer, causing those costs to be internalized in product prices. The three goals of the Product Stewardship Initiative are:

1. Reducing or eliminating the toxic and/or hazardous constituents of products.
2. Using materials, water, and energy efficiently.
3. Promoting the sustainable use of materials by increasing reuse, recycling, and recovery.

The OEA states that "when manufacturers share the costs of recycling products, they have an incentive to use recycled materials in new products and to design products to be less toxic and easier to recycle, incorporating environmental concerns into the earliest phases of product design."[37]

In addition to the Product Stewardship Initiative, Minnesota conducted, between 1999 and 2000, a Demonstration Project for Recycling Used Electronics, which aimed to acquire data on collection systems, recycling markets, costs, and barriers. Partnering with the OEA were Sony Electronics, Panasonic–Matsushita, Waste Management Inc.–Asset Recovery Group, and the American Plastics Council, each of which pledged a minimum of $25,000 to the initiative. Minnesota described the demonstration project as "the first large-scale multi-stakeholder effort in North America to divert used electronic products from municipal waste."[38] In addition to the primary partners, industry participants included retailers such as Computer World and Circuit City, which held collection events at their stores.

The project addressed all electronic and electrical products, with the exception of white goods, air conditioners, and microwave ovens, for which a collection structure already exists in Minnesota. Over a three-month period in 1999, the demonstration project collected 575 tons of used electronics at 64 sites. An important finding was that collection and transport accounted for over 80 percent of the costs of managing these products at end of life. Data from the project also indicated a need for reductions in the number of times products are handled (to reduce costs), better recycling technologies, increased use of recycled content (to spur market development), and regulatory relief.[39]

This demonstration project was pivotal in Sony's and Panasonic's decision to develop programs for recycling their own products in other states. Best Buy's take-back initiative also had its roots in Minnesota, where it joined Panasonic and Sharp in a collection event.

Massachusetts

In 2000, the Massachusetts Executive Office of Environmental Affairs and the University of Massachusetts created the Product Stewardship Institute (PSI) "to assist state and local government agencies in establishing cooperative agreements with industry and developing other initiatives that reduce the health and environmental impacts from consumer products."[40] PSI comprises 17 state governments, 11 local members, and the Northeast Waste Management Officials Association, which represents six states. (See Appendix F for a complete list of members.)

According to PSI's definition of product stewardship, it includes manufacturers taking increasing responsibility for the end-of-life management of their products. Its objectives — like those of EPR — are "to encourage manufacturers to redesign products with fewer toxics, and to make them more durable, reusable, and recyclable, and with recycled materials."[41] PSI has targeted five waste streams: electronics, mercury-containing products, pesticides, paint, and carpet. So far, a major focus has been on electronics.

In 2000, Massachusetts banned the landfilling and incineration of CRTs. At the same time, the state awarded grants to municipalities to set up collection programs and find markets for recycled materials that would ultimately enable the programs to be self-supporting.

This goal has not been accomplished, so additional legislation is now being proposed to prohibit manufacturers from selling products that contain CRTs in Massachusetts unless they have a state-approved plan for managing these products at end of life. Such a plan would include a convenient and accessible collection system that recovers 95 percent of the used equipment. Costs would be borne by the manufacturer and could be included in the product price; customers using the collection system could not be charged a fee.[42] State Representative Mark J. Carron, who is sponsoring the legislation, believes it provides the best chance for these materials to be recovered and reused.[43]

A resolution circulating in Massachusetts (see Appendix G) calls for the state legislature to support the Carron CRT take-back bill and develop additional legislation requiring producer take-back of all consumer electronics and hazardous household products. It also calls for the adoption of statewide procurement guidelines requiring vendors of such products to state and local government to take them back at end of life. The resolution argues that "the costs incurred by Massachusetts cities and towns for disposal of products that contain toxics and are not easily recyclable, particularly electronic products and household hazardous products, are in effect unfunded mandates imposed by the producers of such products on local taxpayers; which takes funds away from other needed local government programs, such as schools, fire protection, emergency services, and police."[44] As of

March 2002, 54 cities and towns in Massachusetts, including Boston, had adopted the resolution and others may do so in the future.[45]

California

In California, the Department of Toxic Substance Control has ruled that CRTs are hazardous waste and cannot be disposed of in landfills or burned in incinerators. Waste managers are now scrambling to find alternative methods of dealing with this waste.

In July 2001, the Board of Supervisors of the city and county of San Francisco adopted a resolution urging statewide implementation of EPR for electronics. The resolution, which is similar to the one circulating in Massachusetts, states that the burden of responsibility for electronic products should be shifted from government and taxpayers to the manufacturers, distributors, and consumers of these products. It urges the state to pass legislation requiring industry to create a program resulting in high recovery rates – one that includes convenient collection systems and incentives for consumers to dispose of end-of-life electronic products properly. If an effective program is not created by industry or enacted by the California legislature by October 15, 2002, San Francisco threatens to take action itself, including the possibility of imposing deposits or fees on electronic equipment at the point of sale.

Similar resolutions have been adopted in other California cities including Los Angeles, San Jose, and Sacramento. These initiatives are being coordinated by four nonprofit organizations – Californians Against Waste, Materials for the Future, Green Capitol, and the Silicon Valley Toxics Coalition. The latter has also undertaken a national Take It Back Campaign that is putting pressure on industry to initiate computer take-back and recycling programs, and on state and local legislatures to require such programs if industry fails to implement them effectively.

Advance Disposal Fees and Landfill Bans

Advance disposal fees are included in the product price paid by consumers. They are based on a product's end-of-life management costs and are used to pay some or all of those costs.

Two states, South Carolina and Arkansas, recently considered legislation that included advance disposal fees to fund the recycling of end-of-life electronic equipment. In South Carolina, the legislation died because of the proposed $5.00 fee on TVs and computer monitors. In Arkansas, the legislation passed but the actual fee was rejected.[46] In both cases, failure of the fees was due to their being perceived as an additional tax.

The part of the Arkansas legislation that did become law instructs state agencies to sell their surplus electronic equipment, with 25 percent of the proceeds to provide revenues for a new computer and electronic recycling fund. The legislation also authorizes the state to impose a ban on the landfilling of computers and electronic equipment, but not before January 1, 2005.[47]

Landfill bans on electronic equipment are under consideration in a number of states, including Connecticut, Florida, Iowa, and New Jersey.[48] As already noted, Massachusetts banned the landfilling of CRTs in 2000.

Other Local Initiatives

In Texas, the city of Houston is working with Waste Management Inc. (WMI) on an electronics recycling pilot project. A broad range of products is accepted, including cell phones (without batteries) and small consumer electronics such as personal digital assistants (e.g., Palm Pilots) and pagers. The equipment is disassembled in Texas, with half the materials then being sent to recyclers in North America and the remainder to markets in Europe and Asia. WMI pays Houston 5 cents per pound for the cell phones and central processing units it provides, while the city pays WMI 25 cents per pound to take computer monitors and 27 cents per pound to take TVs.[49] This arrangement suggests that the economics of managing cell phones are much more favorable than the economics of recycling equipment with CRTs.

In the western part of the US, state and local governments in California, Oregon, and Washington, along with some nongovernmental organizations, have formed the Western Electronic Product Stewardship Initiative (WEPSI) to address management of used electronic equipment. The group is working toward a "shared responsibility" framework and plans to produce a product stewardship workbook to help implement its strategy on the West Coast.

The efforts described in this chapter to address the end-of-life management of electronics in the US represent an important step forward. Traditionally, electronic products have been thrown out in the trash and their end-of-life management has been solely the responsibility of municipal government. The emerging programs indicate that producers are beginning to acknowledge some responsibility for their products after consumers discard them. So far, however, these initiatives have been small in scale and in no way comparable to what will soon be required in Europe (see chapter 5).

5 End-of-Life Management of Electronics Abroad

Efforts to manage electronic waste around the world have been driven in large part by legislation developed in the European Union (EU). Some countries in Europe already have extended producer responsibility (EPR) programs for electronics. These include Sweden and the Netherlands, which belong to the EU, as well as Norway and Switzerland, which do not.*

In some EU member nations, such as Austria and Germany, electronics take-back legislation is on hold pending adoption of two forthcoming EU directives, one on waste electrical and electronics equipment and the other on the use of hazardous substances in these products. Nations with existing take-back laws may have to make significant changes in their programs to comply with these directives. Throughout Europe, anticipation of the directives has led the electronics industry to implement voluntary take-back programs and has spurred research in technologies for managing electrical and electronic waste.

The following discussion focuses on the forthcoming EU directives. It also describes some other European take-back programs, the status of EPR for electronics in Japan, and Australia's national take-back program for cell phones.

Components of an Effective EPR Program

In the previous chapter, an effective program — in which producers are responsible for their products at end of life — was defined as one that:

1. Focuses specifically on the waste generated by end-of-life products.
2. Clearly defines what financial responsibility producers have for the collection, transport, and recycling of their products at end of life.
3. Sets meaningful targets for collection and recycling.
4. Differentiates recycling from technologies such as waste-to-energy conversion.
5. Includes reporting requirements and enforcement mechanisms.
6. Provides producers with incentives to design for reuse/recycling.
7. Provides consumers with incentives to return their used products.

With respect to these elements, existing national programs in Europe and Asia all focus on waste. Generally, they clearly define the responsibility of producers, but this varies considerably from country to country and ranges from responsibility for all aspects of collection, transport, and recycling to responsibility for recycling only. The programs tend to be weak, however, when it comes to setting targets and differentiating recycling from other technologies, and programs that are voluntary typically do not include reporting requirements and enforcement mechanisms. Only Japan's program provides strong incentives to design for recycling, because producers there must pay to recycle their own products. Yet this program discourages consumers from returning their used products, because they are charged a fee for doing so.

