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## Personal Computers and Video Display Terminals in Buildings: Environmental Issues

Personal computers (PC's) and video display terminals (VDT's) are nearly ubiquitous in today's business environment and create environmental problems at all stages of the equipment lifecycle. During manufacture, huge amounts of material—including toxic materials—and energy are used. Packaging, distribution and use consume additional materials and energy. When no longer needed, the vast majority of computers and VDT's are not reclaimed or recycled. PC's and VDT's area major contributors to an immense and rapidly growing global electronic waste problem.

### Environmental Concerns

The main environmental concerns about PC's and VDT's are:

- Energy and materials used in manufacturing
- Health effects on manufacturing workers
- Packaging and distribution of products
- Energy and material consumption during use
- Health effects on users
- Short product life
- Disposal at the end of useful life

### Scale of the Problem

Globally, 130 million PCs are produced annually. The billionth PC was produced in 2002 and unit sales continue to increase. In the U.S. alone 600 million computers will have been sold by the end of 2005, and "of this total, 72 million will have been recycled and 150 million will be in landfills." (Betts, 2005). Although sales of PC's were thought to have peaked as recently as 2002, in the first quarter of 2005, more than 15 million computers were sold in the U.S., with sales of notebooks up 30% and desktops up 10% from the same period in 2004 (CEA, 2004).
With the emergence of India and China as significant competitors in IT and the broader availability of very inexpensive versions of PC's, the environmental problems created by widespread use of PC's will certainly increase in the near future.

### PC and VDT's – The Basics

Personal, desktops computers became generally available as a product in the early 1980's. Prior to the introduction of PC's, "computers" for workers in buildings were "dumb terminals", i.e. VDT's and keyboards connected to large centralized data processing units. PC's shifted the paradigm of computing by extending the processing power into the "terminal" and by enabling the terminals to communicate with each other, not just the central unit. That paradigm now appears to be shifting again to "thin client" computing and greater centralization of computing facilities.

Desktop and portable PC's are assembled from a variety of electronics components – integrated circuit boards, power supplies, hard drives, etc. – inside boxes of metal and plastic. "Peripheral" components such as keyboards, "mice", etc., generally are small electronic components housed in molded plastic shells. Information displays for PC's come in two general types, traditional television-like CRT's and the newer flat-panel Liquid Crystal Displays (LCD's).

**Energy and Materials Used in Manufacturing**

There are two fundamental problems with computer manufacturing: 1) material and energy intensity of the production process and 2) toxicity of the materials involved.

Materials and Energy

A UN study found that computer and screen manufacture takes at least 530 pounds of fossil fuels, 48 pounds of chemicals and 3000 pounds (1.5 tons) of water—"altogether more than the weight of a rhinoceros or a car." (UN, 2004) For a 50 pound computer /VDT combination, this makes a materials-to-product ratio of 71:1, not including packing, distribution, delivery, usage, and disposition energy and materials costs. In comparison, a car or a refrigerator requires just one or two times its weight in natural resources.

In combination with the short lifecycle of the typical computer, the very high energy intensity of computer manufacturing results in "an annual life cycle energy burden that is surprisingly high…[about] 1.3 times that of a refrigerator", (Williams, 2004) itself typically a high energy use appliance. Compared to many similarly ubiquitous appliances, life cycle energy use of a computer is much higher during manufacture (81%) than during its operating lifetime (19%) (*ibid.)*

Toxicity of Materials

"In general, computer equipment is a complicated assembly of more than 1,000 materials, many of which are highly toxic, such as chlorinated and brominated substances, toxic gases, toxic metals, biologically active materials, acids, plastics and plastic additives [which themselves contain polybrominated flame retardants, and hundreds of additives and stabilizers]." (SVTC, 1999) Although many of the components used in PC and VDT manufacture are known toxins, many of the mixtures and material combinations may have unknown health impacts (*ibid*.), as there has been little study on how such combinations interact.

The biggest known problem is lead. "Each computer ... display contains an average of 4 to 8 pounds of lead. The 315 million computers that will become obsolete between 1997 and 2004 contain a total of more than 1.2 billion pounds of lead." (SVTC, 2001, 3). Lead is a bioaccumulative toxic heavy metal that can damage the blood and nervous systems and has especially acute affects on children.

In addition to lead, PC's and VDT's contain additional toxic materials(SVTC, 2001):

- Printed circuit boards and batteries contain cadmium, a bioaccumulative toxin that damages the bones and liver.

