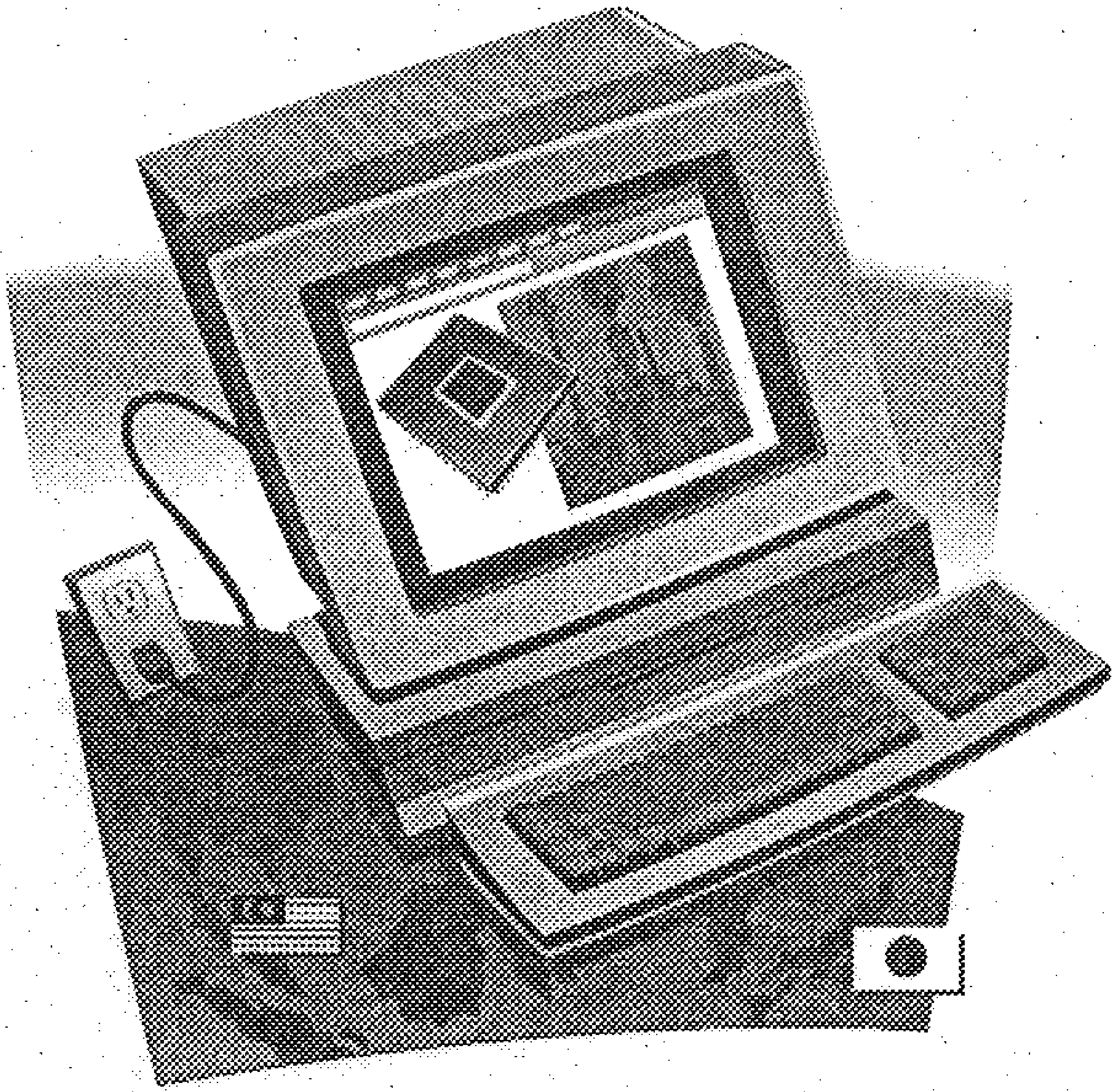
From: 'STUFF: The Secret Lives of Everyday Things,' 1997, John Ryan and Alan Durning, Northwest Environment Watch

COMPUTER



Arriving at work, I sat down at my desk and turned on my computer to check my e-mail. As I cooled off from my ride, the computer warmed up. Its screen flashed the growing number of kilobytes of memory available. But it said nothing about how many kilograms of stuff or kilowatts of energy it was using.

