# Eating Computers Considered Harmful

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## Abstract
Contemporary computing devices contain a concoction of numerous hazardous materials. Though users are more or less protected from these substances, recycling and landfilling reintroduce them to the biosphere where they may be ingested by people. This paper calls on HCI researchers to consider these corporal interactions with computers and critiques HCI's existing responses to the e-waste problem. We propose that whether one would consider eating a particular electronic component offers a surprisingly useful heuristic for whether we ought to be producing it on mass with vanishingly short lifespans. We hypothesize that the adoption of this heuristic might affect user behaviour and present a diet plan for users who wish to take responsibility for their own e-waste by eating it. Finally we propose an alternative direction for HCI researchers to design and advocate for those affected by the material properties of e-waste.

## Author Keywords
e-waste; toxicity; recipe ideas.

## CCS Concepts
**•Human-centered computing → HCI theory, concepts and models; •Hardware → Impact on the environment;** Aging of circuits and systems;

## Introduction

*Take a deep breath... Count to 5... Exhale...*

"That computer ... did you know that it contains more than a thousand different kinds of materials, including toxic gases, toxic metals (such as cadmium, lead, and mercury), acids, plastics, chlorinated and brominated substances, and other additives?" [20, p. 3]

Feels good right? What if I told you that you probably just inhaled a tiny bit of your computer? What if I said some of these bits are toxic or carcinogenic? What if I told you some of these materials will accumulate in your body, that they are a part of you from now until you die? Still feeling relaxed?

This is a paper about the harms of human-computer ingestion; or, colloquially, eating computers.

You are probably thinking that no one in their right mind would eat a computer, but you are wrong. You have already eaten a computer. You are probably eating a computer right now. Perhaps a more accurate description might be that you have ingested materials that used to be a computer. This might be fine if computers contained fewer toxic compounds, in reality they are more densely packed with toxic materials than almost any other significant category of waste we produce. E-waste makes up a relatively small fraction of the total waste stream but by some estimates it accounts for almost half of the heavy metals municipal landfills [15, p. 2], not to mention countless other materials that are bad for your health.

But why are we creating such materially toxic artefacts in the first place? And why are we disposing of these goods after fewer and fewer years? In this paper we borrow William McDonough and Michael Braungart's critique of industrial practices in their classic; *Cradle to Cradle* [20], and introduce this as a critical intervention in HCI's discourse on e-waste.

Existing literature is stuck in the reduce/reuse/recycle paradigm of eco-friendliness. These practices do not keep people and natural systems safe from the corporal effects of e-waste, rather, to paraphrase this paper's key theoretical text; they merely keep us from being poisoned too quickly [20, p. 18].

The cycles through which e-waste comes to interact with our bodies are too large to see, especially in richer parts of the world. But they exist. We are already eating our computers. Our methodology then is to short-circuit these larger cycles that are already happening by discovering how much e-waste the first author can eat without significantly endangering himself.

This paper offers a critical intervention. We put forward the position that, *whether one would eat an electronic device offers a surprisingly useful heuristic as to whether we ought to produce it on mass with vanishingly short lifespans.* We present our findings in the form of a diet plan for those wishing to take responsibility for their own e-waste.

## Harms and HARMS!

This paper is part of a rich tradition in computer science of considering things to be harmful.

Edsger Dijkstra wrote the seminal paper in 1968, where he considered the harms of the "go to statement" [10]. This tradition was inherited by HCI in 1982 when Halasz and Moran considered the harms of analogy [14]. Since then many things, including human-centered design [21], the rainbow colour map [1], usability evaluation [12] and ethnography [7], have been considered harmful by HCI researchers, not to mention countless more in computer science more generally.

All of these harms are negligible when compared to eating computers. Eating a computer may well be *the worst* thing you could do with a computer. Nonetheless it serves a critical purpose in this case. We mean to critique the prevailing crade-to-grave paradigm in industrial electronics, to draw attention to the effects of these devices on our bodies outside the conditions of "use" and to offer the discursive tools for HCI to engage with these corporal interactions. As Greenberg and Buxton note, "considered harmful" has come to "signal a critical essay that advocates change" [12, p. 111]. This too is the goal of our paper.

## The Use and Disuse of Computers

We call on HCI researchers to consider how electronic devices interact with human bodies after their stated lifespan.