- CRT VDT's sometimes contain barium, a toxin that causes brain swelling, muscle weakness, as well as heart, liver and spleen damage.
- PCBs, cables and plastic casings contain brominated flame-retardants, endocrine disrupters that impair normal development of all species, particularly the young
- Cables and plastic computer casings contain Poly Vinyl Chloride (PVC) and release highly toxic dioxins and furans when burned. (Hrudey, 2005)
- Switches, PCBs, and flat panel VDT's contain mercury, a bioaccumulative toxin that causes brain and kidney damage, and developmental defects in developing fetuses.
- Older capacitors and transformers contain poly chlorinated biphenyls (PCBs), probable carcinogens which cause liver damage, damage to reproductive and nervous systems. (UC Davis, 2001)

**Health Effects on Manufacturing Workers**

The ongoing dangers of computer manufacture to workers and communities are well documented. Silicon Valley, the birthplace of the industry where several high-tech-related epidemiological studies have identified clusters of miscarriages and birth defects, now has more toxic Superfund sites than anywhere else in the U.S. (Smith, 2000). Computer component production—including semiconductors, printed circuit boards, disk drives and VDT's—uses "particularly hazardous chemicals, and workers involved in chip manufacturing are now beginning to come forward and [report] cancer clusters." (SVTC,1999).

**Packaging and Distribution of Products**

Assuming an average PC/VDT combination ships in two, 200lb test corrugated cardboard boxes—the PC in a 24"x24"x16" box weighing 2.95 pounds and the VDT in a 24"x24"x24" box weighing 4.2 pounds—the 130 million systems produced annually would require nearly 929 million pounds, or 464,750 tons of cardboard (Uline, 2005).

Computer equipment is generally wrapped in plastic bags and padded with expanded polystyrene (EPS) foam (or similar) in mold or peanut foam. While comprehensive figures for the recycling rate of all PC manufacturers' packaging is not available, 10% of all EPS packaging is recycled each year (EPS.org, 2005) at a limited number of locations in the U.S. Dell's website notes that packaging redesign were projected to save "5 percent reduction in cube size and an annual 1100-ton decrease in weight of shipped corrugate and foam" (Dell, 2005) which represents less than 0.2% of the total cardboard estimated to be shipped above.

The Corrugated Packaging Alliance (2005) claims that "76% of all corrugated is currently recovered for recycling." Assuming this rate for the U.S. and approximately 60 million PCs sold here annually (projected from CEA, 2004), 107 millions pounds—53 thousand tons—of cardboard end up in landfills.

With the exception of Japans' Containers and Packaging Recycling Law and the 25 EU countries under the WEEE directive, there are no requirements that the packaging associated with PCs and VDT's be taken back by manufacturers for reuse, resulting in either the disposal of packaging materials in landfills or recycling—typically "downcycling".

PCs are a global business. Raw materials and components (many of them fossil fuel based) are shipped around the world during the manufacturing process, and then many of the finished products are shipped around the world again, consuming tremendous energy resources in the process. Most of the world's computers are assembled in the U.S., which means that most PCs used abroad must be shipped there (Terra.wire, 2005).

**Energy and Material Consumption During Use**

A typical PC and CRT combination uses approximately 145 watts of power while on, slightly more when working hard, and less while "sleeping" or when an LCD or flat panel VDT replaces a CRT VDT. With over 220 million PCs in use in the U.S. (Computer Industry Almanac, 2005) operating 8 hours per days (though many run 24/7) and 250 days per year, total energy use would be nearly 64 billion kilowatt hours. At an average annual cost of $.10/kWh, that's over $6 billion in annually energy cost of PC and VDT's alone. Adding printers, scanners, hubs, servers and other infrastructure and accessories drives up these numbers.

**Health Effects on Users**

Other than ergonomic problems, there are no proven negative health effects directly attributable to PC's and VDT's in buildings. However, critics continue to raise issues and concerns about effects on indoor air quality from off-gassing and the use of flame-retardant chemicals. A recent study "contends that potentially dangerous elements of brominated fire retardants are turning up in dust samples swiped from computers. The research indicates that the most commonly found example of these substances, widely used fire prevention compounds known as polybrominated diphenyl ethers, or PBDEs, have been found to cause health problems in lab animals.

Perhaps of greater concern is the report's contention that PBDEs, which have been shown to present reproductive and neurological risks to animals used in lab tests, remain persistent in the environment and contaminate food supplies, animals and humans. The researchers claim that the PBDE threat is greatest in North America, where women were found to have the highest levels of the chemicals present in their breast milk, and that PBDE levels are doubling in the U.S. population every two to five years." (Hines, 2004)

There are also ongoing concerns about the breast cancer with the use of CRT VDT's, ozone fumes from laser printers, various reproductive hazards (London Hazards Center, 1993), the offgassing of PVC (see the GreenIT white paper, "Cabling Hazards") and the much-debated effects of exposure to Electromagenetic Fields and Radiation (EMF/EMR). A recent report commissioned by the European Union determined that no negative health effects from EMF/EMR could be proven, but that further study was warranted (EUROPA, 2002).

