Carleton College

Demystifying Electronic Waste:
Exploring Tangible Harms and Solutions

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CS400: Electronic Waste Comps

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Introduction

Although the rise of electronics, both consumer and commercial, is a relatively recent phenomenon, the electronic waste (e-waste) stream is now the fastest growing waste stream in the world. In 2019, the amount of e-waste produced globally increased three times faster than the population (Andeobu). Any piece of technology—from agricultural machinery, to tablets, to kitchen appliances—needs to be properly discarded when it no longer functions or its user no longer wants it. Some organizations have made it their mission to properly handle electronic waste, finding reuse for working electronics, and carefully dismantling and disposing of unusable parts. Other sites often use very unsafe processes for dismantling, causing health issues for workers and often harming the surrounding environment.

In addition to the question of how to safely dispose of and break down electronic waste, in some cases, there are legal barriers to repairing electronic devices that are still considered usable and—as in the case of heart ventilators in hospitals—life-saving. Movements such as "Right to Repair" offer legislative solutions that can limit the monopoly of control manufacturers enforce on their products. This would encourage consumers to claim ownership of their own devices in ways already modeled by hobbyists who participate in computer enthusiasm, such as volunteer organizations and DIY art communities. We will address these barriers in-depth, and discuss tangible solutions that offer hope that these issues will soon be resolved.

Throughout our research on this project, we have reflected on how electronic waste is handled in our own local communities. We had the chance to interact closely with Free Geek Twin Cities, a non profit organization whose mission is to properly recycle and upcycle electronic devices. We have taken so much inspiration from the Free Geek community that we have brought some of their passion back to Carleton College by way of an art installation that utilizes technology from Free Geek. This project has ultimately taught us that there are tangible solutions to handling the problem of electronic waste, and ways we can implement and access them in our own community.

In this paper, we will begin by discussing the impacts of electronic waste on different communities across the globe. These impacts give way to larger, systemic trends that have throughlines in all areas of electronic waste. We will discuss three of these trends, and their broader implications. Finally, we will end by discussing tangible solutions, both in our local communities and beyond.

Case Studies

The problem of the fast-growing electronic waste stream is fundamentally a global issue that has implications in all corners of the world. Electronic waste is a large problem, both in terms of severity and in terms of scope. In order to fully understand it, it is beneficial to focus on specific and tangible examples of the harm being caused to avoid becoming overwhelmed by the sheer size of the problem. These case studies focus on three specific examples of how electronic waste impacts the world in Africa, China, and the United States.

Agbogbloshie in Accra, Ghana

Located in the heart of Accra, Ghana is one of the largest e-waste scrap yards in the world, and the largest in Africa. Agbogbloshie–the name of the commercial district where the scrap yard is located—encompasses over 20 acres of land and doubles as both the workplace and home of many young African men (Minter). Referring to the two legendary cities destroyed by God for their wickedness, this site has been given the nickname "Sodom and Gomorrah" due to the sheer levels of devastation and waste. Ghana—like any other country in the world—produces a significant amount of e-waste—but the majority of the technology that is worked on in Agbogbloshie is imported from either other countries in West Africa or the United States. The amount of unusable e-waste generated by Ghana is less than one percent of the staggering amount of e-waste generated by the United States and a nearly imperceptible fraction of the 41.8 million metric tons of e-waste generated globally.

In a study performed by the United Nations Environment Programme to assess the electronic waste stream around the globe, they found that Ghana imported 215,000 metric tons of "electric and electronic equipment" in order to resell, respair, or dismantle the devices. Thirty percent of that was brand new equipment, and the rest were used goods. Roughly 23 thousand tons of the used e-waste was unsellable and bound for the dump—in this case, Agbogbloshie (Minter). Almost all electronic devices contain toxic chemicals and even if these devices are recyclable, it is very expensive to properly do so. As a result, illegal dumping, burning, and dismantling has become a lucrative business, leading to harsh working conditions, exposure to unsafe levels of toxins, and decimation of the local environment.

