S 510: Electronic Waste Recycling Promotion and Consumer Protection Act

Final Report

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EXECUTIVE SUMMARY

Introduction

The rapidly increasing number of obsolete computers, monitors, and televisions in the United States has the potential to create serious consequences for human health and environmental quality. When this electronic waste (e-waste) is placed into landfills, toxic components of this waste can enter the environment. The Electronic Waste Recycling Promotion and Consumer Protection Act (the Bill) was introduced to the United States Senate (title s. 510) in March of 2005 to encourage further study of the hazards associated with this waste and to promote an e-waste recycling program on a national level. In this report a multi-step approach is taken to examine the science behind this piece of legislation.

Electronic Waste: The Problem

The amount of electronic products being purchased in America is increasing rapidly. Correspondingly, e-waste is the fastest growing type of municipal solid waste. E-waste contains lead, mercury, and other toxins known to cause severe health problems in humans, particularly children. According to the proposed legislation we are analyzing, e-waste is defined as computer central processing units, monitors, and televisions. In addition, the term sometimes is defined to include cell phones, pagers, i-pods, and other digital devices. Even with the narrow definition used in the Bill, consumption of e-waste products is increasing rapidly, with the lifetime and relative cost of computers diminishing. Currently, many older computers are placed in storage, but eventually these units will find their way into landfills unless a better disposal solution is provided. There is currently poor access to alternate methods of disposal for most consumers. As more e-waste is placed in landfills, exposure to environmental toxins is likely to increase, resulting in elevated risks of cancer as well as increased occurrences of developmental and neurological disorders.

The Electronic Waste Recycling Promotion and Consumer Protection Act

The Bill aims to promote recycling through creating incentives for individuals and large scale recyclers. It creates a fifteen dollar tax credit for individual consumers and an eight dollar per-unit tax credit for large-scale recyclers. It also requires the Environmental Protection Agency (EPA) to analyze different methods of funding a national recycling program. If within three years these measures result in general access to recycling across the United States, the Bill makes disposing of e-waste products in landfills illegal.

The unified national recycling system created by the legislation would eliminate the need to adjust to different regulatory standards in individual states and encourage more uniform recycling practices. Currently many people do not have convenient access to recycling. The proposed legislation would attempt to change that by expanding the recycling industry through incentives, with the eventual goal of removing all e-waste from the municipal waste stream.

THE PROBLEM OF ELECTRONIC WASTE

Most people are not aware of the potential negative impact of the rapidly increasing use of computers, monitors, and televisions in the United States (see Figure 1). When these products are placed in landfills or incinerated, they pose health risks due to the hazardous materials they contain. While relatively small increases are currently occurring in the numbers placed in the municipal waste stream, these products are being purchased at a rapidly increasing rate, and many outdated computers are currently in storage in people's basements and closets (see Figure 1). If this massive amount of stored electronic waste (e-waste) were to enter the municipal waste stream, the toxins in it could result in severe negative environmental and health impacts. In addition, valuable materials from the computers would be lost due to the lack of effective recycling. E-waste constitutes only 1.5-8 percent of municipal solid waste,[1,2] yet it is accumulating at a rate three times that of other solid waste.[1,3]

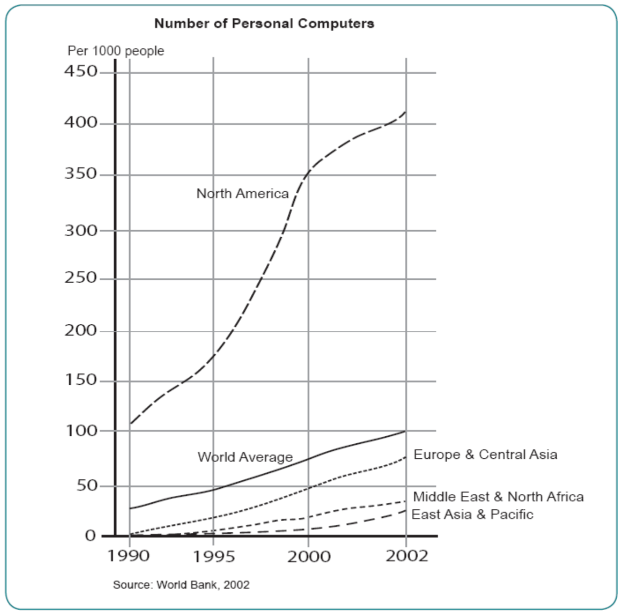


Figure 1: This figure from the World Bank (2002) shows the increasing rates of ownership of personal computers.

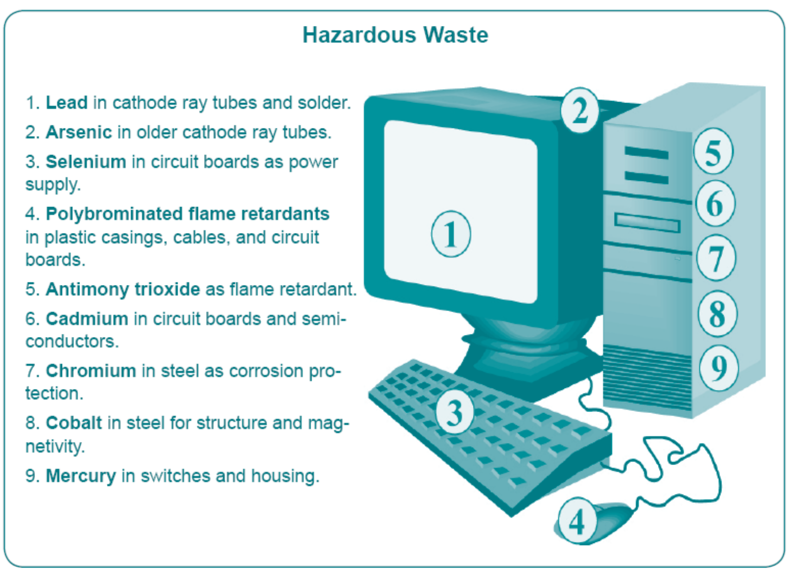


Figure 2: This figure from the Texas Senate Research Center shows the location of contaminants in a standard home computer.