**Disposal at the End of Useful Life**

While buildings last decades and HVAC and furniture systems 10 or more years, typical PC lifespans range from two to four years (Kyrnin, 2005)—these short lifecycles are driven by "upgrades" and advances in technology such new, more demanding software applications (Computer Take Back, 2004).

"Low take back rates and increasing dependence on electronics for convenience and essential business functions has become a serious problem—due to the increasingly rapid advance of technology, we are creating a stockpile of used and obsolete equipment that we have no means to deal with. The National Safety Council projects that nearly 250 million computers will become obsolete by 2007". (U.S. EPA, 2005)

In 2003 HP, Dell and IBM alone, shipped approximately 60 million PCs. It is estimated that in that same period 12 million PC's were taken of out service. (SVTC, 2003). While all three manufacturers offer "recycling" programs, the take back rate is relatively low (Spooner, 2004). For example, Dell sold 55 million machines between 1997 and 2001 but has recovered only 2.2 million (SVTC, 2003). Electronics that are not stockpiled or recycled end up in landfills, or are shipped abroad for "recycling"—"an alarming 50 to 80 per cent of American E-waste destined for "recycling" actually becomes global toxic trade." (Computer Take Back, 2004).

Dangers of Landfill Disposal

Discarded computers are hazardous waste (SVTC, 2001) and when landfilled, all the toxins identified above are in danger of release into the environment. As of 2001, consumer electronics contributed 40% of all lead found in landfills, and roughly 70% of heavy metals including mercury and cadmium—all of these mix together and have the potential to contaminate groundwater, even as they cause other environmental and public health risks. "All garbage landfills leak." (SVTC).

CNet News notes that 45 mercury-related and 21 electronics bills have been introduced at the state level in the U.S., and California, Oregon and Arkansas bills propose to add fees to the price of PCs [to prevent landfill disposal and] cover recycling costs (2005). There is currently no U.S. federal legislation on reduction of toxics in PCs or on recycling or take back policies. In California, landfilling CRTs (which are considered hazardous waste, as they are in other states, including Massachusetts, Minnesota and Maine) is prohibited. Nationally, in states without "specific landfill bans for CRTs, any non-residential CRT containing hazardous waste [including lead] is banned from landfilling…" (Computer Take Back, 2004).

Recycling

The National Safety Council reported in 1999 that only 11% of discarded computers were recycled, compared with 28% of overall municipal solid waste. Other estimates of computer recycling range from 5% to 15%, compared to a 42% rate for overall solid waste and a 70% rate for major appliances like refrigerators, washing machines, and dryers.

Unfortunately, much E-waste is not properly recycled but is exported as E-waste to China, India and other Pacific Rim countries, where much of these materials are burnt in the open air—the most dangerous method of E-waste disposal—to reclaim the most valuable constituents of

electronics, such as gold and copper (SVTC, 2001). This practice results in dangerous or fatal levels of lead, PCBs and other toxins. Even when "properly" recycled, new evidence is emerging that computer recyclers themselves have high levels of dangerous chemicals in their blood (SVTC, 1999).

According to the International Association of Electronics Recyclers, "nine countries already have corporate "take back" laws for discarded electronics--including computers in some cases--and that 22 more countries will join them within five years (CNet News, 2005). At the same time, the European Union has passed and begun implementing the Waste Electrical, Electronic Equipment Directive (WEEE), which takes effect across the European Union (EU) in 2006. Its objectives are the prevention of land filling waste electrical and electronic equipment, promoting the reuse of electrical and electronic equipment, and improving "the environmental performance of all operators involved in life cycle of electrical and electronic equipment". (KTL, 2005). The associated Restriction of Hazardous Substances Directive (RoHS) bans use of some toxic materials such as lead, cadmium, and some brominated flame-retardants (Greiner 2002) which will require the use of products that do not use such toxic materials.

## Sources for additional information

Electronic Product Recovery and Recycling (EPR2) and Electronics Recycling Summit - A series of presentations on many facets of the issues discussed in this paper.
http://www.nsc.org/ehc/epr2/2001pres.htm

U.S. EPA on eCycling http://www.epa.gov/epaoswer/hazwaste/recycle/ecycling/index.htm

Environmental News Network – Regular articles on subjects relevant to this topic.
http://www.enn.com/today.html?id=535

Silicon Valley Toxics Coalition – Information clearing house on high tech toxics issues.
http://www.svtc.org/

Consumer Reports http://www.eco-labels.org/greenconsumers/products.cfm?product=desktopcomputer&page=GovtIndustry
Green Design Computer Recycling Page – Information on green design and computing from Carnegie Mellon University. http://www.ce.cmu.edu/GreenDesign/comprec/

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