"You wanted to use a computer but somehow you have become party to a process of waste and distruction" [20, p. 4]

HCI has focussed almost exclusively on the human-computer interactions which occur during the relatively short "functional lifespan" of our electronic devices. But these devices continue to interact with our bodies long after they have ceased to function and have been "thrown away".

The problem begins with "away". It is a convenient fiction. As McDonough and Braungart quip, "in planetary terms, we're all downstream" [20, p. 127]. The best we can hope for is that the distance between us and a very large pile of e-waste is "far".

HCI's primary concern is with the *use* of technological artefacts. Accordingly, the "user" is foundational to its theory and rhetoric [23]. But what of the expansive period of *disuse* that dwarfs the functional lifespans of electronic components? What of the countless "disusers" who are affected by the material properties of our devices once they are discarded? HCI is failing to advocate for, and to design for these people.

An example helps to illustrate the point; I am writing this paper on a computer, in this instance I am the user and as such my needs have been carefully considered by its designers. It is truly a pleasure to use. Even though this computer is packed full of toxic substances, I am reasonably well protected from them. But my computer and others like it are used for only three to four years before things begin to break or users decide to upgrade. If all goes well, it will be taken to an e-waste recycling service. Here, some of its more valuable materials will be rescued if they occur in high enough quantities; much will be too impure or too cheap to recycle. Some may be shipped overseas, some may be buried or burned. Eventually, through leaching, burning or imperfect recycling practices, these materials will make their way into the soil, the water or the air. They will again become *bioavailable*, whether through the food we eat, the water we drink or the air we breathe. HCI has little to say about these corporal interactions with technology. But why not? Why can't we design for disusers as well as users?

## Conceptualising E-Waste

Industry figures and environmental groups began raising concerns about the ecological effects of e-waste in the early 2000s [17]. One highly influential report was *Exporting Harm*, published by the Basel Action Network in 2002 [22]. This report presents e-waste as a problem "of crisis proportions" citing the hazardous concoction of materials present in electronic devices and the alarming rates of obsolescence. But the central claim of the report is that in large part our e-waste is exported to developing countries under the pretence of "recycling".

These claims were further endorsed in a United Nations report; *E-waste, the hidden side of IT equipment's manufacturing and use*, published in 2005 [24]. It too addresses the numerous hazards posed by e-waste and raises concerns about "rich countries, dumping their old devices in developing countries" [24]. Both have been heavily cited in the academic literature on the subject [17, p. 150]. They have shaped the dominant narrative on e-waste; one characterised by “developed” countries of the “global north” dumping waste in “developing” countries of the “global south”. This position is well argued in Hull’s paper “Poisoning the Poor for Profit” [15]. Material is often exported to countries where it can be more cheaply recycled, countries which sometimes lack facilities to recycle or dispose of the material safely. “Adults and children use archaic reclamation techniques... which routinely expose them to some of the most toxic compounds on earth” [15, p. 3].

There is also a “minority” position that questions the standard e-waste narrative. Lepawsky for example claims that e-waste trade is predominately characterised by regional interactions and that waste from “developed” to “developing” countries makes up “less that 1% of total trade” [17, p. 148]. He also notes that the authors of *Exporting Harm* have retracted some of their claims on this front [17, p. 150].

“Eco-efficiency is an outwardly admireable, even noble, concept, but it is not a strategy for success over the long term, because it does not reach deep enough. It works within the same system that caused the problem in the first place, merely slowing it down.” [20, p. 61–62]

Researchers ought to be wary of analyses like this which take trade data at face value. Investigative journalists have found examples illicit export [13] which offer reason enough to distrust official figures. However we should also be wary of reductive categories like “developed” and “developing” that allow researchers to play the saviour. Cooper and Bowers have already identified this interventionist streak in HCI research, which exoticises users and establishes the remit of HCI to “rescue” them [6].

Regardless of the true scale of the e-waste export problem, it is clear that the health costs of electronic devices are predominately externalised from users to disusers. Effects increase the closer one is to waste and recycling services.

## HCI on E-Waste

Since *Exporting Harm* raised the issue of e-waste in public discourse a number of HCI researchers have addressed this challenge in papers and projects.