Toxic Chemicals Present in E-waste

Computers and display units contain significant amounts of material that are hazardous to human health if they are not disposed of properly. Monitors and televisions constitute 40% of all lead and 70% of all heavy metals found in landfills (see Figure 2). These heavy metals and other toxins that can leach into the soil from landfills, evaporate into the air, and enter the air through incineration.[4]

Toxic Chemicals Present in E-waste: Overview and Uncertainty

Toxins in e-waste include polyvinyl chloride (PVC plastics), copper, lead, mercury, arsenic (in older models), cadmium, manganese, cobalt, gold, and iron.[3] Between 1994 and 2003, disposal of PCs resulted in 718,000 tons of lead, 287 tons of mercury, and 1,363 tons of cadmium being placed in landfills.[2] Mercury, chromium, lead, and brominated flame retardants will be discussed here as they are the greatest in quantity and are likely to cause the most adverse health effects in humans. The effect of toxins on the environment will also be considered.

In addition, there is uncertainty about the intensity of the impact of chemicals in e-waste on human health. Toxicology is not an exact science, and there is rarely universal agreement on how a given chemical substance affects human physiology. This disagreement is compounded by the fact that hazard identification tests are often conducted using mice and rats, and then extrapolated to identify human carcinogens and toxins.[5] The physical differences between rodents and humans make it difficult to establish acceptable levels of human exposure based solely on these animal studies.[5] Sometimes limited epidemiological case studies do exist, yet these studies usually provide only limited amounts of additional data. After the toxins and their effects are described, some of the uncertainties related to them are also discussed.

Toxic Chemicals Present in E-waste: Location of the Chemicals

Flame-retardants containing bromine are used in cables, plastic casing, and circuit boards. Circuit boards in a computer contain lead and cadmium.[3] Switches and flat panel screens contain mercury, and semi-conductors contain cadmium.[3]

A major source of hazardous waste in computer and television screens is cathode ray tubes (CRTs). CRTs contain lead and barium, and older CRTs contain arsenic.[6] Figure 3 illustrates a CRT. The CRT contains an electron gun that shoots electrons at high speeds to produce color images on television and computer screens.[6] The acceleration of electrons requires high voltages to accelerate the electrons, and these voltages must be insulated from the external surfaces.[6] The decelerating electrons also produce x-rays, so the casing must absorb these x-rays.[6] Lead is used in the envelope encasing this process, as well as in the panel glass screen.[6] Flat panel monitors and televisions do not use CRTs and thus do not contribute lead to the waste stream; however, these products do contain significant levels of mercury.[6]

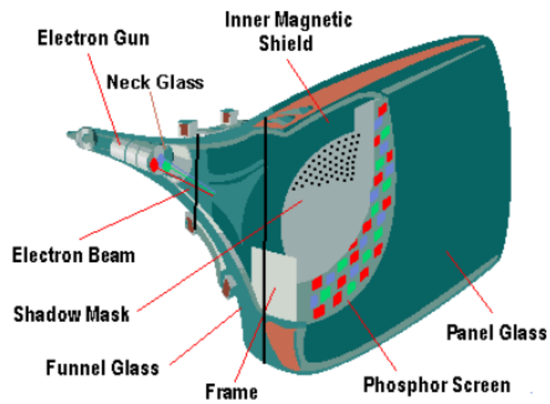


Figure 3: Illustrates a cathode ray tube (CRT), which is in computer and TV monitors. The lead in the monitors is mainly contained in the neck and the funnel glass of the CRT.[2]

Toxic Chemicals Present in E-waste: Mercury

The elemental form of mercury evaporates into the atmosphere and precipitates to the ground when it rains. In the soil, it is processed by bacteria and becomes methylmercury. This new form bioaccumulates, meaning it collects in animals' fatty tissues.[7] It begins collecting at the bottom of the aquatic food chain, and builds up in greater levels the farther up the food chain it goes. Depending on levels of exposure, the methylmercury's effects can range from mild to severe. People are most often exposed to mercury through food, particularly through eating fish and shellfish.[7] In fact, pregnant women are often advised against eating fish that could potentially contain mercury because of the damage it can do to a developing fetus. Fetuses and small children are most susceptible to mercury toxins, particularly the effects of methylmercury on the nervous system.[7] The primary health effect of methylmercury is impaired neurological development, and it can affect cognitive abilities, memory, attention, language, and fine motor and spatial skills.[7] Some symptoms are tremors, emotional changes, insomnia, headaches, disturbances in sensations, changes in nerve responses, and performance deficits on tests of cognitive function.[3] At higher exposures, mercury can cause kidney effects, respiratory failure and death.[7] It is important to stress that methylmercury exposure does not require direct exposure to the source of the mercury; eating fish that were exposed to methylmercury during their developmental stage is sufficient. [7]

Effects of methylmercury exposure on wildlife can include mortality, reduced fertility, slower growth and development and abnormal behavior that effects survival, depending on the level of exposure.[7] In addition, research indicates that the endocrine system of fish may be altered by the levels of methylmercury found in the environment.[7] The endocrine system releases hormones necessary for growth and development, meaning that young fish are unable to develop into healthy adult fish.[7]

Mercury is not listed by the EPA as a human carcinogen. However, the EPA lists existing studies of the human health effects as "inadequate."[5] Indeed, many scientists believe current permissible levels of mercury exposure are too high.[8] There are also great controversies about mercury related to method of exposure, and what happens to this element once it enters the environment or a landfill.[8]