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* The European Union comprises the 15 member states of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Norway and Switzerland are not members of the EU.

In Europe, all of this will soon change with the adoption of the EU directives, which cover an extraordinarily broad range of products, set ambitious collection and recycling targets, clearly define recycling, and require strict reporting and enforcement. The EU directives will also mandate the elimination of many hazardous substances from electrical and electronic products.

Europe's Twin Directives on Electronic Waste

The debate over how electronic waste should be managed and who should pay the costs has been going on in Europe for over a decade. Currently, two directives are going through the final stages of the EU adoption process: the *Directive of the European Parliament and of the Council on Waste Electrical and Electronic Equipment* (the WEEE directive) and the *Directive of the European Parliament and of the Council on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment* (the RoHS directive).

The legislative process in the European Union is complicated. The executive branch – the European Commission – is the source of policy initiatives; the Council, comprising the environmental ministers of the member states, adopts legislation in consultation with the European Parliament. There is now general agreement on the key issues addressed in the WEEE and RoHS directives, but many of the specific provisions are still not finalized. If the Council and the Parliament do not ultimately agree, the directives will go to a Conciliation Committee that will resolve the differences. As of December 2001, it is expected that the two directives will be finalized within the next year. Once the directives are adopted, the EU member states must pass their own national legislation to implement them.

The twin directives are sweeping in scope. They cover all products that come with a battery or an electrical cord, from heavy medical and telecommunications equipment to household appliances to small consumer items such as toys, clocks, and hair dryers. There are ten categories of products and each has its own recycling targets. Cell phones are in category 3, covering information technology and telecommunications equipment. Also in this category are mainframe computers, PCs, printers, calculators, fax machines, and wired telephones.

The issue of waste electronics was originally addressed by a single WEEE directive. In 2000, however, the Commission decided to split the provisions into two separate directives, with important implications. Since the legal basis of the WEEE directive is environmental protection, member states are free to pass more restrictive legislation in their own countries. The legal basis of the RoHS directive, on the other hand, is free trade, which prevents member states from adopting more restrictive legislation. In the future, the EU expects to propose a third directive, on the design and manufacture of electrical and electronic equipment.[1]

Directive on Waste Electrical and Electronic Equipment

The context for the WEEE directive is the proliferation of electrical and electronic equipment entering Europe's waste stream. Electrical and electronic waste accounted for 4 percent of EU municipal waste in 1998, and is growing at 3 to 5 percent each year – three times faster than the average municipal waste stream. Over 90 percent of electrical and electronic waste in Europe goes to disposal facilities (instead of being reused or recycled), where it contributes a large proportion of the pollutants.[2] Many EU member states have either adopted policies to address the problem or have such policies under consideration. One of the goals of the WEEE directive is to "harmonize" these different approaches.

The directive's general aim is to avoid the generation of waste and preserve valuable resources. The WEEE directive firmly embraces EPR and states: "By establishing producer responsibility this Directive encourages the design and production of electrical and electronic equipment which take into full account and facilitate their repair, possible upgrading, re-use, disassembly and recycling."[3] The following are some key requirements of the WEEE directive that apply to cell phones:[4]

- Electrical and electronic waste must be collected separately from other waste.
- Households must be able to return used equipment free of charge.
- Producers must provide product information that allows consumers to identify components and hazardous substances.
- Hazardous substances must be removed from products and managed in accordance with the EU waste directives.
- By a specified date (still under discussion) 65 percent (by weight) of separately collected waste from products in category 3 (information technology and telecommunications equipment) must be reused or recycled, and 75 percent must be recovered (this includes waste-to-energy conversion, in which materials are burned to recover energy). These rates will apply to cell phones and other hand-held wireless electronic devices.
- Member states must collect data on the amounts of equipment put on the market each year, as well as on the amounts collected and recycled, and report this information to the European Commission at three-year intervals.

Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment

The RoHS directive establishes restrictions on the use of some heavy metals and brominated flame retardants (see chapter 3 for a discussion of these substances). There is intense debate on the date of this phaseout, with the European Parliament supporting 2006, the EU Council supporting 2007, and industry supporting 2008. EU member states must ensure that new products put on the market after the specified date do not contain lead, mercury, cadmium, hexavalent chromium, or either of two types of brominated flame retardant: polybrominated biphenyls (PBBs) or polybrominated diphenyl ethers (PBDEs). Athough PBBs are not being made at present, regulators concluded that a ban on these substances was warranted in case some company wishes to produce them again in the future.[5] Some exemptions will be allowed if substitution with a nonhazardous material is not feasible or would outweigh the environmental benefits.

WEEE and RoHS Directives: Outstanding Issues

Some substantive differences still exist between the legislation approved by the Council and by the European Parliament. Heavy lobbying from all sides continues, and changes in the directives will undoubtedly be made before final adoption.

Target dates. There is intense debate over the dates at which targets must be reached. In addition to the target date for phasing out hazardous substances, there will be a specified date for meeting the collection, recovery, and reuse/recycling targets.

Individual versus collective responsibility. A key issue is whether producer responsibility should be individual or collective. When producers have individual responsibility, they pay specifically for the recycling of their own brand products; with collective responsibility, all producers jointly share the costs of managing all their waste products. The Council wants this decision left up to the member states. The Parliament wants to require individual responsibility — a position supported by companies such as Electrolux, IBM, Hewlett-Packard, Sony, Nokia, and Ericsson.[6] Hewlett-Packard is a strong supporter of individual responsibility, advocating a system in which "the individual manufacturer has as much control over the take-back cost of its products as possible." HP opposes systems with uniform take-back fees, even when these are controlled by industry, because they do not achieve the lowest possible overall costs.[7]

Although the terms have not been well defined, the distinction between individual and collective responsibility hinges on whether the system will reward companies that "do the right thing" by designing less wasteful, more recyclable products and developing economical recycling strategies. For example, if a company must pay to recycle its own products, it will benefit from product designs that are easier and cheaper to recycle. But if all companies pay the same fee (based on their market share) to recycle a product, such as $20 per computer, there will be no incentive to make computers that are more recyclable. While collective responsibility provides a funding mechanism but no incentives for companies to design for recycling, individual responsibility does provide such incentives. However, individual responsibility also entails some sorting or tracking of used products by brand, which can be costly.

There are also some murky areas in between: for example, if companies do not pay to recycle their own products but do pay fees based on factors that determine a product's recyclability, such as weight, material composition, and toxicity. Finally, it should be noted that individual responsibility does not preclude producers from working together to collect, transport, and recycle used products. They can set up joint programs under this model, but individual responsibility would require that the fees they pay be based on the cost of recycling their own products.

Historical waste. The debate on individual versus collective responsibility relates to new products only. Many of the products that will fall under the directives are "historical," meaning they were sold before the directives came into effect. For these products, there appears to be agreement that responsibility should be collective, since there is no reason to provide incentives for product design.

Orphan products. Another contentious issue is the problem of "orphans." These are products made by producers that no longer exist or cannot be found when the time comes to manage the waste. Industry strongly opposes having to pay to manage orphan products, which it sees as encouraging "free riders" (companies that benefit from a take-back/recycling system but do not contribute to it financially) and punishing companies that design products to facilitate end-of-life management.[8] Many companies have argued that government should pay the costs of managing orphan products.

Other issues. Remaining to be resolved as lobbying enters its final phase are the following:

- Collection targets for waste from households: the Council wants an average of 4 kilograms (8.8 pounds) per person per year; the Parliament wants 6 kilograms (13.2 pounds) per person per year.
- The point at which producers become responsible for waste equipment: will they have to collect it from households or can they pick it up at an aggregation point established by municipalities?
- Which products should be exempted from the phaseout of lead solder.
- Which brominated flame retardants should be phased out.
- Whether printed wiring boards from cell phones should be singled out for selective treatment (these components account for most of a cell phone's environmental impacts).

Again, some changes in the directives are likely before they are finally adopted. But whatever their ultimate form, it is clear they will require substantial reductions in the toxic content of electrical and electronic equipment, along with substantial increases in the rates of reuse and recycling.

The EU's Directives Are Spurring Innovation

Research on recycling technologies is being conducted all over the world, but there is particular pressure to develop new, less costly methods in Europe, where collection targets and recycling rates will be mandated by the WEEE directive.

One example of this is the ADSM (active disassembly using smart materials) project funded by the EU and being conducted at Brunel University (UK), Stuttgart University (Germany), and Gaiker Technology Center (Spain). Researchers are evaluating materials to be used in fasteners that will be able to disassemble themselves at specific triggering temperatures. Designs incorporating such materials could lead to electronic consumer products that disassemble themselves automatically. Researchers have developed a simple cell phone that can disassemble itself in 1.5 seconds; the mean disassembly time for all cell phones tested was 8 seconds. The researchers note that component recovery is key to reducing environmental impacts and that the current practice of dismantling by hand discourages recovery because of its high costs. ADSM can also be used to separate materials for recycling.[9]

Another effort is under way at Nokia, the world's largest maker of cell phones. The company is developing biodegradable plastics that would allow every phone part to be reused or recycled. The new materials have been tested in clip-on covers for cell phones, but so far they have not passed performance tests.[10]

Other EPR Models Abroad

EPR programs for electronic products in Sweden, the Netherlands, Norway, and Switzerland already include cell phones. However, none of these programs are based on individual producer responsibility, so they do not provide incentives to design products to facilitate end-of-life management. Typically, they use advance disposal fees paid by consumers to fund recycling. These fees are universal for individual product categories; for example, the fee for a cell phone is the same irrespective of actual recycling costs, even though these depend on a product's weight, material composition, ease of disassembly, and toxic components. Some national programs include recycling targets and reporting requirements and some do not. Even those that do, however, will have to be strengthened to conform to the requirements of the forthcoming WEEE and RoHS directives.