Some in HCI have proposed “creative reuse” and “maker culture” as a solution to the e-waste problem e.g. [28][9][19]. These papers present numerous encouraging examples of electronic devices rescued from the incinerator by thrifty, creative makers. Roedl et al. [23] note that “the maker” has been central to HCI’s discussion of sustainability, but argue that the maker’s agency is curtailed by social structures more than HCI’s optimistic characterisation suggests.

Lodato and Loi [18] propose “love” as a framing device through which to engage with e-waste. Thomas et al.’s heartfelt design fiction/letter written from the perspective of a two and a half year old computer, “I am more than the sum of my parts” [27], operates in a related manner. Though the authors do not explicity frame the work around love, the sweet and melancholic tone of the work addresses emotions rather than rational faculties;

> I’m still the same computer you gleefully unboxed two and a half years ago... Let’s not end this prematurely. Let’s stay together [27].

These responses fit into the broader reduce/reuse/recycle paradigm in waste management. Creative reuse solutions encourage makers to take on the possibly hazardous work of opening up and repurposing old electronics. “Love” responses ask users to resist obsolescence; to reduce their waste by using their devices for longer or if all else fails to ensure the parts are recycled responsibly. McDonough and Braungart derisively call this “the less bad approach” [20] because it fails to challenge the prevailing cradle-to-grave paradigm in industrial manufacturing. It fails to question why our devices must be so toxic in the first place. It celebrates eight years of functional use before an eternity in landfill because it might have been fewer. In short, these reponses only barely slow the flow of toxic e-waste into our bodies; some recycling practices may even accelerate the process.

## E-Waste equals food

In challenging the cradle-to-grave mentality, McDonough and Braungart proclaim that nature has no concept of waste [20, p. 92]. “Waste equals food!” We are determined to interpret this claim literally.[1] As we stated in the introduction to this paper; you have already eaten a computer. The difficulty then is that the pace of this process is so achingly slow as to be invisible. We propose to short-circuit this cycle; to go straight to the source, as it were.

HCI has been more or less silent on the topic of eating computers. Even Brueggemann et al. [3], who make early strides in this regard by licking interfaces, note that gustatory exploration has been largely absent from HCI research. While there has been some discussion in HCI with regard to food and computers [16], this has taken the form of a techno-positivist practice, augmenting our experience of eating with digital technologies.

The largest body of research on human-computer ingestion comes from epidemiological research in regions in the vicinity of e-waste dumps or recycling sites. Fu et al. [11] found that rice grown near an e-waste recycling facility in southeast China contained above average levels of a range of heavy metals; As, Cd, Hg and Pb. Their analysis showed that these were likely ingested by the local population sometimes at above tolerable daily levels. Zheng et al. [29] study heavy metals Cd, Pb, Cu, Zn, and Ni in another region near an e-waste area. The authors found that exposure to these heavy metals through rice, vegetables and dust presented the greatest risk for adults in the region. Song and Li [25] review the field of research on the health impacts of e-waste in China. They found that ingestion is a significant way humans absorb toxins from e-waste. The heavy metals reviewed affected “behavior and learning abilities” and could cause “liver damage... lung cancer and kidney damage” [25, p. 450]. The authors noted that due to bioaccumulation exposure is accordingly concentrated “when people ingest meat”, which is higher on the food chain. Chan et al. [4] when measuring the impact of dioxins from the burning of e-waste also found that meat consumption is a significant factor for these chemicals. They also demonstrate that these dioxins can be passed to the next generation through breastfeeding.

In the language of McDonough and Braungart, electronic devices are a “product plus”; you just wanted the laptop to scroll facebook and maybe organise your calendar, you didn’t want the toxic bits that will slowly poison the biosphere and everyone you know with it. Reducing, reusing and recycling are insufficient responses to this challenge; we need to fundamentally rethink manufacturing processes.

If we were to offer you this toxic concoction to eat you would rightly decline; why not adopt this as a heuristic? If you would not eat it yourself, why feed these materials into the soil; they will reach you eventually.

## E-Waste Not E-Want Not

What if we banned the disposal of e-waste? Moreover, what if we mandated that old electronic devices must be eaten? Picture a world where users were forced to eat their old smartphone before a new one could be bought; how much might the desire for a new iPhone diminish if the old one were to end up in your muesli?

[1] In reality McDonough and Braungart are clear that biological and technical material cycles must be kept separate. *They do not endorse eating e-waste.* [20, p. 104-5].