Toxic Chemicals Present in E-waste: Lead

Lead is one of the most abundant toxic byproducts of e-waste and has many well-documented detrimental human health effects.[9] Exposure to lead can occur from contaminated drinking water and often causes damage to the brain and nervous system.[9] Lead poisoning has the greatest health effect on children, and can cause slowed growth, hearing problems, and behavior and learning problems. In adults, lead can cause reproductive problems, high blood pressure, and memory and concentration problems.[9]

The Environmental effects of lead are just as detrimental. Organisms exposed to lead have a lower chance of reproduction because of behavioral changes or physical disorders from the exposure.[9]

The toxic properties of lead are well-studied, and there is little controversy associated with the toxicity of this element. The EPA states that, "by comparison to most other environmental toxicants, the degree of uncertainty about the health effects of lead is quite low".[10] It is classified as a probable human carcinogen, which means that there is no safe level of exposure below which negative health consequences may not occur. Lead is one of the most studied of the chemicals in e-waste because of the frequency of exposure and the severe negative health effects in children.

Toxic Chemicals Present in E-waste: Chromium

Hexavalent chromium, Cr(VI), can damage DNA and has been linked to asthmatic bronchitis.[11] After entering the organism from the environment, chromium is reduced to trivalent chromium, which then binds to proteins[12] This triggers an immune system reaction that can have damaging effects on the body. All Cr(VI) compounds are potential carcinogens.[11] Health effects associated with Cr(VI) exposure include skin irritation and ulceration, asthma and respiratory irritation, perforated eardrums, kidney damage, liver damage, pulmonary congestion and edema, epigastric (upper abdomen) pain, and erosion and discoloration of the teeth.[12] The lungs, kidneys, and intestines are especially vulnerable, and if chromium lodges in tissues, its long-term action may lead to cancerous growth.[12] In some studies, chromium was reported as one of the factors of incidence of premature senility.[11]

In the environment, chromium can harm aquatic ecosystems, having negative effects on salmon and amphibian populations, and can also harm terrestrial biota.[12]

Chromium IV is generally agreed to be capable of causing cancer when inhaled; however, there is uncertainty if it is carcinogenic through the oral route of exposure.[12] Chromium III is an essential human nutrient in small doses and has a higher maximum daily exposure risk according to the EPA, meaning that it is less likely to be severely detrimental.[12]

Toxic Chemicals Present in E-waste: Brominated Flame Retardants
Brominated Flame Retardents (BFRs) are added to consumer e-waste products in an effort to reduce the risk of injury or damage from fire.[13] They are found on printed circuit boards, components such as plastic covers and cables as well as plastic covers of televisions.[13] Although less is known about BFRs than many other contaminants, research has shown that one of these flame retardants, Polybrominated Diphenylethers (PDBE) might act as an endocrine disrupter.[14] Flame retardant (Polybrominated Biphenyls or PBB) may increase cancer risk to the digestive and lymph systems.[14]

Scientists believe that once BFRs are released into the environment through landfill leachate and incineration they are concentrated in the food chain, accumulating in fatty tissues in a similar fashion to the bioaccumulation of methylmercury described above.[14]

Risk analysts are concerned about BFRs because of their persistence, bioaccumulation, and potential for toxicity in humans; however, scientific understanding of the health and environmental effects of BFRs is very limited and results from the current literature are incomplete and often conflicting.[15] Additionally, the major pathway for human BFR exposure is unknown. A report published in *Environmental Health Perspectives* stating that the "toxicology database [for BFRs] is inadequate to truly understand the risk."[16]

E-waste in Landfills

The methods humans have developed for disposing of waste are imperfect and may result in detrimental effects to the environment and humans. When e-waste is disposed of in landfills, toxins can leach into groundwater or nearby water bodies. For instance, lead can leach from landfills into drinking water supplies,[9] and mercury can leach into surrounding soils. Chromium may contaminate the environment through landfill leachate, and air contamination can occur when materials containing chromium are incinerated. Landfills and incineration are currently major exposure pathways for humans to the hazardous chemicals found in e-waste.[3] Landfills are of particular concern since currently there are few other viable methods of disposal for most consumers. They face the choice of keeping the old computer indefinitely in a closet, or placing it in a landfill.

While landfills are designed to process toxins and waste, leaking can occur in the lining, or toxins may evaporate off of leachate ponds. Leachate is the liquid formed when water percolates through the toxic substances deposited in landfills and absorbs the toxins. It pools in the bottom of the landfill and is pumped out into a nearby pond. Contaminants may also be released into the air when waste is crushed or incinerated. Municipal solid waste workers also occasionally transport contaminants on their clothing.

The basic parts of a landfill are the bottom liner system, the cells, storm water drainage system, the methane collection system, the covering and the leachate collection system (see Figure 4).[17]

Components of Landfills: Bottom Liner System

The bottom liner system separates trash and subsequent leachate from groundwater. It is the main defense in municipal waste sites to prevent toxic substances such as e-waste from environmental exposure. These are designed to be impervious to leaks. However, over time they can deteriorate and become ineffective, allowing the toxins to leak into the surrounding soil and groundwater.[17]

Components of Landfills: Cells (old and new)

Trash is stored in cells within a landfill. After a certain period of time, a cell will be covered over, and a new cell will begin above. Precipitation is allowed to percolate between cells to the bottom of a landfill, leaching toxins out of e-waste products as it descends until it reaches the impermeable layer at the bottom.[17]

Components of Landfills: Storm Water Drainage System

The storm water drainage system is designed to collect rain water that falls on a landfill to prevent flooding and environmental exposure.[17]

Components of Landfills: Leachate Collection System

The Leachate collection system collects water that has percolated through the landfill and absorbed toxic contaminants from e-waste and other hazardous materials. The contaminated leachate is then pumped out into a nearby leachate collection pond, where the contaminated water is contained. This water is still able to evaporate, however, releasing toxins into the atmosphere.[17]