Switzerland's Take-Back Program

One program that has been cited as a possible model for the US is Switzerland's electronics take-back initiative. The SWICO Recycling Guarantee program is run by the Swiss Association of Information, Communication and Organisation Technology (SWICO), a nonprofit company organized by industry with over 400 member companies. Participation in the program was originally voluntary but was mandated by a national ordinance in 1998.

Under the SWICO program, retailers, manufacturers, and importers must take back their equipment free of charge and manage it in "an environmentally tolerable way."[11] The scope of covered products is very broad and includes household appliances, consumer electronics, and information and communications equipment. Small consumer items like hair dryers, electric toothbrushes, and shavers are also included. Products covered by the WEEE directive and not by SWICO include toys, power tools, and light bulbs.[12] Consumers are required by law to return all covered products.

Switzerland's "Ordinance on the Return, the Taking Back and the Disposal of Electrical and Electronic Appliances" states that iron, copper, and other metals should be recycled, that problematic components such as mercury switches and PCB condensers should be removed, and that nonrecyclable mixed plastics should be incinerated.[13] The SWICO Recycling Guarantee includes no recycling targets, however.

SWICO sets a national fee schedule based on the sales price of equipment. Customers pay this fee when they purchase the product. A fee of 16 cents is imposed on each cell phone sold to cover the costs of recycling.

The cost is low because the number of phones sold greatly exceeds the number that enters the waste stream in a given year. By comparison, the recycling fee for a TV set is $20.[14]

A 2000 report from Switzerland's environment office stated that the program was working well for larger items such as refrigerators, TVs, and office equipment. However, it was not working for small items like toasters and cell phones, which people were discarding along with their rubbish.[15]

The ECTEL Project: A Voluntary Industry Program

There have been a number of voluntary take-back programs for cell phones in Europe. The most notable of these was carried out by the Cellular Phones Take-back Working Group of the European Trade Organization for the Telecommunication and Professional Electronics Industry (ECTEL). In this pilot project, the participating companies (Alcatel, Ericsson, Motorola, Nokia, Panasonic, and Philips) took back their own phones in the UK and Sweden during 1997.

The ECTEL working group compiled detailed technical data on the program and analyzed the results. Key findings included the following:[16]

- Component recovery is far more beneficial to the environment than metals recovery.
- Significant environmental impacts of cell phone take-back and recycling come from collection and transport, not from the reprocessing of materials.
- The recycling infrastructure is immature.
- Recycling is not profitable and metals recovery is the least costly option.

Academics in the UK analyzed the ECTEL data using energy as a proxy for environmental impacts. End-of-life options studied were metals recovery through smelting or disassembly for component recovery with plastic recycling. For both options, the researchers found a positive energy balance. Their conclusion was that "it is to be expected that take-back (of cell phones) will have benefits in terms of improved materials recovery and avoided energy and environmental burdens."[17]

EPR in Japan

EPR has developed quite differently in Japan than in Europe. In particular, take-back in Japan does not have to be free — consumers pay when they bring used equipment back to retailers. Legislation making producers responsible for end-of-life refrigerators, air conditioners, TVs, and washing machines was passed in 1998. Take-back will soon be extended to include computers, and cell phones and other electronic products will ultimately be covered as well.[18]

When retailers take back used appliances in Japan, they send them to aggregation points set up by producers, which are responsible for their reuse and recycling. Producers set the take-back fees for their own products, and the expectation was that they would compete in setting those fees. In fact, however, the major producers all set the same fees and, according to the Ministry of Economy, Trade and Industry (METI), they are now competing fiercely to design lighter and slimmer products that are cheaper and easier to recycle. They are also designing for disassembly, reducing the number of plastic resins in their products, and reusing parts.[19]

This system is an example of individual producer responsibility. Since producers have both physical and financial responsibility for recycling their own products, they have a strong incentive to design for recyclability. This has resulted in increased communication between product designers and those responsible for recycling, and has facilitated the incorporation of end-of-life criteria into new product design.[20]

On the minus side, the Japanese system creates a disincentive for consumers to bring used products back to the retailer, since they must pay to do so. While consumers may be willing to pay to return a refrigerator, they may be less willing to bring back a cell phone they can easily throw out in the trash. In fact, the country's environment ministry has reported an increase in illegal dumping of TVs.[21]

The take-back system for personal computers, scheduled to begin in April 2002, departs from the individual responsibility model. Unlike the system for appliances, it imposes an advance disposal fee on the PC sale price, with the revenues going into a fund for recycling. The fees have not yet been set but are expected to be about 3000 to 4000 yen ($25 to $33) for desktops and about 1000 to 1500 yen ($8 to $12) for laptops. There will be additional charges for collection. For computers already sold, consumers will have to pay recycling and collection fees when they turn in the used products.[22]

The government intends to negotiate recycling targets for electronics with industry and to require reporting. In addition, companies will have to develop design-for-environment programs and report on these to the government.[23] METI has already issued design guidelines for computers that require manufacturers to conserve resources and make long-lasting products that use fewer materials and include more recyclable materials.[24]

Cell Phone Take-Back in Australia

Most national take-back programs for cell phones are part of a more comprehensive program for electronic products. Australia is unique in implementing a national program solely for cell phones. The Mobile Phone Industry Recycling Program (MPIRP) was launched in 1999. At that time, Australia closed down its analog network and installed a cellular network, making over one million cell phones obsolete. MPIRP was set up to keep these phones out of landfills.[25] The take-back program is voluntary and is run by the Australian Mobile Telecommunications Association (AMTA), which acts as its administrator and financial custodian.[26]

Each month, manufacturers pay a 30 cent (US $0.15) fee for every handset they put on the market. Carriers pay a 12 cent (US $0.06) fee per handset according to a formula based on their market share. AMTA collects the fees, contracts with recyclers, and pays all recycling and promotional costs from the revenues generated by the fees. Consumers can drop off phones free of charge at 1650 participating retailers. AMTA provides the retailers with bins and empties them when they are full. All brands of phones are collected, although two manufacturers do not participate in the program. All collected items, including handsets, batteries, and accessories, are sent to smelters for metals recovery.

So far, only 30 tons of equipment have been collected since MPIRP's inception in 1999.[27] To promote the program, AMTA entered into a partnership in 2000 with Planet Ark, a nonprofit environmental organization. The Phones 4 Planet Ark campaign, described as the "world's biggest mobile phone recycling program,"[28] aims to recycle 120 tons of cell phones and cell phone batteries each year — about 500,000 phones.[29] Participating manufacturers and network carriers include Alcatel, Ericsson, Mitsubishi, Motorola, NEC, Nokia, Panasonic, Philips, RF Industries, Samsung, AAPT, Cable & Wireless Optus, OneTel, Orange, Telstra, Virgin Mobile, and Vodafone.[30] The program's purpose is to keep cell phones out of landfills, but there appears to be no effort to reuse the phones or recover components for reuse.

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.

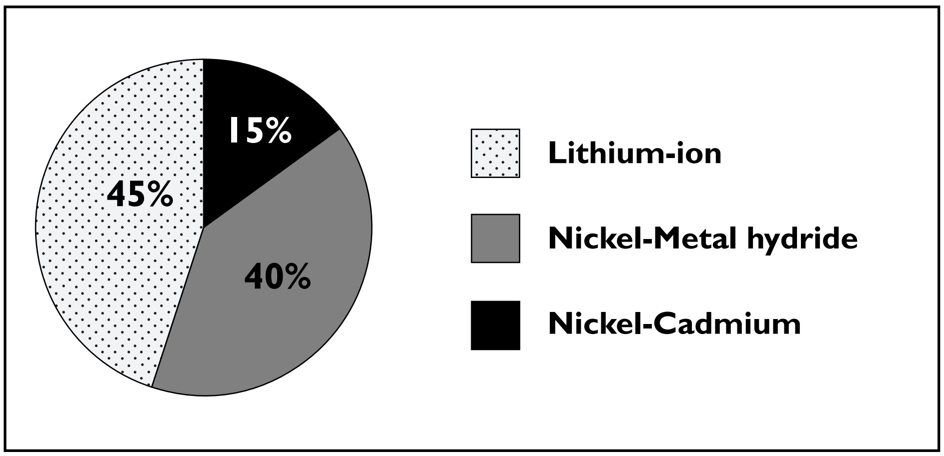
Until the mid-1990s, Ni-Cd batteries provided the power for most cell phones and other wireless devices.[3] In common use since the 1950s, Ni-Cds are the least expensive rechargeables. They have been used in a large number of electronic products but are now losing market share to newer, more efficient 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	Li-ion
		(% of battery weight)**		
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

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* 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]

7 Looking Toward the Future of the Wireless World

In 1992, when Al Gore warned that the US would have to prepare for the arrival of the "information superhighway" if it was to maintain its competitive position in the global economy, few people knew what he was talking about. Now, a decade later, the information superhighway — i.e., the Internet — permeates almost every aspect of our lives. The amount of information that can be easily accessed, transmitted, and stored by computers, and the pervasive role of computers in our lives, could not have been imagined only a short time ago.

And the pace of change is accelerating. Having grown accustomed to the wired society of the 1990s, we now must adapt to a new, wireless world — a world in which we have the freedom to make our purchases, do our chores, be entertained, and send and receive a great range of information anytime, anywhere, from the air to the outback and everyplace in between, through the use of hand-held wireless devices.

Untethering the Internet

The shift from a computer-dependent, wired Internet to a mobile or wireless Internet does not simply mean the ability of wireless devices to handle current Internet applications. As the following examples illustrate, the mobility that wireless devices afford makes possible a multitude of new applications. In Europe, which is well ahead of the US in the use of cell phones, these devices are being used to execute banking transactions and purchase soda from vending machines.