Electricity A 150-watt current of electricity, enough to power two incandescent light bulbs, had brought the computer to life

The United States owns 40 percent of the world's 300 million computers. Computers take 5 percent of the electricity used in American offices. In comparison, lighting uses 20–25 percent.

A gun inside my monitor sent a beam of electrons across the 20-inch display, lighting colored phosphors on the inside of the screen and a precise pattern of pixels on the outside: I had no e-mail. The display consumed about as much power as the rest of the computer's components combined. A "screen saver" popped up on my screen after a few minutes, but the images of swimming tropical fish saved no electricity: my monitor used as much power as ever. Most of the time personal computers are turned on, they are not actually being used. In addition, one-third of computers in the United States are left on at night and on weekends.

Electricity in Seattle might come from anywhere on "the grid," the complex network of power plants and transmission lines that keeps a constant flow of electrons available from all over the western United States and beyond. But my computer was probably powered by a hydroelectric dam blocking a Northwest salmon stream, and most likely of all, eastern Washington's Grand Coulee Dam, the Northwest's largest generator of electricity. When completed in 1941, Grand Coulee walled off 1,000 miles of salmon habitat in the upper Columbia River and exterminated North America's largest salmon, the legendary "June hogs," chinooks more

Turn-Ons and Turn-Offs

Many people leave computers on because they believe that turning computer equipment off and on is bad for it. In fact, turning my computer off is *good* for it. By reducing the time it generates heat and mechanical stress—the two leading causes of personal computer failure—turning my computer off at night is likely to increase its lifespan.

than five feet long and weighing 100 pounds or more. Dams have blocked more than one-third of all salmon habitat in the seven-state and one-province Columbia Basin.

Chips The beige computer that stares at me 40 hours a week consists of about 55 pounds of plastics, metals, glass, and silicon. But the heart of this fantastically intricate machine is one-fiftieth of a pound of silicon and metal formed into integrated circuits, also known as semiconductors, or simply chips.

Though the chips weigh next to nothing, making them generated more waste than making any other part of my computer. The 400-step process of making chips and covering them with millions of microscopic electrical switches began with silica mined in Washington. Silica, or silicon dioxide, the basic ingredient of sand, is the most abundant substance in the Earth's crust. The silica was heated with carbon in an Oregon plant to form carbon monoxide and 98 percent pure silicon. This silicon was heated with hydrochloric acid, then with hydrogen gas, and cooled to form a "hyperpure" silicon rod eight inches across. The crystalline

Fax à la Modem

If I used the computer's modem and my printer to read my faxes, I could have avoided buying a fax machine and the bleached, difficult-to-recycle, and annoyingly curly fax paper. If I use e-mail or print my faxes on the back sides of scrap paper, I avoid buying any new paper at all. It takes about 20 times more energy to manufacture a sheet of virgin paper than to laser-print an image onto it.

In fact, for a typical computer system, it takes at least as much energy to make a year's worth of paper as it does to run the computer for that time. Computers were supposed to herald paperless offices, but with multiple drafts and reprinting to correct every little error, computerization has probably *increased* paper—and energy—demand.

Garbage In, Garbage Out?

Waste generated in manufacturing a typical computer

Component	Product Weight (pounds)	Total Waste (pounds)	Hazardous Waste (pounds)
Chips	~0	89	7
Chip packages	1	1	0
Circuit boards	4	46	40
Monitor	50	3	2
Total	55	139	49

Does not include other computer components or waste from raw material extraction

rod was sliced into wafers less than a millimeter thick, and these were ground and chemically polished to a mirrorlike shine and trucked to the chip manufacturer in California's Silicon Valley.

The chip factory, called a wafer fab, stretched longer than two football fields and housed equipment manufactured by more than 100 companies around the world. My computer's chips—one wafer's worth—were made in "clean rooms," where only one to five particles were present in each cubic foot of air and workers wore gowns, booties, and gloves to avoid contaminating the wafers. In contrast, hospital operating rooms have 10,000 to 100,000 particles per cubic foot; outside air contains 500,000 to 1 million particles. Keeping these rooms particle free required pumping the inside air through special filters that removed fine particles. But the filters did not remove solvent vapors, some of which were toxic, from the air the workers breathed.