In an well worn statistic, at the height of the iPhone's success, 1.5 million units were sold with 77% going to people who already owned an iPhone [8]. This culture of obsolescence is a broader trend than Apple's customerbase. In the 1990s an average user would retain a mobile phone for three to four years, by 2010 this had reduced by more than half to just 18 months [8]. A similar claim is made of computers which dropped from four to six years of use in 1997 to just two years in 2005 [26, p. 348].

What if consumers were forced to eat their e-waste? We predict this would dramatically reduce the desireability of new products and counteract "psychological obsolescence" (see [26]), especially for those products containing toxic materials. Consumers would likely put off the decision to upgrade until absolutely necessary, furthermore they would demand that companies used fewer toxic materials in their devices, that they were made safe.

Forced e-waste consumption may be unrealistic but as we have already shown, we are already eating our electronic devices. Why then, should we not demand the same protections? Why should we not demand that toxic materials are removed from our devices?

## HCI: Human Computer Ingestion

In this section we offer a diet plan for those hypothetical consumers forced to eat their e-waste. We present a set of recipe ideas that will have you eating your way to a new computer in no time. The diet focusses on healthy alternatives to some of the more toxic components in your average computer and it even tastes great!

## Monday

Get the week off to a good start with our tongue-tingling toasted muesli (Figure 1). This meal is packed full of goodness, with pumpkin seeds, almonds, dried fruit and insulated copper wires. Get your dose of brominated fire-retardants along with a decent helping of copper.

**Figure 1:** Toasted muesli with almonds, insulated copper wires, bolts and banana. Serve with milk or yoghurt, and if you're feeling naughty, a dollop of thermal grease.

Copper is the perfect ingredient for connecting various meal components and plastic insulation maintains freshness.

Note: if tongue-tingling lasts longer than four hours seek medical attention.

**Figure 2:** Platter of fresh peaches, crunchy soldering headers, raw almonds, brown rice crackers and a 555 timer chip.

**Figure 3:** Roasted vegetable and quinoa salad with a side of fresh kale and a full rack of resistors.

## Tuesday

Tuesday's meal focusses on light, fiber rich foods and prototyping components (Figure 2). The phosphor bronze headers perfectly complement the salty crackers. The meal also includes an integrated circuit (IC); a bite-sized computer made from a silicon wafer (delicious) embedded in a thin coating of ceramic or polymer plastic. The wafer is baked in an oven with arsenic and boron for semiconductive properties.

We use the 555 timer chip; one of the most abundant integrated circuits (ICs) ever produced, but any 7400-series IC can be used in its place.

## Wednesday

A hearty meal is the perfect antidote to midweek blues. This one is a sensation. We stack oven roasted vegetables over a bed of quinoa and a side of iron rich, cruncy kale. The real hero of this dish is a sumtuous full rack of resistors.

We used 10k ohm in our version but you can use what ever is available at your local electronics market. These can be barbequed, smoked or served raw with a drizzle of lemon juice.

**Figure 4:** Avo toast. Wholemeal sourdough bread with baby lettuce, red LED lights and spiced avocado topped with a ceramic resonator.

## Thursday

Our take on avocado toast combines fresh salad ingredients with the best local sourdough you can find (Figure 4). LED lights brighten this dish while the acidity of the spanish onion and the ceramic resonator really cut through the richness of the avocado. Meal components are syncronised to 16MHz by the ceramic resonator, a sure fire way to keep your day running smoothly.

Tip: If you want to make your own bread, solder your dough to the pan for better heat convection.