Components of Landfills: Methane Collection System

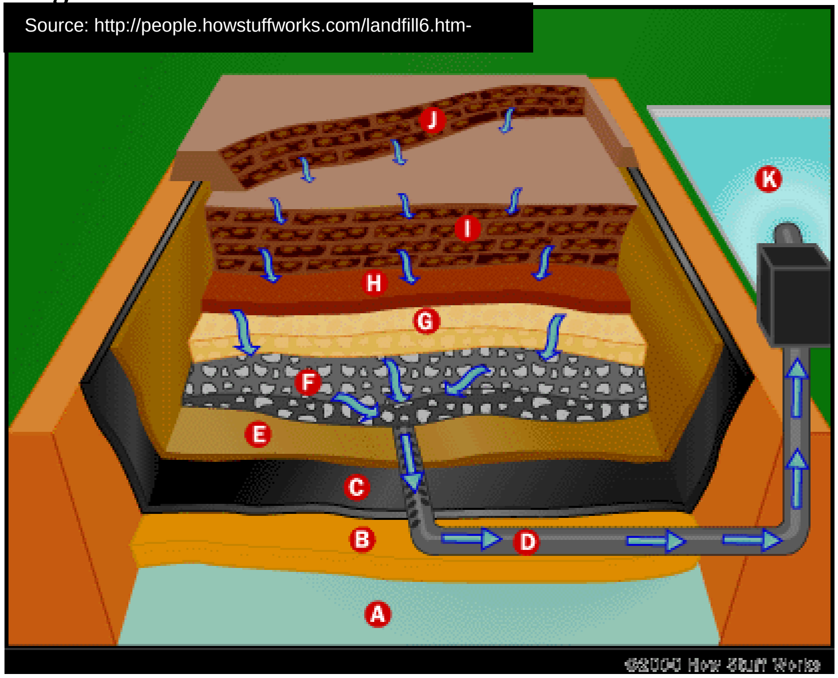
The methane collection system collects methane gas formed during the breakdown of solid waste. Methane is a highly flammable greenhouse gas, and needs to be collected to prevent risk of explosion in the presence of an ignition source. Once collected this gas can be flared off or used as a fuel to generate electrical power.[17]

Components of Landfills: Covering or Cap

The covering seals off the top of the landfill once it has been filled. This prevents atmospheric exposure to hazardous chemicals once the landfill is no longer in use and reduces the leaching of toxins due to precipitation.[17]

Overall, there are potential sources of environmental exposure to toxins present in e-waste at each stage of the landfill process. These are relatively mature technologies, and it is unlikely that new breakthroughs will drastically reduce the likelihood of exposure to contaminants from landfills. With the growing stream of e-waste projected to enter the market, the exposure risks associated with landfills are a major concern.

Diagram of a Cross-Section of a Landfill



A- Ground Water
B- Compacted Clay
C- Plastic Layer
D- Leachate Collection Pipe
E- Geotextile Mat
F- Gravel
G- Drainage Layer
H- Soil Layer
I- Old Cell
J- New Cell
K- Leachate Pond

Figure 4: This figure outlines the basic parts of a landfill. Landfills may leak into the environment, and are sometimes near water bodies.
Source: http://people.howstuffworks.com/landfill6.htm-[17]

Disposal Problems and Loss of Resources

Currently, less than 10 percent of e-waste produced is reused or recycled.[1] This means that the majority of the e-waste is disposed of in landfills, where it can eventually create health problems through human exposure. Some computer manufacturers intentionally design their products for short life cycles and employ materials and processes that hinder recycling efforts with the objective of requiring consumers to purchase new products.[18] However, in addition to hazardous materials, e-waste contains valuable resources (such as gold, copper, and aluminum) which are lost if the waste is not recycled.[19]

Lack of Domestic Incentives for Recycling/Reuse

E-waste recycling systems are currently scarce in the United States; as a result, businesses and individual consumers experience difficulty when attempting to recycle electronic devices. Consumers often face a lengthy trip to find the nearest recycler and a high cost for parting with the device when they arrive. In addition, interstate recycling (made necessary by the scarcity of programs), compounded with unclear regulation, inflates the cost of recycling.[18]

As a result of these disincentives to domestic recycling, 50-80% of the e-waste produced in the United States that does not enter landfills is exported to developing countries, where hazardous material regulations are less severe or nonexistent.[2] Unsafe recycling practices in these countries can be highly hazardous to workers, and often create even greater health hazards than disposal in landfills.[2]

SUMMARY OF THE LEGISLATION

Existing Legislation

In the U.S., four states have current regulations prohibiting discarding cathode ray tubes in landfills. Additionally, three states have general e-waste legislation, and 26 others have begun developing similar statutes. These independent programs create a variety of different laws and restrictions, the lack of uniformity of which could create additional, unnecessary costs for the electronics industry and recyclers.[20] National legislation could potentially eliminate the problems associated with state-to-state variations in e-waste regulation.

At present there is no cohesive federal legislation in the United States which regulates the disposal of electronic waste (e-waste) by households or small producers. Where businesses and other non-household producers are sufficiently large, their disposal of e-waste is regulated under hazardous waste legislation. However, the disposal of e-waste regularly falls outside the remit of the legislation, despite the fact that it contains materials such as lead, chromium, cadmium, mercury, and brominated flame retardants. Nationally, the Resource Conservation and Recovery Act (RCRA) of 1976 regulates the procedure for disposing of hazardous waste (including e-waste) by large generators, but exempts households and other small-quantity-generators (up to 220 pounds per month) from hazardous waste management requirements.[21] As such, most states allow consumers to throw e-waste into landfills as municipal solid waste (ordinary household waste).