In the US, the technology sell-off of 2001 put a crimp in plans to introduce some of the more fanciful and futuristic wireless devices then on the drawing boards. At the same time, the terrorist attacks of September 11 demonstrated the usefulness of wireless devices such as cell phones and pagers in a crisis. BlackBerry, the always-on, instant e-mail device, was especially useful and has been highly successful in the US — despite an initial cost of about $400 and service costs of $40 a month. While retail sales in general fell dramatically following the attacks, there was a surge in sales of wireless communications devices. Apparently, people increasingly view these products as a necessity, particularly parents wishing to keep close tabs on their children during difficult times. While the technology bubble has burst, there are still numerous products on the horizon that will undoubtedly succeed and become an integral part of our everyday lives. Like most changes, however, the shift to wireless is also claiming some victims. Pay phones, for instance, may soon be a thing of the past, with revenues plummeting as callers opt for the convenience of cell phones.

Locator Functions

Federal Communications Commission (FCC) regulations require that wireless carriers provide "automatic location identification" (ALI) for their cell phone subscribers. The purpose of this feature, which makes the caller's geographical location known to the person receiving the call, is to facilitate the response of emergency workers to 911 calls. Twenty-five percent of newly activated cell phones in the US were supposed to have ALI capacity by December 2001, and 100 percent were to have it by December 2002.[1] The 2001 deadline was not met, however, and the carriers have asked for more time.

In addition to its use in emergencies, ALI promises to have many marketing applications. Retailers will be able to promote their products by sending messages to people passing by their stores: the Gap can send a message about a special sale on jeans and Starbucks can remind passersby to come in for a latte. Cell phone users will be able to summon a taxi to their precise location. Diners will be able to get descriptions of restaurants in the immediate vicinity. And there will be a proliferation of navigation systems for downloading maps and getting directions.

Thus, mobility does not just mean getting stock quotes or sports scores on the beach or on a ski lift. Rather, it offers a plethora of location-based services and information, including the ability to track the whereabouts of children, pets, workers, and equipment — getting lost may become an obsolete concept for denizens of the wireless world. International Data Corp., a market research firm, estimates the US market for locator-based services at $6 billion annually by 2005.[2]

Two new locator products in the US are Wherify and Digital Angel, for locating children and the elderly. These are watch-like devices that track an individual's location and transmit the information to a relative or guardian through a secure web site. The marketing challenge is to get the cost of such devices low enough to appeal to the general public. At present they cost about $300, with additional monthly subscription fees ranging from $10 to $40. Locator devices also raise privacy issues, since they will enable individuals to be tracked anyplace at any time.[3]

Wireless Connecting and Networking

Soon electronic devices will be able to communicate with one another without the need for wires. With new connecting technologies such as Bluetooth, HomeRF, and 802.11b, net-enabled cell phones will be able to download music or data from the web and send it to other devices instantly; at airports, travelers will be able to download the latest flight information directly onto their cell phones. According to Walter Mossberg, technology columnist at the *Wall Street Journal,* in the future, distinctions between hand-held devices will be based on whether they are "alive" or "dead." A live device will be one that can instantly connect with other networks to exchange messages and download web content.[4]

Bluetooth (named after a tenth-century Danish king who united Denmark and Norway) was developed by a number of major electronic companies, including IBM, Ericsson, Nokia, Intel, and Toshiba. It automatically "unites" electronic devices within 30 feet of each other without a cable — an operating range about the size of a room. Its most widespread application is expected to be as an interface between a headset and a cell phone, permitting hands-free calling without any wires.[5] Although high prices have slowed Bluetooth's acceptance, manufacturers hope to be able to add the technology to products for about $5 — one-third the current price.[6] The investment bank UBS Warburg estimates the market for Bluetooth at over $1 billion worldwide — about $900 million for cell phones alone by 2002.[7]

Bluetooth is now being challenged by two newer technologies, HomeRF and 802.11b. These operate at higher speeds and can cover a larger range — about 160 feet for HomeRF and about 300 feet for 802.11b. They also use more power and cost more, so Bluetooth has an advantage in small devices such as cell phones and personal digital assistants (PDAs).

Beyond Voice Communication

While voice may remain the dominant application for cell phones, text and graphic communications are also promising. In Europe and Asia, teenagers are enthralled by short message services (SMS), often sending as many as 20 to 50 text messages each day. SMS has become extremely profitable for service providers, which charge by the message. In 2001, *Business Week* magazine predicted that Europeans would send 200 billion text messages by the end of that year and one trillion by 2003.[8]

In addition, people are increasingly using their phones to download text from the Internet. In 2000, the number of wireless Internet subscribers in the US was estimated at 5 million. Analysts expect this number to reach over 84 million by 2005.[9]

Along with voice and text, cell phones have been developed with the ability to send and receive photographs. Equipped with (or capable of connecting to) digital cameras, the phones can transmit images by e-mail. The Nokia 7650, for example, has a built-in digital camera; photos can be stored on the phone's "photo album" and sent to another phone.[10]

Monitoring the Body

The new wireless technologies also open up many possibilities for monitoring an individual's vital signs and other physical phenomena. Digital Angel (described above), in addition to providing the wearer's location, can monitor his or her vital signs, report the information to others, and summon emergency aid. The Smart Train sneaker, under development by Reebok, has a built-in microprocessor that provides instant feedback on the wearer's speed, distance covered, and calories burned (a feature to measure heart rate may be added). All of this information can be transmitted by radio to a wristwatch display. In partnership with Reebok, FitSense Technology has developed technology for relaying data from the wristwatch display to a personal computer.[11]

BodyMedia, Inc., is pursuing "bioinformatics," which it describes as "the intersection of life sciences and digital technologies." Its SenseWear armband monitors the wearer's sleep patterns, blood pressure, and other vital signs and transmits them to a computer. The device can warn of medical problems and remind wearers to take their medication. Many companies are competing in this field. Hewlett-Packard has a healthcare solutions unit with 5000 employees and over $1 billion in annual sales.[12] The management consulting firm McKinsey & Co. estimates that the US market for wireless monitoring devices will reach $70 billion by 2005.[13] More sophisticated monitoring devices are being developed for healthcare professionals.

Wearable Computers

The growth in wireless gadgets is leading to the development of a group of products known as "wearables." Some of these are traditional garments designed to carry small wireless devices, such as a raincoat with pockets labeled for a PDA and a cell phone. Phillips and Levi Strauss tried to take this idea one step further by introducing a jacket with electronic gadgetry built in. The $900 garment came with an MP3 player, cell phone, headset, and remote control device, all interconnected by an electronic circuit woven into the fabric. Although this product was cumbersome and did not prove successful, it may have been a portent of things to come.[14]

According to Steven K. Feiner, a professor at Columbia University, computers are someday likely to be wired directly into our neural systems.[15] In the meantime, his laboratory is developing complicated wearable computers, including a backpack filled with equipment that sends information to a display screen on a pair of goggles; a small hand-held computer communicates by radio with the backpack. Intended for military and commercial users, these models may be adapted for consumer use as their weight and cost come down.[16]

Some devices are even being incorporated into jewelry. Casio is selling digital watches that also function as MP3 players, digital cameras, voice recorders, global positioning system receivers, and personal organizers.[17] A relative of wearables are "smart" garments. Clothing under development by Motorola, for example, can "tell" a washing machine how it should be washed.[18]

According to Edward Newman of Xybernaut Corp, "Every user of today's 200 million cellular telephones is a target for a wearable computer." Newman cites projections that the worldwide market for wearables will reach $1.2 to $1.4 billion by 2003, with about half the market being in the US.[19]

Kids Go Wireless

Many wireless gadgets have counterparts intended for children. These tend to be cheaper and less sophisticated, and come with lots of color and sound. Electronic organizers for kids generally cost under $100 and provide phone books, planners, translation services, and cameras, as well as messaging services and music. According to the consulting firm Yankee Group, by 2005, the percentage of kids aged 10 to 19 using cell phones will reach 68 percent, surpassing the adult ownership rate of 62 percent.[20] Although kid-friendly wireless devices are a $25 billion market in the US,[21] their use has become a concern in some school districts, which have banned them in schools for being disruptive.

Accessories

Accessories for wireless devices are also proliferating. These include adapters, headsets, carrying cases, antennae, charger kits, and all kinds of cables and connectors for devices not yet interconnected through wireless technology such as Bluetooth. Fashion plays a role, and designer face plates for cell phones can be purchased in colors to match one's wardrobe or adorned with cartoon characters. These products present a substantial waste problem because they may weigh more than the devices themselves and they are not standardized for different makes and models. As a result, each device has its own array of accessories, which generally cannot be used when a new phone is purchased.

Convergence versus Differentiation

The text, photo, locator, and other functions described in the previous sections exemplify the explosion now under way in new applications for wireless devices. This has resulted in two simultaneous trends: convergence and differentiation. On the one hand, wireless devices continue to be designed for specific functions such as voice communication or personal organizing. On the other hand, engineers are aiming to create devices that offer some combination these functions, along with others such as music and video, web browsing, e-mail, and short-text messaging.

