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.