My silicon wafer was cleaned with acid, then heated to form a protective surface layer of silicon dioxide. Workers looking through microscopes used ultraviolet light, light-sensitive chemicals, chemical developers, patterned masks, and some of the most precise machinery ever invented to etch a pattern of minute circuits across the wafer. Further etching created holes in which high-energy machines planted phosphorus and boron, which would eventually carry electricity through my finished chips. Each of these steps was repeated several times, and after most of the steps, the chips were chemically or mechanically cleaned.

Producing the chips in my computer generated 89 pounds of waste—4,500 times the chips' own weight[1]—and used 2,800 gallons of water. State-of-the-art wafer fabs could have made the same chips, allowing me to do all the same computer tasks, with less than half the waste.

Paper-thin layers of Arizona copper were applied to each chip's surface, chemically etched (to create the wiring connecting the chip's circuits), cleaned, then oxidized for insulation. Machines applied an even thinner layer of gold to the back of each chip. After more chemical cleaning, a ship carried my wafer to Malaysia in a box of unbleached Oregon Douglas-fir pulp with shock-absorbing inserts of black polypropylene foam from Japan. The shippers would reuse the box and the foam inserts six times before recycling them.

Chemputer Age

About 700 different materials and chemicals went into manufacturing my computer; half of these were hazardous. Computer plant workers exposed to toxic chemicals have suffered lung diseases, skin rashes, and even increased rates of miscarriage. Electronics manufacturers have bestowed California's Silicon Valley (Santa Clara County) with large areas of contaminated groundwater and the highest concentration of Superfund hazardous waste sites in the United States.

Chemical use and pollution remain heavy in the industry, but computer manufacturers, at least in the United States, have made progress in reducing their toxic releases. According to EPA's Toxic Release Inventory, computer manufacturers generated 10 million pounds of toxic waste in 1990, two-thirds less than they did in 1987.

Chip Packages In a factory operating around the clock near Kuala Lumpur, Malaysian workers earning about $2 an hour and Japanese robots running on coal-fired electricity cut my wafer into hundreds of individual chips and assembled them into "packages." Each package consisted of a chip, frame, wires, and plastic housing. The packages enabled the chip to be wired to the rest of my computer.

Face-masked, gloved workers glued each chip to an etched copper frame, ran tiny wires of South African gold between the frame and the chip, and molded a plastic compound around the package. Because gold is so expensive, almost none is wasted. But because it is so expensive, gold miners can profitably mine ores that have less than one part per million of gold, leaving behind huge piles of mineral waste contaminated with toxic metals and the cyanide used to extract the gold.

Circuit Boards My completed chip packages were shipped back to the United States. There my computer manufacturer inserted them into printed circuit boards in the disk drives, keyboard, and other devices, as well as into the "motherboard," the main circuit board on which most internal components are mounted. I once watched a technician open up my computer to add more memory and was fascinated by the maze of boards with tiny solderlike wires zigzagging throughout like the streets of a miniature city. How unnerving, though, to rely so heavily on a piece of equipment whose workings I have little hope of understanding.

A Texas factory made my circuit boards. Their manufacture used more chemicals, energy, and water, and generated more hazardous waste, than the making of any other part of my computer. Machines cut boards made of copper, fiberglass, and epoxy resin to size, drilled holes in them, and cleaned them. In a process not unlike making chips, the holes were plated with a thin layer of copper and the boards etched with circuit patterns. This process generated airborne particulates, acid fumes, VOCs, and other chemical wastes.

Then the boards were plated with layers of copper and of tin-lead solder. The tin was imported from Brazil, and the lead was recovered from dead car batteries in Houston. Recycled lead meets 60 percent of U.S. demand annually. The United States consumes half the world's lead, mostly for car parts. Because lead is highly toxic and hard to dispose of legally, 90 percent of car batteries are recycled after use. Yet lead waste from electronic goods is almost never recycled. Scattered throughout the computer, lead solder is costly to recycle.

Etching and cleaning left behind a pattern of copper wiring on the circuit boards. Assembling and soldering the boards also produced lead, copper, VOCs, and solvent wastes.

Copper

The computer's 2.5 pounds of copper began as copper sulfide ore, much of it mined from the Chilean Andes for export to Asia. By law, 10 percent of Chile's copper revenues go to the Chilean military.

If the ore contained 0.9 percent copper (the global industry average), making my computer required excavating 280 pounds of ore and at least 300 pounds of other rock lying on top of the ore. The ore was pulverized, mixed with water and chemicals, and boiled to obtain pure copper. Boiling also produced sulfur dioxide (SO_2), which causes acid rain. Worldwide, the SO_2 emitted in copper production is equivalent to one-fourth the SO_2 emissions of all industrial nations.