Increasing sales of new electronics have created concern about the volume of such hazardous materials being placed in the waste stream. Such concerns have prompted individual states to take action, as well as independent campaigns and industry initiatives. At state level, significant measures have been enacted since 2001, including landmark bills in California and Maine, which opened the floodgates for state level legislation on this subject. The website for the national conference of state legislatures notes that between January and July 2005 at least 26 states introduced e-waste legislation, the same number as introduced such legislation during all of 2004.[22]

In addition, there have been a number of stewardship initiatives by major electronics manufacturers, retailers and associations, including companies such as Apple Computer, HP, Compaq and Dell. Non-profit groups have established campaigns such as the Computer Take-Back Campaign, with the aim of encouraging manufacturers to take responsibility for the full life-cycle of their products.[23] These efforts and programs have sprung from increasing knowledge of the hazards associated with placing e-waste in the municipal waste stream.

Proposed Legislation

The Electronic Waste Recycling Promotion and Consumer Protection Act (the Bill) was created out of the need for national legislation addressing the threat posed by the toxicity of e-waste to humans. It was introduced to the Senate on 3 March 2005 (title s. 510) by Senator Ron Wyden. It was read twice and referred to the Committee on Finance.[21] The Bill was separately referred to the House of Representatives on 14 November 2005, (title H.R.4316) by Ms Millender-McDonald, and it has since been referred to the sub-committee on Environment and Hazardous Materials for a period to be determined.[21]

The Bill was created to examine the dangers of toxins in e-waste and to promote an e-waste recycling program on the national level. It creates a fifteen dollar tax credit for individual consumers and an eight dollar per-unit tax credit for large-scale recyclers.[24] It also requires the Environmental Protection Agency (EPA) to analyze different methods of funding a recycling program. If the measures result in general access to recycling across the United States within three years, the Bill has the potential to make disposing of e-waste products in landfills illegal.[24]

The objective of the Bill is to encourage the formation of a national recycling program as a result of concerns about the growing tide of e-waste entering the municipal waste stream and being stored in people's homes. Switzerland, the Netherlands and Japan have enacted legislation which regulates the disposal of end-of-life equipment. The European Union is also in the process of developing regulations which would require manufacturers and importers to take back e-waste for recycling and waste management, keeping it separate from the municipal waste stream. A universally agreed upon definition of the term "e-waste" does not currently exist. In fact, determining what qualifies as e-waste is a point of contention. Many organizations employ broad definitions such as, "any appliance using an electric power supply that has reached its end-of-life."[25]

In contrast, the Bill employs a more specific designation, limiting e-waste to "any display screen or system unit."[24] This narrow definition includes central processing units of personal computers, as well as television and computer monitors, but excludes items such as cellular phones, mp3 players and personal assistant devices. Increasing e-waste is assumed to be a concern because it contains many materials that are hazardous to human health, and municipal waste sites may not satisfactorily prevent environmental exposure to these toxins. As a result, the Bill is an introductory piece of legislation that aims to remove e-waste from the municipal waste stream by encouraging recycling.

ANALYSIS OF THE PROPOSED SOLUTION

The proposed solution in the Bill is comprised of five main provisions: (1.) A recycler tax credit, (2.) consumer tax credit, (3.) Consider prohibiting the disposal of e-waste three years after enactment of the Bill, provided sufficient recycling centers area available, (4.) Recycle all e-waste generated by federal government, (5.) Study the feasibility of nationwide recycling program.[24] There are several advantages and disadvantages inherent in the solutions proposed by the Bill.

Recycler Tax Credit

This solution in the Bill (Section 4) targets the recyclers of e-waste. A recycler is defined as any eligible taxpayer who collects and recycles at least 5,000 units of e-waste.[24] The amount of the proposed credit is $8 per unit of e-waste collected.[24] The credit would take effect as soon as regulations are issued and expire three years from that date.[24]

Recycler Tax Credit: Pros and Cons
In essence, this provision creates an economic incentive for recyclers through the creation of a tax credit, with the aim of encouraging organizations to expand or create e-waste recycling businesses. This economic incentive may be quite compelling as it would amount to a minimum tax credit of $40,000 dollars for participating organizations.[26] The benefit to recyclers may be enough to actually change the behavior of some businesses and companies and lead to an increase in the number of recycling facilities and the number of computers being recycled.

The cost of the tax credit will be borne the federal government. Based on the Environmental Protection Agency's (EPA's) estimate that at least 40 million units will be recycled in 2007 alone, if all recyclers claimed the $8/unit credit, the loss in taxes to the federal government would be $320 million.[27] However, this estimate does not take into account the incentive of the tax credit, which may increase the number of units recycled significantly. The tax credit expires in three years. When it expires there may be a dip in computer recycling because there is no longer an economic incentive. The hope is that after three years, the economic benefits of recycling will eliminate the need for a government subsidy.

Consumer Tax Credit

The Consumer Tax Credit (Section 5 of the Bill) addresses e-waste disposal by individuals. A consumer is defined as any taxpayer who recycles at least one unit of e-waste; the amount of the proposed credit is $15.[24] Unlike the tax credit for recyclers, however, this is not a credit per unit but a total credit regardless of number of units recycled.[24] Like the tax credit for recyclers, this provision would take effect as soon as regulations are issued and expire three years from that date

Consumer Tax Credit: Pros and Cons
Like the Recycler Tax Credit, this solution creates a financial incentive for consumers to recycle. However, it may not be an adequate incentive for most consumers, particularly if recycling is not convenient (i.e. a consumer must deliver e-waste to a collection-point, regardless of distance).[10] Additionally, limited recycling infrastructure may make recycling unfeasible, and providing the necessary documentation to prove e-waste was recycled by a certified recycler will add an administrative burden.[10] Thus, although the Bill aims to change the behavior of individuals, the $15 tax credit may not be sufficient to offset the additional inconvenience to the consumer.