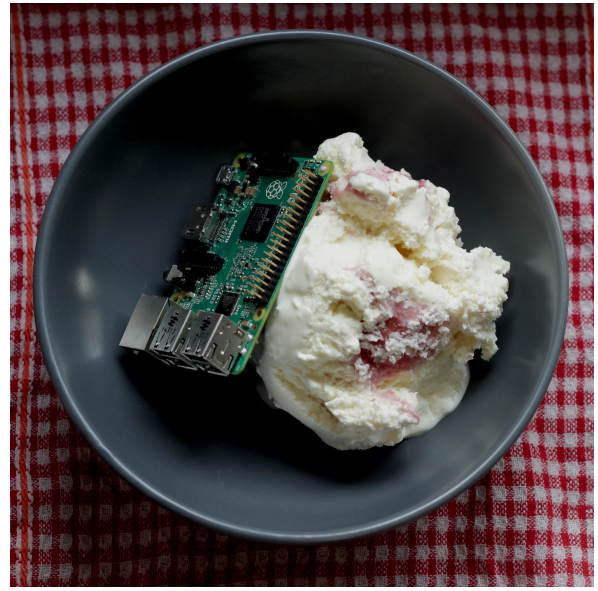

**Figure 5:** Raspberry whitechoc icecream and raspberry pi.

## Friday (Cheat Day)

Diets are hard; why not celebrate the end of the week with a meal that can actually run linux? (Figure 5) This credit card sized treat has all the components a real computer has. Yeah, we know it's not healthy, but we won't tell if you won't.

These meals are only a guide, feel free to experiment with your own ideas; just remember to watch your intake of lead, cadmium, mercury, copper, zinc, nickle, arsenic, aluminium, phosphorus, tantalum, silver, gold, tin, alkylphenols, acids, plastics, endocrine-disruptors, organotins, phthalates, polyvinyl chloride and brominated substances.

In researching the stated diet plan we found nothing in a computer that did not contain some significant health hazard. Even the plastic in computers is more hazardous than regular plastic! Naturally, manufacturers do not intend for these parts to be eaten, by the same token disusers are not intending to eat these parts, but it is happening. Changing these practices will require designers and manufacturers to engage with what happens to their products during its period of disuse.

## Designing for Disuse

There is a material contradiction in the way we build electronic devices. Much of their mass is robust, unmoving, stable parts. They ought to last, and many do. Even those which do "break" are often still full of working components which could be salvaged. But no material robustness can defend an electronic device from obsolescence in the minds of consumers, in the plans of corporations or in the quickening march of technological progress.

In most cases, old components will not be reused; it is more costly to strip devices of working parts than it is to build these parts from scratch. Whether we consider whole devices or constituent components the lifecycle is the same; a few years of functional use before an eternity of disuse. Here we meet the material contradiction; we know smartphones will be discarded in less than a decade and yet we build them from materials that will not breakdown, that cannot be safely returned to the soil.

Some have argued that we must design electronic components for recycling [5]. Currently, electronic components are usually amalgamations of many materials that are difficult to separate. If we designed components to be easily sortable into raw materials perhaps less would go to landfill. This suggestion fails to contend with the toxicity of e-waste. It would require constant vigilance to juggle the toxic materials in computers lest they reenter the biosphere. It would also demand perfect recycling practices, such that no material is lost in the process. We are unlikely to see a process of this kind in the near future.

Instead of designing for recycling, we ought to design for disuse.

This will require that HCI researchers begin to examine those interactions that occur outside the conditions of "use". Many of these interactions may be corporal rather than cognitive. We may need to call on expertise from outside the discipline.

A first step is to understand how the interest of users and disusers are aligned or misaligned. How might user demand for cheap, fast, beautiful devices push negative externalities onto disusers? How might a device whose designers considered its disuse react when dumped in landfill or burned? In nature after a tree drops its leaves, they break down and feed the soil, McDonough and Braungart propose that we adopt as a model for industrial production [20, p. 103–04]. Though the current materiality of computing could not be further this goal, non-toxic alternatives for many components may be possible.

In previous work we have demonstrated a wooden device that can be used to compute a feedforward artificial neural network [2]. Devices such as these can be composted, or burned with little concern. However, a return to analog computing is likely inappropriate in most cases. It is imperative then that we discover non-toxic replacements for existing electronic components or significantly lower the barrier to reuse and recycling of these parts.

## Conclusion

All of these issues are characterised by a material contradiction in our artefacts. I write these words on a laptop computer made of metal and glass. It is so outwardly robust, so resistant to corrosion, that these parts would easily outlast my own fragile body. Instead some unknown failure has rendered my keyboard and trackpad inoperative. Now I must carry a USB keyboard and mouse with me everywhere I go. “Maybe you should get a new laptop” people tell me. I won’t. It’s made of fucking metal! Had these materials been arranged in the form of a wristwatch it might have been an heirloom. Years from now, my grandchildren, when arriving to a meeting on time, might have smiled and thought of their grandpa who died of complications after trying to eat a computer.

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