Most major producers are introducing products with convergent functions. For example, Kyocera, Ericsson, Nokia, and NeoPoint are marketing PDA-equipped phones with web access. By 2004, the percentage of cell phones with Internet access is expected to rise to 94 percent, from only 2.4 percent in 1999.[22]

Handspring, a maker of PDAs, has announced a new product line called Treo — devices that combine a mobile phone, wireless e-mail, and web browsing, as well as providing the usual features of hand-held computers such as calendars and address books.[23] Another converged product, which was a big hit at the Spring 2001 Consumer Electronics Show, is the PC-Ephone. This is a Windows-based PDA with built-in phone capability. Using Bluetooth technology, the PDA communicates with a tiny phone that resembles a fat pen. This pen also acts as a pointer for the PDA's touch screen. The device fits in the palm of the hand and sells for about $1500.[24]

Research In Motion (RIM) Ltd.'s BlackBerry e-mail devices have been successful primarily because of their simplicity. Now, however, the producer is adding features such as the ability to make cell phone calls. RIM is even considering the addition of document editing, web surfing, and banking services, so the device can function "as a remote control for your office PC."[25]

Such "converged" devices are desirable to consumers because they reduce the load of equipment they have to carry around. But they present challenges for designers. Placing multiple functions on a single device can compromise the quality of individual functions and make the product complicated to use. Also, all-in-one devices are often expensive and therefore attractive mainly to business users. According to Jeff Hawkes, co-founder of Palm, Inc., "People would rather have a single device, but they won't put up with major compromises."[26]

As convergence proceeds, so too does differentiation. According to an article that appeared the *Wall Street Journal,* some people regularly carry eight or more different wireless devices at the same time. The article gives the example of an investment banker who carries a BlackBerry, a Palm Pilot PDA, a Compaq iPaq PC, two cell phones, an e-book, and two MP3 players.[27] It remains to be seen whether the demand for single-function devices that are lightweight and simple to operate will exceed the demand for more complex converged devices with combined functions. Currently, both trends seem strong and have tended to offset one another.

The waste implications of convergence versus differentiation are also unclear. Convergence could result in decreased waste, since the weight of a single product with multiple functions will be less than the combined weight of all the single-function devices it replaces. On the other hand, a converged device is likely to weigh more than any single-function product. One thing is certain, however: the rapid increase in applications for wireless devices will bring an overall increase in the amount of waste from these products.

The Throwaway Cell Phone

There have been numerous reports in the media over the past few years about the imminent introduction of disposable cell phones, but so far these have failed to materialize.[28] Several companies, however, have reportedly developed such phones and have plans to market them. Regardless of whether or not these particular products become successful, the widespread use of disposable phones is a real possibility. If this comes about, the amount of waste from cell phones would increase substantially, unless steps are taken to recover the phones for reuse or recycling.

The disposable cell phones now under development are targeted at vacationers, business travelers, travelers from abroad (who cannot use their own cell phones in the US because of incompatible technical standards), and children considered too young to use conventional cell phones. Manufacturers have not provided details on the material composition of these products, but presumably they and their power supplies will contain toxic substances similar to those found in conventional cell phones and other wireless electronic products.

The following companies have plans to market disposable cell phones:

- **Dieceland Technologies** hopes to sell its disposable cell phone, the Phone-Card-Phone, at locations such as grocery stores, fast food restaurants, bars, airports, hotels, and car rental offices.[29] It expects to offer the phone, equipped for outgoing calls only and with 60 minutes of airtime, for approximately $9.99.[30] The company claims to have received 100 million purchase orders in the US and 300 million globally.[31] Dieceland has entered into an agreement with GE Capital to market and distribute the phone through GE's Prepaid operation.

The Phone-Card-Phone is approximately two inches by three inches and about three credit cards thick. It is manufactured by printing cell phone circuitry onto a paper substrate, which is then sealed and laminated.[32] Metallic inks are used instead of real wires: the ink is printed onto the paper substrate and other components are then inserted into or fixed to the substrate surface.[33] A plastic battery case with one AAA alkaline battery slips onto one end of the phone and a reusable headset plugs into one corner.[34] GE has indicated that the Phone-Card-Phone can be returned to retailers for a refund of $2.00 to $3.00 each, but has provided no details on what it plans to do with the returned products.[35]

- **Hop-On Wireless** has developed a voice-activated wallet-sized disposable phone, for outgoing calls only, that will cost approximately $30 for 60 minutes of airtime.[36] The company expects to sell the phones at national drug stores, convenience stores, and variety stores in all major US metropolitan areas served by its network.[37] The phone consists of a biodegradable plastic handset 2.25 inches wide by 4.25 inches long by .40 inch thick that will have two buttons, "call" and "end."[38] It will have an internal antenna, an earbud/microphone, and a zinc-air battery that is expected to last three to six months.[39]

  Hop-On Wireless has indicated that consumers bringing their phones back to the place of purchase will receive a refund, but the size of the refund has not been specified.[40] The company claims it is committed to getting the phones back, from an "environmental and economic standpoint." A confusing label bearing the words "Disposable. Please Recycle" is to be attached.[41] Upon receipt of the returned phones, Hop-On Wireless plans to melt down the casing, recast it, recharge the phone with calling minutes, and send it back to the marketplace for resale.[42] Fuji Films is working with Hop-On Wireless to cross-promote its cameras and the Hop-On Wireless disposable phone as part of a "tourist" package.[43]

- **New Horizons Technologies International Inc**. describes its Cyclone phone as "the next generation disposable cell phone."[44] The phone will cost approximately $39.95, which will include 60 minutes of nationwide airtime.[45] New Horizons will offer the Cyclone nationwide early in 2002, initially through wireless service providers and later at gas stations, convenience stores, groceries, and drug stores.[46] The company also anticipates offering a "travel fun kit" for tourists featuring both a Cyclone phone and a disposable camera.[47]

  The Cyclone is equipped to make and receive calls and comes with a replaceable case.[48] It is a simplified version of a conventional cell phone, but without such features as a display screen or voice mail. It is 4.3 inches long by 2.1 inches high by 1.2 inches wide and weighs less than five ounces (including three AA alkaline batteries).[49] New Horizons has an agreement with Duracell whereby the latter will be the exclusive provider of batteries included with each phone.[50]

  Once the initial 60 minutes of airtime are depleted, purchasers of the Cyclone may either buy more airtime or return the phone to New Horizons (or participating stores) for a $5.00 rebate.[51] Returned phones will be sent for recycling; those with usable printed wiring boards will receive a new plastic case and be resold.[52] According to New Horizons, it is "encouraging people to recycle the phones, although they are priced so that they are disposable."[53]

In addition, **Telespree Communications** is developing wireless software technologies with potential applications in a variety of communication devices. Contrary to reports that the company is developing a disposable cell phone,[54] Telespree executives say they have no plans to manufacture such a product.[55]

An outstanding question is whether disposable cell phones are cost-effective for wireless carriers, which will have to add subscribers for short periods of time. Proponents believe they can be profitable for wireless carriers as well as manufacturers, especially if customers have the option of reusing their phones by adding airtime and components are reused or recycled.[56] However, in an investigative report, the *San Francisco Chronicle* described disposable cell phones as "all promise, no delivery," citing the small size of the manufacturers involved and the legal problems incurred by one of them.[57] Nevertheless, the prospect remains that some company will introduce such phones in the future, even if the products described above never make it to market or become widely used. If and when such phones do become available, it is important to ensure that reuse and recycling programs are in place. Otherwise, the additional waste they generate will become the burden of municipal waste facilities and the taxpayers who fund them.

Short-Term Phone Rentals

An alternative to disposable phones is short-term phone rentals, which at least a dozen companies are offering for international travelers. Some airports already have kiosks where arriving passengers can rent phones, or they can be obtained directly through rental companies or service providers. Rental costs are high, however: Roberts Rent-a-Phone in New York City charges $40 per week for a phone and $10 to ship it to the customer, in addition to per minute charges for incoming and outgoing calls. Calling the US from Europe costs $2.25 per minute. Some of the large US service providers are also entering the rental business, with Nextel Worldwide and AT&T's World Connect programs both offering international rental options.[58]

Kodak's Throwaway Camera: A Model for Reuse/Recycling

Introduced less than 15 years ago, single-use cameras currently produce one out of every five color negatives made by amateurs worldwide.[59] Some have predicted that the impact of the throwaway cell phone on communications will be similar to that of the single-use camera on photography.[60] But these observers are overlooking a crucial lesson from the history of single-use cameras.

When Kodak came out with out the disposable Fling in 1988, it met with an outcry from consumers and environmentalists because of the waste it would generate. In response, the company changed the camera's name to the Fun Saver and announced it would take back and recycle the product. Kodak likewise changed its marketing campaign to one that promoted a "recyclable" camera.

The end result was a camera redesigned to maximize value after recovery, a strategy Kodak has found to be extremely profitable. The company is able to reuse most of the parts, with the remainder being recycled and used as feedstock in the manufacture of new cameras. Usually, only the battery and lens need to be replaced; the rest of the camera can be reused about ten times.

Kodak reports having reused/recycled over 420 million cameras since 1990, with reuse/recycling rates of over 75 percent in the US and 60 percent worldwide.[61] Kodak, Fuji, and Konica now collect each other's cameras and exchange them for reuse and recycling. Kodak, originally chastised with a "Wastemaker Award" for the Fling, has now earned numerous environmental awards for its Fun Saver take-back program.

Kodak's program is not completely applicable to cell phones, since the company gets its cameras back from photofinishers rather than consumers, which is much easier. However, many aspects of its experience are relevant, particularly the way the product has been redesigned to maximize value at end of life. To facilitate recycling, Kodak replaced the camera welds with snap fasteners and used more-robust components to permit reuse. Kodak reports that its take-back program and focus on design for recycling captures significant savings in energy, raw materials, and labor, with new cameras using only 25 percent of the raw materials and 33 percent of the energy needed to produce the original Fling.[62]

The Challenge for Cell Phones

Initial promotion of throwaway cell phones, like that of the single-use camera, has emphasized the convenience of their disposability. Kodak, however, soon realized it would have to take back and recycle its product to make it acceptable to consumers. Now concern is mounting about the waste that disposable phones could create. In New York State, draft legislation is being circulated that would ban disposable phones from incinerators and landfills, and require sellers to take them back free of charge and reuse and recycle them.[63] In this climate, the makers of disposable cell phones are likewise beginning to talk about their products' recyclability.

The success of camera reuse and recycling indicates that this can be profitable for small, inexpensive products. In the case of disposable phones, the challenge is that they will have to be collected from consumers directly, but this is not an insurmountable problem. Take-back programs can be designed that provide consumers with economic incentives to return their used products, such as deposit/refund systems or discounts on new phones when used phones are returned.