Prohibiting Disposal of E-waste

This proposed solution (in Section 6 of the Bill) targets the behavior of e-waste consumers and landfill operators. It proposes making it illegal (three years after enactment) for a solid waste operator to receive qualified e-waste, unless it is recycling the e-waste.[24] However, the implementation of this provision of the bill is left to the EPA, who must (at that point in time) determine whether the 'majority of households have sufficient access to recycling services.'[24] In order to increase this access, this section also proposes that the EPA issue guidelines that will make it easier for waste handlers to recycle e-waste. This includes classifying qualified e-waste as 'universal waste', which encourages the recycling and proper disposal of e-waste.[27]

Prohibiting Disposal of E-waste: Pros and Cons
A ban on the disposal of e-waste effectively requires recycling. This creates a clear mandate to address the problem of e-waste. The Bill also calls for EPA to issue guidelines within six months of enactment of the Bill to assist in the development of recycling procedures.[24] This may provide incentives to help interested waste handlers move toward e-waste recycling.

While this solution has the potential for many positive outcomes, it also has several disadvantages. First, it hinges on the EPA determining that the 'majority of households have sufficient access to recycling services.'[24] This requirement may not be met in three years. There is no concrete solution in the legislation to require the creation of this infrastructure. Additionally, the term 'sufficient' access is ambiguous, and may lead to a debate over interpretation.

Recycling all E-waste Generated by the Federal Government

Section 7 of the Bill addresses e-waste generated by the Federal Government. It proposes that all e-waste generated by the federal government is recycled.[24] Responsibility for ensuring this happens is assigned to the head of each executive agency.[24]

Recycling all E-waste Generated by the Federal Government: Pros and Cons
This solution provides the immediate reduction of a large source of e-waste. It creates a culture of recycling within the federal government that denotes a certain commitment to the issue, and may make future e-waste legislation more robust and amenable to

policymakers. It also provides an opportunity for the EPA to become familiar with the obstacles and impacts of e-waste recycling, and may provide a model for future programs.[28] The disadvantage of this solution is that it may impose substantial costs on taxpayers rather than product manufacturers.

Study Feasibility of Nationwide Recycling Program

Section 8 in the Bill proposes the EPA conduct a feasibility study for a nationwide recycling program that preempts any state program. The study should include an analysis of multiple approaches including (1) collection of an advanced recycling fee, (2) collection of an end-of-life fee, (3) producer responsibility, and (4) extension of a tax credit.[24] Within one year, the results of the study must be reported to Congress. Included in the report must be a cost-benefit analysis of each program, and the quantities of e-waste recycled.[24] A cost-benefit and feasibility analysis of including emerging e-waste streams (such as cell phones and personal organizational devices) in the program will also be included in the report.[24]

Study Feasibility of Nationwide Recycling Program: Pros and Cons
This approach concedes that many options are available and deserve equal consideration before taking action. It allows for a reasonable amount of time for the EPA to consider alternatives (one year), and provides the opportunity to incorporate new information while considering a plan. Additionally, if this recycling program is enacted, regulations will be nationally streamlined which may translate into a clearer mandate and fewer costs for manufactures and national recyclers. It would also extend recycling opportunities to consumers in states without an existing e-waste program.

There are, however, several disadvantages to this solution. First of all, it is not a concrete solution that can be enacted, but rather the plan to study the feasibility of a concrete action. Additionally, the nationwide program may be less stringent or effective than local or state programs.

Overall Pros and Cons of the Bill

This Bill could be a step in the right direction to addressing the growing problem of e-waste in the United States. It outlines several enforceable options through economic incentives and requires the recycling of all Federally-produced e-waste. It introduces means by which to address the problem of e-waste. It also attempts to introduce the infrastructure and information-gathering needed for a national program over the next three years. This provides time to prepare for banning the disposal of e-waste. If this ban were included in the Bill without ensuring that the necessary infrastructure was in place, it may result in the illegal dumping of e-waste.

It also provides a universal approach to e-waste. Current e-waste regulations create an uneven regulatory regime. Some states and localities have enacted legislation addressing e-waste, while others have not.[29] This makes it difficult for manufacturers to comply with regulations that vary from state to state.

Additionally, only large-quantity generators are currently regulated; this Bill expands regulation to the federal government and provides incentives for individuals and small producers of e-waste.

The Bill provides tax credit incentives without necessarily providing the needed facilities for recycling. This means that individuals who would like to recycle may not have local centers to drop off e-waste. The Bill does not include a requirement for establishing recycling centers or state where these facilities are needed.

Another possible weakness of the Bill is that it does not place the obligation of recycling on manufacturers. Although the Bill states that if a nationwide program is enacted it may make the producers of e-waste responsible for collecting, recycling or arranging for the recycling of e-waste, it currently places no onus on manufacturers to take responsibility for their product.

In a similar vein, the legislation focuses only on the endpoint of the e-waste problem. It contains no legislation or plan to look at improving the production of these products to create a less toxic product to begin with.

An additional disadvantage is that, although time is needed to address the viability of a national program, given the toxicity of e-waste, it is questionable whether the legislation deals with the issue quickly enough.

How Key Stakeholders View the Issue

How Stakeholders View the Issue: Manufactures

Manufacturers of electronic devices have a variety of opinions about e-waste. Some companies are concerned about the effects mandatory recycling programs could have on what is already considered a highly competitive industry with thin profit margins.[30] Other groups—primarily those that have already made progress implementing recycling programs—see the e-waste issue as an opportunity to gain a competitive advantage.[1] Company's such as Dell and HP have already begun programs to take back and recycle their old machines, attempting to gain an advantage over the competition. They argue that it could end up being advantageous to manufacturers to take back old machines, since they could salvage parts and materials from them and potentially save money over having to buy those things new.

How Stakeholders View the Issue: Consumers

As mentioned previously, consumers are often unaware of the possibility of recycling their e-waste, and individuals alert to the option are commonly faced with major logistical difficulties and costs.[18] Additionally, the majority of consumers remain unconscious of the negative health effects associated with current e-waste disposal practices.