Though my computer contains less copper than my car (40 pounds) or the pipes and wires in my house (even more), it was enough to have a big impact. Mining, crushing, grinding, and smelting the 2.5 pounds of copper required the energy equivalent of 73 gallons of gasoline. Mining and producing metals accounts for about 7 percent of global energy consumption.

Monitor When I use my computer, I don't see the chips, chip packages, and circuit boards hard at work on the inside. All I pay attention to is what appears on the screen—the wide end of a cathode-ray tube (CRT), a vacuum tube made of glass with electron guns at the far end. Like almost all computer monitors sold in the United States, my CRT was made in Japan.

A manufacturer in Osaka used various chemicals and ultraviolet light to etch a minute pattern of black stripes and then red, green, and blue phosphors on the glass for my monitor's front panel. Every color I see on my screen is actually a combination of these three colors.

The sides of the CRT were soldered to the front panel with lead oxide and heated, fusing the parts together to form a bulb. Discarded color monitors are classified as hazardous waste because of lead in the glass. By the year 2005, about 150 million personal computers will have been sent to landfills in the United States. They will occupy about 300 million cubic feet, equivalent to a football field stacked a mile high in computer trash.

Heart of Glass

A glassworks in Kobe made the glass for the front of my monitor, using mostly local sand and electricity from a power plant burning Australian coal. The glass also contained 6–10 percent each of strontium oxide (from Mexican ore), sodium oxide (from local salt), potassium oxide (from Russian ore), and barium oxide (from Chinese ore).

A different manufacturer made the CRT's sides. Its glass contained 22 percent lead oxide (to absorb x-rays generated by the CRT) from Australia and was coated with graphite made from Saudi petroleum. Because a monitor contains five different types of glass, and their compositions vary by manufacturer, the glass from old monitors is seldom recycled.

Ships, planes, and trucks brought the various computer components to the California plant where they were assembled. The finished computer was carefully boxed with polystyrene foam inserts and trucked to a suburban superstore. I ordered it over the phone; a delivery truck brought it to my office.

In all, the factories making my 55-pound computer generated 139 pounds of waste and used 7,300 gallons of water and 2,300 kilowatt-hours of energy (about one-fourth the energy the computer would use over its four-year lifetime). State-of-the-art factories could have made the same computer with half to two-thirds less waste. And different computers—with flat-panel displays (like those in laptop computers) instead of today's big vacuum tube monitors, for example—could have been made with even less waste.

Plastic? Tusk, Tusk

My computer was enclosed in a shell of ABS (acrylonitrile-butadiene-styrene) plastic. It was mostly Saudi Arabian oil, refined near Los Angeles. A nearby chemical plant turned the oil, along with benzene (from Wyoming coal), ammonia (from Texas natural gas), heat, catalysts, and chemicals, into the ABS ingredients. These ingredients were mixed into small pellets and injected under heat and pressure into a mold. They fused together, taking the basic shape of my computer.

Plastic has a deservedly poor environmental reputation, but it began as an environmental good guy. In 1868, during a severe shortage of tusks, a New England manufacturer of ivory billiard balls offered a $10,000 prize to anyone who could come up with a suitable replacement for ivory. A few years later, a printer from Albany, New York, won the prize with a product he called celluloid.

The world's first plastic, celluloid would later be used for (even synonymous with) motion-picture film. Yet when a British scientist had invented the substance in 1850, he deemed it useless; he gladly sold the patent rights to the American printer.

The computer industry thrives on the rapid adoption of new technologies and resists change much less than older industries. If nudged by governments and consumers, the computer industry could apply its technical expertise toward cleaning up its own act—and fast.

I stepped out to grab some lunch. I left my computer on.

What to Do?

- Print less often. Send e-mail instead of faxes, and print on scrap paper when you can.
- Turn off your computer, or at least your screen, whenever you're not using it.
- Choose the most power-saving settings in your computer's setup. Look for EPA's Energy Star logo if you buy new equipment.
- If you need to upgrade your computer, have new memory or circuit boards added rather than replacing the whole thing.
- If you need a new computer altogether, refurbish a used one or buy a laptop, before buying a new desktop. Laptop computers weigh about one-tenth as much as desktop computers and require about one-third the electricity.