For manufacturers, cost-effective reuse and recycling of disposable cell phones will depend on factoring end-of-life management issues into the design of their products. The challenge is to design the phones in ways that facilitate disassembly and reuse of components, and to make them from materials that are economical to recycle.

Because wireless technology is changing so rapidly, this is an opportune moment to address the waste these products create. Cell phones and other wireless products are constantly being redesigned and new ones introduced. To encourage creation of products that are easier to reuse and recycle, design criteria need to be broadened to include these goals. Designing products that generate less waste and are easier to disassemble, reuse, and recycle is a far more practical strategy than waiting for a deluge of wireless products to enter the waste stream and then searching for ways to manage this waste in an environmentally responsible manner.

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Appendix A: EPA's Draft List of PBTs Commonly Found in Hazardous Waste

PBT Chemical Name	Chemical Abstract Service (CAS) Number (A given chemical may have more than one name but only one CAS number. Use CAS numbers to search numerous databases for more information on these chemicals.)
Acenaphthene	83-32-9
Acenaphthylene	208-96-8
Anthracene	120-12-7
Antimony	7440-36-0
Arsenic	7440-38-2
Benzo(g,h,i) perylene	191-24-2
Beryllium	7440-41-7
Bis(2-ethylhexyl) phthalate [See also Di(2-ethylhexyl) phthalate (DEHP)]	117-81-7
Butylbenzyl phthalate	85-68-7
Cadmium	7440-43-9
Chloroform	67-66-3
Chromium	7440-47-3
Copper	7440-50-8
Cyanide	57-12-5
Dibutyl phthalate (DBP)	84-74-2
Di(2-ethylhexyl) phthalate (DEHP) [See also Bis(2-ethylhexyl) phthalate]	117-81-7
1,2-Dichlorobenzene	95-50-1
1,3-Dichlorobenzene	541-73-1
1,4-Dichlorobenzene	106-46-7
1,1-Dichloroethane [See also Ethylidene dichloride]	75-34-3

EPA's Draft List of PBTs Commonly Found in Hazardous Waste (continued)

Dioxins [See also Polychlorinated dibenzodioxins (PCDD)]	No CAS number has been assigned to this class of chemicals. However, individual chlorinated dioxin compounds have CAS numbers (e.g., the CAS No. for 2,3,7,8-TCDD is 17646-01-6). See http://www.epa.gov/tri/TRIdioxinguidance.pdf for more information on how dioxins are to be reported to the national Toxics Release Inventory (TRI).
Endosulfan, alpha-	959-98-8
Endosulfan, beta-	33213-65-9
Ethylidene dichloride [See also 1,1-Dichloroethane]	75-34-3
Fluoranthene	206-44-0
Fluorene	86-73-7
Heptachlor	76-44-8
Heptachlor epoxide	1024-57-3
Hexachlorobenzene (HCB)	118-74-1
Hexachloro-1,3-butadiene (Hexachlorobutadiene)	87-68-3
Hexachlorocyclohexane, gamma [See also Lindane]	58-89-9
Lead	7439-92-1
Lindane [See also Hexachlorocyclohexane, gamma]	58-89-9
Mercury	7439-97-6
Methoxychlor	72-43-5
Methyl chloroform [See also 1,1,1-Trichloroethane]	71-55-6
2-Methylnaphthalene	91-57-6
Naphthalene	91-20-3
Nickel	7440-02-0
Nitrobenzene	98-95-3
Octachlorostyrene (OCS)	29082-74-4
Pentachlorobenzene	608-93-5

EPA's Draft List of PBTs Commonly Found in Hazardous Waste (concluded)

Pentachloronitrobenzene [See also Quintozene]	82-68-8
Pentachlorophenol (PCP)	87-86-5
Phenanthrene	85-01-8
Phenol	108-95-2
Polychlorinated dibenzodioxins (PCDD) [See also Dioxins]	No CAS number has been assigned to this class of chemicals. However, individual chlorinated dioxin compounds have CAS numbers (e.g., the CAS No. for 2,3,7,8-TCDD is 17646-01-6). See http://www.epa.gov.tri/TRIdioxinguidance.pdf for more information about how dioxins are to be reported to the national Toxics Release Inventory (TRI).
Polychlorinated dibenzofurans (PCDFs)	No CAS number has been assigned to this class of chemicals. However, individual chlorinated furan compounds have CAS numbers (e.g., the CAS No. for 2,3,7,8-TCDF is 51207-31-9). See http://www.epa.gov/tri/TRIdioxinguidance.pdf more information about how PCDFs are to be reported to the TRI.
Polycyclic aromatic hydrocarbons/compounds (PAHs/PACs)	No CAS number has been assigned to this class of chemicals. However, individual PAHs have CAS numbers. (See http://www.epa.gov/tri/pac.pdf for more information about how PAHs are to be reported to the TRI.)
Pyrene	129-00-0
Quintozene [See also Pentachloronitrobenzene]	82-68-8
Selenium	7782-49-2
1,2,4,5-Tetrachlorobenzene	95-94-3
1,2,4-Trichlorobenzene	120-82-1
1,1,1-Trichloroethane [See also Methyl chloroform]	71-55-6
2,4,5-Trichlorophenol	95-95-4
2,4,6-Tris(1,1-dimethylethyl) phenol	732-26-3
Zinc	7440-66-6

Appendix B: Denmark S/D Vendor Questionnaire

5. SUBSTANCES AND MATERIALS IN THE PRODUCT

Hazardous substances	Present in the product	Not present in the product	Don't know
Arsenic and –compounds	☐	☐	☐
Beryllium oxide, BeO	☐	☐	☐
Lead and –compounds	☐	☐	☐
Brominated flame retardants	☐	☐	☐
Cadmium and –compounds	☐	☐	☐
Hexavalent chromium	☐	☐	☐
Lithium compounds	☐	☐	☐
Copper and –compounds	☐	☐	☐
Mercury and –compounds	☐	☐	☐
Nickel and –compounds	☐	☐	☐
PCB	☐	☐	☐
PVC	☐	☐	☐
Selenium	☐	☐	☐

Scarce resources

Material	Present in the product	Not present in the product	Don't know
Gold	☐	☐	☐
Palladium	☐	☐	☐
Platinum	☐	☐	☐
Silver	☐	☐	☐
Tin	☐	☐	☐
Zinc	☐	☐	☐

Is the product's packaging made from recycled materials? Fully ☐ Partly ☐ % ___ No ☐
Is the product's user's manual made from recycled paper? Fully ☐ Partly ☐ % ___ No ☐
The weight of the user's manual? ______ grams

6. DISPOSAL FRIENDLINESS / **7. DESIGN ISSUES**

Component	Easy to separate*	Not easy to separate*	Not present in the product	Component can be eliminated or made smaller	Component can be repaired or up-graded
Wire/Cord	☐	☐	☐		☐
Power supply	☐	☐	☐		☐
Electronic display	☐	☐	☐	☐	☐
Printed wire board	☐	☐	☐	☐	☐
Flame retarded plastic part	☐	☐	☐	☐	☐
House	☐	☐	☐		☐
Keyboard or touch board	☐	☐	☐		☐
Microphone	☐	☐	☐		☐
Loudspeaker	☐	☐	☐		☐
Selenium drum	☐	☐	☐	☐	☐
Mercury switch	☐	☐	☐	☐	☐
Nickel-cadmium switch	☐	☐	☐	☐	☐
NiMH battery	☐	☐	☐		☐
Lithium battery	☐	☐	☐	☐	☐
Mercury battery	☐	☐	☐	☐	☐
Regular battery	☐	☐	☐	☐	☐
Colour or toner cartridge	☐	☐	☐	☐	☐

Does the producer take back the product? Yes ☐ No ☐

*The component is easy to separate if it can be separated non-destructively with normal tools.

Appendix C: The Ericsson List of Banned and Restricted Substances

PURPOSE

The purpose is to meet laws and legislation or expected new laws and legislation due to strong trends in the countries we are operating in.

DIRECTIVE

These lists specify the chemical substances that are generally banned from Ericsson´s operations.

The substances are not to be present in the products Ericsson delivers to the market nor in products Ericsson purchases from other suppliers, and pertains to everything from electronics to furniture and other materials.

Nor shall they be present in the production processes used in fabrication of the products.

A sub-division has been made, with two lists of banned substances and another two lists of substances, which are to eventually phased out. This is to be interpreted such that

- banned substances shall under no circumstances be present, not even in low concentrations,
- restricted substances shall be phased out as soon as possible and replaced with technically and economically acceptable alternatives. This assumes that alternative solutions are actively being sought.

The focus of the ban and the restriction are on any deliberate use of the listed chemical substances.

Conversely, the ban or restriction does not apply in any cases where such a presence derives from a natural contamination, that is, an undesired presence in very small concentrations.

APPLICATION

All product managers, product design functions and purchasing functions are responsible as well as Ericsson suppliers.