Consumers ultimately bear the cost for any e-waste recycling efforts (either directly or indirectly) and may react with either reluctance or support to e-waste recycling initiatives depending on how the issue is perceived.[1] Adequate education of the problems with current e-waste disposal practices will be important to help consumers understand the dangers posed by toxins in computers that are allowed to enter the waste stream.

How Stakeholders View the Issue: Retailers

Retailers provide a key link between manufacturers and consumers. This places them in a unique position to become involved with the collection of e-waste. In fact, many retailers have already participated in recycling programs to some extent since large scale consumers are already required to recycle.[30] Some retailers wish to be drawn further into e-waste issues, others remain hesitant.

How Stakeholders View the Issue: Government

In the case of national e-waste recycling legislation, the federal government would have to oversee and possibly fund portions of the project. As a result, the government sees the problem in terms of how to best use the existing waste disposal infrastructure and how to create additional e-waste recycling services within a set time frame.[24] The federal government is also concerned that state run initiatives may create a tangle of regulations in the near future that will impede the creation of national legislation.

How Stakeholders View the Issue: Recyclers

Recyclers stand to benefit directly from any legislation mandating reprocessing of e-waste. They hope that additional support in the form of government subsidies will allow what is essentially a young industry to continue to grow.[20] Recyclers would also like to see manufacturers make computers easier to disassemble and recycle.[1] There is currently a very thin profit margin, and economies of scale in addition to incentives could increase that margin.

UNCERTAINTIES RELATED TO E-WASTE EXPOSURE

The Bill focuses on the negative human health impacts associated with certain chemical compounds contained in e-waste. As a proposed solution to these problems, it suggests that the recycling of e-waste should be increased.[24] To evaluate this approach, it is necessary to examine the scientific uncertainties surrounding several issues associated with e-waste: the health effects of toxins contained in e-waste; human exposure to toxins through e-waste disposal in landfills; and human exposure to toxins through various e-waste recycling methods. The complexities associated with each of these topics lead to differences in opinion about both the problem of e-waste disposal and the proposed solution of e-waste recycling. This is not to suggest that placing e-waste in landfills is an adequate option, merely that it is unclear exactly how detrimental it is, and if recycling is a significant improvement from a health standpoint.

Uncertainties Related to Human Exposure: Landfills

The Bill assumes that if e-waste is placed in landfills, eventually there is human exposure to the toxic components of this waste. However, there are several uncertainties related to this assumption. These include: a poor understanding of what level of the toxins in the environment can be attributed to leakage from landfills; difficulty determining what level of human exposure to these toxins is occurring as a result; and how much of this exposure can be attributed directly to the e-waste component of the landfill.

Modern landfills are designed to contain wastes without leaking into the surrounding air, water, and soil. However, a report by the EPA states that, "even the best liner and leachate collection system will ultimately fail due to natural deterioration."[31] According to the *Zero Waste* website, other studies found that 82% of surveyed landfill cells had leaks. Industry representatives have argued that no leakage of toxins occurs from landfills. For example, Fern Abrams, director of environmental policy at IPC-Association Connecting Electronics Industries, an industry group based in Illinois, stated, "It has never been shown that lead is actually leaching out of landfills."[30]

Unfortunately, directly measuring the toxins present in a landfill is not always straightforward. There are usually controversies and uncertainties about what toxins are present, where the toxins come from, and how much of each toxin is able to enter the environment [32]. Currently there is research being conducted in an attempt to quantify the amount of toxins in landfill leachate that can be linked to computers and TV monitors. An example of this research is a study conducted by Timothy Townsend, a University of Florida environmental engineer. The EPA sponsored a report by Townsend in 2004, which found that e-waste items leached lead at levels that exceed the EPA threshold for categorizing a waste as hazardous.[16] Other studies include finding out how polybrominated diphenyl ethers or PBDE, which are used as flame retardants, migrate from electronic waste into human tissue, according to the University of British Columbia.[8]

While scientists generally believe that humans are exposed to dangerous chemicals by e-waste placed in landfills, more research is needed to fully understand human exposure to e-waste toxins from landfill leaks.[12,14,16] A greater understanding of how much of the toxins in e-waste are leaving landfill sites, and of what quantities of toxins humans are actually being exposed to as a result, would help to resolve the debates related to this issue.

Uncertainties Related to Human Exposure: E-waste Recycling

The Bill assumes that e-waste recycling reduces human exposure to the toxins contained in computers. However, the wide variety of processes which could be classified as "e-waste recycling" leaves many unresolved questions related to human exposure to toxins during recycling. It is uncertain whether e-waste recycling practices eliminate all human exposure to e-waste toxins, and if they do not, what the exposure rates are. In addition, some e-waste recycling practices use strong acids that create additional chemicals that must be disposed of safely. Finally, some analysts believe that hazardous materials are left as an end result of the recycling process.[21]

Some studies report negative health effects suffered by workers that recycle e-waste utilizing the most rudimentary methods. For example, some recyclers utilize prison labor force workers to hammer apart cathode ray tubes—one of the most toxic parts of computers and televisions.[33] Research reveals that people dismantling e-waste showed significantly higher levels of all brominated flame retardants in their blood.[33] Since these toxins accumulated in human tissue, this problem can have a cumulative effect. This may indicate that toxins may be released into the environment during these processes.

Thus, various e-waste recycling methods involve a range of levels of human exposure to e-waste toxins. Therefore, scientific controversy exists about how to evaluate which recycling methods are the most beneficial for preventing adverse health effects in workers.

It is generally agreed upon in the scientific community that e-waste contains potentially toxic compounds. Furthermore, the human health effects resulting from exposure to some of these toxins, such as lead, are well understood. However, controversies still exist in relation to acceptable levels of human exposure to poorly studied e-waste toxins such as cadmium. Additionally, the exact structure of these chemicals is important. For example, chromium and mercury are much more toxic in some forms than in others, and it is unclear if e-waste disposal exposes humans to the more benign or more harmful forms of these elements.

Limited evidence currently exists demonstrating the method by which modern landfills leak into the environment. Therefore, scientists debate the risk posed to humans by disposing of e-waste in landfills.[34] Additionally, science cannot clearly determine which e-waste recycling methods are the most environmentally friendly.[35]

It is apparent from this analysis that further study is needed to assess human exposure to e-waste toxins, and the routes of exposure to these toxins. In the meantime, it seems clear that any method which reduces human exposure to the toxins in e-waste is a positive step, but that recycling may not be adequate. If the Bill were enacted, quantitative evaluations of its success could shed some light on these issues.

QUANTITATIVE MEASUREMENTS OF THE SOLUTION'S SUCCESS

The Bill attempts to address the problem of e-waste in landfills and the resulting potential for human harm caused by emission of toxic substances. To evaluate quantitative measures that could be used to evaluate the scientific success of the Bill, it is necessary to consider the ways in which stakeholders currently measure the success of e-waste programs. It is also necessary to evaluate these methods against potential alternatives, which may more accurately measure the success of recycling programs.

How E-waste Recycling Is Currently Measured

Stakeholders measure program success differently. Regulators (EPA), manufacturers, the recycling industry and consumers have diverse criteria motivating their support of, or participation in, e-waste recycling.

The EPA's "Electronics Action Plan" contains four targets (see Figure 5 below) for e-waste recycling improvement.[36] These address future e-waste flows at the manufacturer level in a broad, strategic fashion but do not consider e-waste present in landfills or the expected influx of computers and TV monitors. The EPA uses external factors including number of manufacturers educated and businesses participating in voluntary partnerships with EPA. The EPA does not quantify the amount of toxic substances eliminated due to new design guidelines.[37]

Tonnage or "mass" of e-waste inflow is one of few metrics that the recycling industry keeps data for. This data collection was established for other regulations regarding the handling of hazardous waste and is not designed to accurately measure the factors needed to manage the growing e-waste problem. For example, pure tonnage is not an indicator of toxicity. It does not take into account that the initial recycler's recovered materials are land-filled by a second recycler downstream in the process.[38] It fails to consider that the expense, energy and environmental impact of recycling material in the current system may exceed the benefits from its recovery. In addition, it does not reflect the costs associated with government subsidies often necessary to make recycling profitable.[38]

Figure 5. EPA Targets - Electronics Action Plan [36]

- Measuring amounts of priority/toxic chemicals of national concern that manufacturers have removed from products through redesign.
- Identify substances to be removed in consultation with stakeholders.
- Targets for the number of computers and TVs recycled or reused nationally.
- The nature and volume of electronics handled by states and community electronics recycling programs.

Other Metrics That May Better Measure Program Success

Adjusting the well-known and commonly-used tonnage or mass metric to incorporate factors such as value, energy used, and environmental impact provides a more comprehensive method of measuring the program's success.

This measure takes into consideration:

- quality of inflows and outflows of e-waste,
- embedded materials that must be extracted from these flows,
- value-added performance of individual recyclers,
- net energy consumption of recycling versus new manufacture, and
- environmental impact of primary versus secondary commodities.

Figure 6. Atlee & Kirchain Value-Based Recyclability Metrics[38]

Index Name	What It Measures
Value Retention Index	Ranks recovery effectiveness of recycling operation or industry
Value Added Index	Assesses performance of individual recyclers by value they add to recovered materials
Energy Index	Compares energy to reuse materials with that required to produce new materials
Environmental Impact Index	Compares environmental impact of recovering used materials with that of procuring new

As stakeholder expertise in e-waste recycling grows, more methods of evaluation become available. It may be possible to monitor toxins and heavy metals in landfill leachate pools before implementation of the Bill and again after to determine levels of air and groundwater contamination.[16] However, due to the cost and administrative burden, such a measure would currently be difficult to implement. In addition, the role of computer re-use in slowing the inflow of e-waste to landfills is noticeably absent from the Bill.[39] With federal initiatives underway to increase the use of technology in schools and rural communities, it is possible that reuse may increase.[39] If this occurs, reuse could become an important indicator.

With multiple states, the European Union, and the US Senate searching for ways to establish and implement e-waste recycling infrastructures, metrics for effectively measuring the progress of these efforts are evolving rapidly. As expertise of stakeholders grows and public education proliferates, measurements for program success can be expected to improve in accuracy and relevance.

CONCLUSION

E-waste has emerged as perhaps the most critical waste disposal issue of the twenty-first century. The problem is exacerbated by the increasing rate of computer and television production in the United States, and by the relatively short life spans of recent computer models. Additionally, the number of computers currently in storage would result in a massive influx of toxins to the municipal waste stream if they were landfilled. The presence of lead, mercury, brominated flame retardants, and chromium along with other hazardous chemicals may lead to potentially severe negative health effects if exposed to the environment through conventional disposal. Although there is some debate about the specific type and level of risk involved with each substance, there is little doubt that these hazardous chemicals will cause significant harm over the course of the twenty first century if they are not disposed of properly. The potential risks to the developing nervous systems of babies and children are particularly significant.

The Bill could be an important step toward addressing the growing problem of e-waste in the United States. It provides recycling incentives for certain types of e-waste, requires the recycling of federally-generated e-waste, and outlines a plan to address the feasibility of creating a national program.

The Bill is only a first step. It promotes studies and analysis without stating a clear commitment to implementing a national e-waste recycling plan. It does not contain concrete measures to increase the infrastructure needed for a national e-waste recycling plan. Further, the does not denote the responsibility of manufacturers for managing the e-waste created by their products. It focuses only on the end-life of e-waste, and not on the production of this waste. Pollution prevention might work in the case of e-waste by reducing the toxics that are used to manufacture electronic goods.

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