The Ericsson list of banned substances (in products)

	Group of substances	Substance	Chemical name	CAS-number	Main area of use	Main risk
1	Metals	Cadmium and its compounds except in batteries and thick film pastes		Various	Pigments	Toxic
		-	Leadchromate	7758-97-6	Pigments	Bioaccummulative
		Mercury and its compounds except in electric lighting		Various	Electronic equipment.	Toxic
2	CFCs-chlorofluorocarbons	CFC 11	Trichlorofluoromethane	75-69-4	Solvents and coolants	Ozone depletion
		CFC 113	1.1.2-trichloro-1.2.2-trifluoroethane	76-13-1		
		CFC 114	Tetrafluorodichloroethane	76-14-2		
		CFC 115	Chloropentafluoroethane	76-15-3		
		CFC 12	Dichlorodifluoromethane	75-71-8		
3	HCFCs-chloroflourohydrocarbons	HCFC 22	Chlorodifluoromethane	75-45-6		
4	Brominated flame retardants	PBB - polybrominated biphenyls	Dekabromobiphenyl	13654-09-6	Plastics	Bioaccumulative
		PBDE - polybrominated diphenylethers	Pentabromodiphenylether	32534-81-9		
			Octabromodiphenylether	32536-52-0		
			Decabromodiphenylether	1163-19-5		
5	Halons-bromofluorochlorocarbons	Halon 1211	Bromodifluorochloromethane	353-59-3	Fire extinguisher	Ozone depletion
		Halon 1301	Bromotrifluoromethane	75-63-8		
		Halon 2402	Dibromotetrafluoroethane	124-73-2		
6	Chlorinated hydrocarbons	-	Carbon tetrachloride	56-23-5	Solvents	Ozone depletion
		-	Methylene chloride	75-09-2		Carcinogenic
		-	1.1.1-trichloroethane	71-55-6		Ozone depletion
		Chloroparaffins	-	63449-39-8	Lubricants, plasticisers	Bioaccumulative

The Ericsson list of banned substances (in production)

	Group of substances	Substance	Chemical name	CAS-number	Main area of use	Main risk
1	CFCs-chlorofluorocarbons	CFC 11	Trichlorofluoromethane	75-69-4	Solvents and coolants	Ozone depletion
		CFC 113	1.1.2-trichloro-1.2.2-trifluoroethane	76-13-1		
		CFC 114	Tetrafluorodichloroethane	76-14-2		
		CFC 115	Chloropentafluoroethane	76-15-3		
		CFC 12	Dichlorodifluoromethane	75-71-8		
2	HCFCs-chloroflourohydrocarbons	HCFC 22	Chlorodifluoromethane	75-45-6		
		HCFC 141 b	1.1-dichloro-1-fluoroethane	1717-00-6		
		HCFC 142 b	1-chloro-1.1-difluoroethane	75-68-3		
3	Chlorinated hydrocarbons	-	Carbon tetrachloride	56-23-5	Solvents	Ozone depletion
		-	Methylene chloride	75-09-2		Carcinogenic
		-	1.1.1-trichloroethane	71-55-6		Ozone depletion
		-	Chlorobromomethane	74-97-5		
4	Surfactants	Nonylphenolethoxylates	Nonylphenolpolyglycolethers	9016-45-9	Cleaning agents	Bioaccumulative

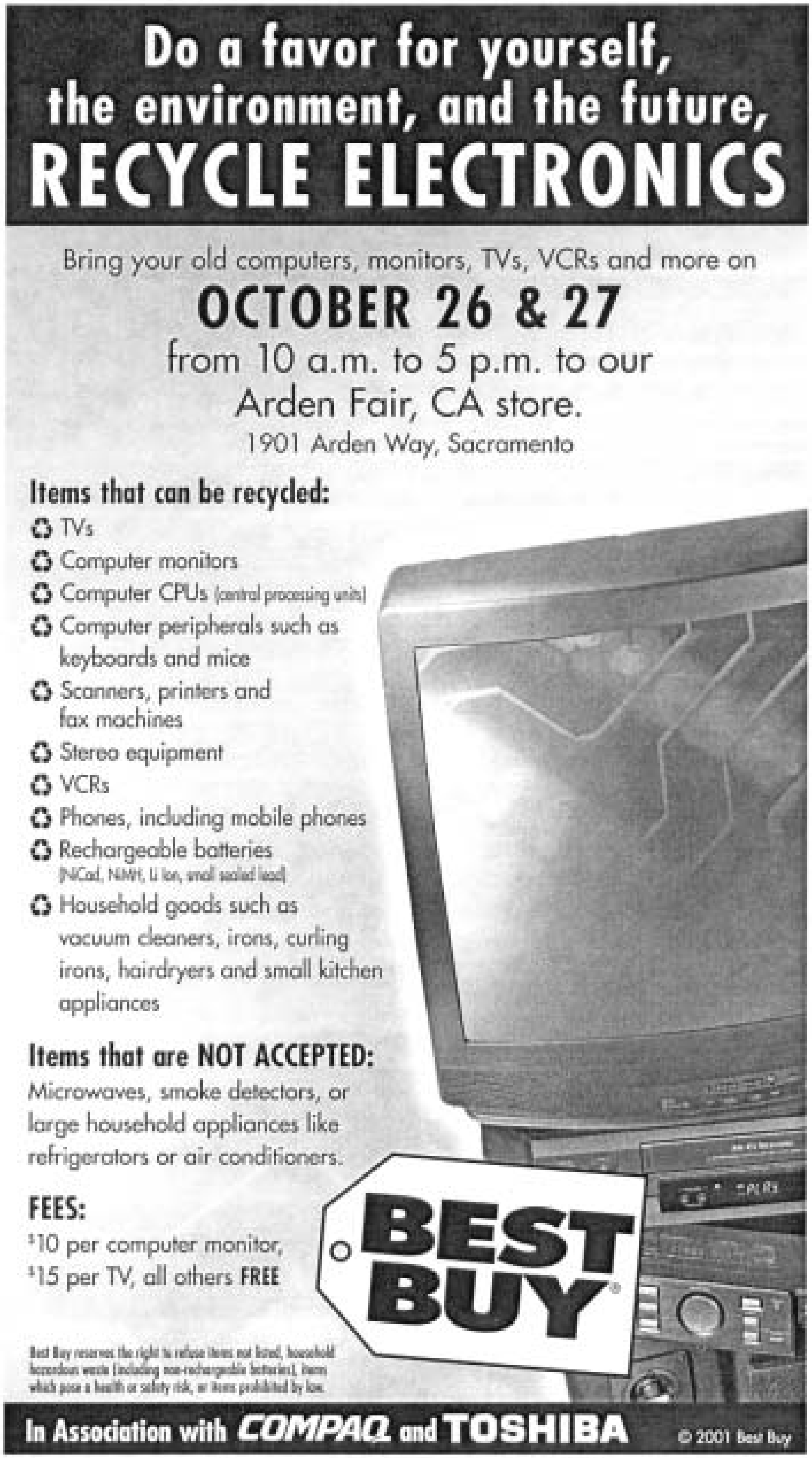
The Ericsson list of restricted substances (in products)

	Group of substances	Substance	Chemical name	CAS-number	Main area of use	Main risk
1	Metals	Antimony and its compounds		Various	Electronic equipment	Toxic
		Arsenic and its compounds except in semiconductors		Various		
		Beryllium and its compounds except in berylliumcopperalloys (<3 % Be)		Various		
		Bismuth	-	7440-69-9		Negative for recycling
		Cadmium in batteries	-	7440-43-9		Carcinogenic
		Chromium(VI)compounds	-	18540-29-9	Surface treatment	Allergenic
		Lead and its compounds	-	Various	Electronic equipment, pigments, stabilizers	Bioaccumulative
		Nickel and alloys except in steel alloys. Applicable only when in skin contact		Various	Electronic equipment	Allergenic
		Organo-tin compounds	-	Various	Stabilizers	Toxic
2	Halogenated flame retardants	TBBA, reactive or additive	Tetrabromobisphenol-A	79-94-7	Printed boards	Bioaccumulative
		All others	-	Various	Plastics	
3	Halogenated hydrocarbons	FCs - fluorocarbons	-	Various	Coolants	Global warming potential
		HCFCs- chlorofluorohydrocarbons		Various		Ozone depletion
		HFCs - fluorohydrocarbons except coolants		Various	Solvents	Global warming potential
4	Organic compounds	Azo compounds with carcinogenic amino compounds		Various	LCDs, plastics	Carcinogenic
		-	Formaldehyde	50-00-0	Preservatives	Allergenic
5	Plasticisers	Phthalates	Various	Various	Polyvinylchloride (PVC)	Bioaccumulative, ecotoxic
6	Polymers	Halogenated polymers except PVC in power cables		Various	Electronic and mechanical equipment	Corrosion and/or risk of formation of halogenated dibenzodioxins and -furans at uncontrolled fire

The Ericsson list of restricted substances (in production)

	Group of substances	Substance	Chemical name	CAS-number	Main area of use	Main risk
1	Halogenated hydrocarbons	FCs - fluorocarbons		Various	Coolants	Global warming potential
		HCFCs- chlorofluorohydrocarbons		Various		Ozone depletion
		HFCs - fluorohydrocarbons except coolants		Various	Solvents	Global warming potential
		Perchloroethylene	Tetrachloroethylene	127-18-4		Carcinogenic
		-	Trichloroethylene	79-01-6		
2	Organic compounds	EDTA	Ethylenediaminetetraaceteic acid	64-02-8	Complexing agent	Bioaccumulative

Appendix D: Advertisement for Best Buy's Take-Back Program



Appendix E: National Electronics Product Stewardship Initiative (NEPSI) Members

NATIONAL ELECTRONICS PRODUCT STEWARDSHIP INITIATIVE

Stakeholders for the NEPSI Process as of November 2001 include:

GOVERNMENTS

1. Mike Paparian (916-341-6035), Board Member, California Integrated Waste Management Board/California EPA; or Mark Kennedy (916-341-6033), Technical Advisor to Board Member Paparian, CIWMB; or Peggy Harris (916-324-7663), State Regulatory Program Division Chief Department of Toxic Substance Control, California EPA
2. Raoul Clarke (850-921-9216), Environmental Administrator, Division of Waste Management, or Jack Price (850-921-9218), Environmental Manager, Florida Department of Environmental Protection
3. Liz Christiansen, Division Administrator, Waste Management Division, Iowa Department of Natural Resources, or Merry Rankin, Iowa Department of Natural Resources
4. Gina McCarthy (617-626-1040), Assistant Secretary, Massachusetts Executive Office of Environmental Affairs, or Greg Cooper, Mass. Department of Env. Protection
5. Sherry Enzler (651-215-0263), Director, Minnesota Office of Environmental Assistance; or Maureen Hickman (651-215-0271), MOEA
6. Jim Hull (573-526-3902), Director, Solid Waste Management Program, Missouri Department of Natural Resources
7. Frank Coolick (609-633-1418) or Guy Watson, Division of Solid and Hazardous Waste, New Jersey Department of Environmental Protection
8. Jan Whitworth, (503-229-6434) or Abby Boudouris (503-229-6108), Oregon Department of Environmental Quality
9. Ted Campbell (803-737-0477), South Carolina Department of Commerce; or William Culler, Director, South Carolina Department of Health and Environmental Control, Office of Solid Waste Reduction and Recycling
10. Cullen Stephenson, Director, Solid Waste and Financial Assistance Program, Washington Department of Ecology; or Chipper Hervieux (360-407-6756), WA Dept. of Ecology
11. Sego Jackson (425-388-6490), Principal Planner, Snohomish County, WA (lead); Scott Klag (503-797-1665), Senior Planner, Metro/Portland, OR (alternate)
12. Jim Kordiak (763-788-9651), Commissioner, Solid Waste Management Coordinating Board, MN; or Anne Gelbmann (651-430-6683), SWMCB
13. Clare Lindsay (703-308-7266), U.S. Environmental Protection Agency, Office of Solid Waste; Gordon Hui (703-308-9037), USEPA-OSW
14. Bill Cass (617-367-8558), Executive Director, Northeast Waste Management Officials Association
15. Scott Cassel (978-934-4855), Director, Product Stewardship Institute, University of Massachusetts/Lowell

PRODUCERS

1. Heather Bowman (703-907-7582) or Holly Evans (703-907-7576), Electronic Industries Alliance
2. David Thompson (201-271-3486), Panasonic
3. David Isaacs (202-84-7033) or Renee St. Denis (916-785-8034), Hewlett Packard
4. Charles Dolci or Cheryl Miller, Sun
5. Patti Franco (202-962-8550) or Butch Teglas (865-521-4322), Philips
6. Mark Small, or Doug Smith, Sony

7. Mario Rufino (516-328-5610), Canon
8. Ed Nevins (973-315-5161), JVC
9. George Lundberg (503-617-5607), Epson
10. Joe Johnson, Microsoft
11. David White (972-894-4156), Nokia
12. Ted Wagner (317-587-5257), Thomson Consumer Electronics
13. Joseph Burke, Dell
14. Frank Marella (201-529-9408), Sharp
15. Jennifer Shepherd (510-661-3922), Solectron

OTHER STAKEHOLDERS

1. Lynn Rubinstein (802-254-3636), Northeast Recycling Council
2. Wayne Rifer (503-644-0294) or David Stitzhal (206-723-0528), Western Electronics Product Stewardship Initiative/Northwest Product Stewardship Council
3. Ted Smith (408-287-6707), Silicon Valley Toxics Coalition, San Jose, CA
4. Shelia Davis (415-561-6530), Materials for the Future, San Francisco, CA
5. Kate Krebs (703-683-9025), National Recycling Coalition, Alexandria, VA
6. Buddy Graham (304-372-1143), Polymer Alliance Zone of West Virginia
7. Greg Vorhees, Envirocycle
8. Bette Fishbein (212-361-2400), INFORM, New York, NY
9. Jeremiah Baumann (202-546-9707), US PIRG
10. Kevin McCarthy, or Joe Aho, Waste Management, Inc.
11. Steve Skurnac (408-998-4930), Micro Metallics
12. Lisa Collins (703-264-0042), DMC Electronics Recycling
13. Julie Rhodes (317-631-5395), Reuse Development Organization, Indianapolis, IN
14. Dustin Mirick, Best Buy, Eden Prairie, MN, or Tricia Conroy, e4 Partners
15. Alan Winik or Jim Oliver, Circuit City
16. John McNabb (781-383-6202), Clean Water Action, Boston, MA
17. Reggie Caudill, New Jersey Institute of Technology
18. Margaret Walls (202-328-5092), Resources for the Future

The Center for Clean Products and Clean Technologies at the University of Tennessee is coordinating the NEPSI Dialogue. For information contact:

Gary Davis
865-974-1835
or
Catherine Wilt
865-974-1915

University of Tennessee
Center for Clean Products and Clean Technologies

Appendix F: Product Stewardship Institute Members

PRODUCT STEWARDSHIP INSTITUTE

Sustainable Solutions to Protect Our Environment

COALITION MEMBERS AND AFFILIATE MEMBERS* OF THE PRODUCT STEWARDSHIP INSTITUTE

January 28, 2002

State Members

- California
- Florida
- Indiana
- Iowa
- Massachusetts
- Minnesota
- Missouri
- Nebraska
- New Jersey
- North Carolina
- Oregon
- Pennsylvania
- Tennessee
- South Carolina
- Utah
- Washington
- Wisconsin
- Northeast Waste Management Officials Association – representing the views of the solid waste programs from the following NEWMOA members state agencies:
    - Connecticut
    - Maine
    - New Hampshire
    - New York
    - Rhode Island
    - Vermont

Local Members

- Sonoma County Waste Management Agency, CA
- South Shore Recycling Cooperative, MA
- Hennepin County, MN
- Solid Waste Mgt Coordinating Board, MN
- Washington County, MN
- City of Greensboro, NC
- Winston-Salem/Forsyth County, NC
- Metro, OR
- King County, WA
- Seattle, WA
- Snohomish County, WA

* Coalition Members and Affiliate Members are those state and local government agencies whose chief environmental or elected official has designated an agency point contact to work with the Product Stewardship Institute and government agencies around the country on product stewardship issues. Coalition Members pay an annual membership fee for substantial input into PSI activities, whereas Affiliate Members pay no membership fee.

University of Massachusetts/Lowell • Pinanski Hall, Room 303 • One University Avenue • Lowell, MA 01854
Telephone: (978) 934-4861 • Fax: (978) 934-3050 • www.ProductStewardshipInstitute.org

Appendix G: Massachusetts Resolution on Electronics Take-Back

RESOLUTION SUPPORTING PRODUCER TAKE BACK OF CATHODE RAY TUBES, ELECTRONICS, & HOUSEHOLD HAZARDOUS PRODUCTS

Whereas, discarded electronic products, including computer monitors, televisions, computers and others, are an increasing problem for Massachusetts cities & towns, who have to deal with more than 75,000 tons of electronic waste each year, which is expected to increase to 300,000 tons each year by 2005; and

Whereas, discarded electronic products contain lead, cadmium, mercury, hexavalent chromium, polyvinyl chloride, brominated flame retardant and other toxic materials that can pose hazards to human health and the environment when landfilled or incinerated; and

Whereas, the Commonwealth of Massachusetts, on April 1, 2000, because of the toxicity of this waste, prohibited the disposal of discarded cathode ray tubes (CRT's), such as those found in televisions and computer monitors, in municipal landfills or incinerators, which has increased local government costs for recycling discarded CRT's; and,

Whereas, Massachusetts residents generate an estimated 6 pounds per year of household hazardous products, such as paint, septic cleaners, pesticides, fingernail polish, and shoe polish, and Massachusetts cities & towns spend thousands of dollars each year for collection events to divert these household hazardous products from disposal; and

Whereas, the costs incurred by Massachusetts cities and towns for disposal of products that contain toxics and are not easily recyclable, particularly electronic products and household hazardous products, are in effect unfunded mandates imposed by the producers of such products on local taxpayers; which takes funds away from other needed local government programs, such as schools, fire protection, emergency services, and police; and

Whereas, the Massachusetts *Beyond 2000 Solid Waste Master Plan* adopted December 20, 2000, commits the Executive Office of Environmental Affairs to develop a Product Stewardship Policy that will encourage or require producers to take greater responsibility for the costs of disposing of their discarded products, but this needed state policy has not yet been adopted; and

Whereas, Producer Take Back requirements, which have been adopted in many countries across the world, will shift the burden of disposal costs for electronic and household products from local taxpayers back to the producers, internalizing these costs and giving a market incentive to design products that are durable, less toxic and recyclable; and

NOW, THEREFORE, BE IT RESOLVED, that the Board of Selectmen of the Town of _____________:

1. Calls on its State Representative and State Senator to support passage of H-3154, *An act to require manufacturers to take back used cathode ray tubes*; and
2. Calls on the Legislature to develop and support legislation to require Producer Take Back for all consumer electronics products, computers, and household hazardous products; and
3. Calls on Governor Jane Swift to support H-3154, to support Producer Take Back legislation for consumer electronics, computers, and household hazardous products, to adopt a statewide Producer Take Back policy, and to adopt statewide procurement guidelines to require vendors who provide products to state and local government to take back discarded electronics and household hazardous products.

Publications and Membership

Related Publications

Leasing: A Step Toward Producer Responsibility
Bette K. Fishbein, INFORM, Inc.; Lorraine S. McGarry, Duke University, Nicholas School of the Environment; and Patricia S. Dillon, Tufts University, The Gordon Institute (2000, 75 pp., $30)

Extended Producer Responsibility: A Materials Policy for the 21st Century
Bette Fishbein; John Ehrenfeld, MIT; and John Young, Materials Efficiency Project (2000, 290 pp., $30)

Waste at Work: Prevention Strategies for the Bottom Line
John Winter and Anne Marie Alonso (1999, 105 pp., $30)

Purchasing Strategies to Prevent Waste and Save Money
National Recycling Coalition and INFORM (©1999, 40 pp.)
For more information or to purchase a copy, please contact the National Recycling Coalition at (703) 683-9025 x225, or visit their website.

Getting an "A" at Lunch: Smart Strategies to Reduce Waste in Campus Dining
David Saphire (1998, 26 pp., $30)

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