Nasara, 25, uses Styropor, an insulating material from refrigerators, to light a fire ("Agbogbloshie: The World's Largest e-Waste Dump – in Pictures")

Many different substances are burned on site, because it is the easiest and fastest way to dispose of materials. Most of what is burned on site is automobile tires that have been dismantled from shipments of cars, and the burning rubber produces dangerous levels of carbon monoxide and other hazardous substances into the air that ultimately infiltrates the respiratory systems of the workers of Agbogbloshie and residents of the surrounding area. Large piles of wire are also frequently burned to get to the metals on the inside, and depending on when the wire insulation was made, the smoke can contain dioxin, heavy metals, and other pollutants that pose a strong threat to human health (Minter). Injuries such as "burns, untreated wounds, eye damage, lung and back problems" affect the majority of workers, and many are diagnosed with chronic nausea, anorexia, debilitating headaches, and respiratory problems. These working conditions are clearly hazardous and, in some cases, life-threatening.

When the majority of e-waste is exported from highly developed to underdeveloped countries, the electronic waste stream as a whole is a problem of racism and unjustly targeting impoverished members of society. Residents of privileged societies—often in wealthy, white communities—are raised to take on an "out of sight, out of mind" approach to waste management, and therefore rely on the underprivileged to uphold their veil of ignorance. Because little to no care or attention is being devoted to the maintenance of this waste stream, e-waste workers are suffocated by the amount of waste they must attend to. These men rely on the work provided by the site to survive, and it is a massive humanitarian crisis that their work

leads directly to their death since most workers die from cancer sometime in their 20s ("Agbogbloshie: World's Largest e-Waste Dump").

A close study of Agbogbloshie demonstrates the complexity of the problem of electronic waste. The incredible amounts of e-waste that are currently being generated make it hard to dispose of it as fast as necessary, and without proper infrastructure and external support, places like Agbogbloshie cannot safely dismantle and recycle the electronic devices they receive. Ultimately, the workers at Agbogbloshie must resort to unsafe recycling techniques to simply keep up with the rate of waste generated.

Guiyu, China

Another town that has become infamous for its electronic waste problem is Guiyu, China—a small town located in the Guangdong province. Tens of millions of tons of electronic garbage, including computer monitors, batteries, TVs, and cell phones, are sent to Guiyu as their last destination every year. The rationale behind Guiyu taking electronic waste is primarily driven by economic incentives. Strict domestic regulations in developed countries, combined with the ease of free trade and the lack of regulations or unenforced regulations in developing countries, have led to the export of e-waste to places like Guiyu ("Electronic Waste in Guiyu"). This has created an industry that employs tens of thousands of people, many of whom are poverty-stricken citizens who have migrated to Guiyu to work in processing e-waste. The value of the parts and metals contained within discarded electronics provides an incentive for workers to recover them, even if it means working long hours in hazardous conditions for low pay. The town has become a hub for e-waste processing and recycling, with an estimated 150,000 working in the industry. However, this comes at a high environmental and health cost for the people living in the area.

Electronic waste is extremely detrimental to the communities, individuals, and environments where it is dumped. E-waste contains various toxic chemicals and biological hazards that can harm human health and the environment if not correctly disposed of.

The dangers of e-waste extend beyond the physical space it occupies and into the realm of chemical hazards. The materials used in the production of electronics, including lead, cadmium, mercury, and polychlorinated biphenyls (PCBs), pose significant risks to human health and the environment. Lead is a toxic chemical that can damage the nervous system and cause

developmental delays in children (Grant et al.). Nearly all electronics contain some lead since lead wire could be used to connect from the electric pole of an electronic part or an electronic component. It is also widely used for batteries, pigments, ammunition, and cable sheathing. Cadmium is a carcinogen that can cause lung cancer and kidney damage (Grant et al.). But it is an important component in contacts and switches, where many laptop computers possess rechargeable nickel-cadmium (Ni-Cd) batteries. Compounds containing cadmium have also been used in manufacturing many different PVC products, including wire insulation (Morton). Mercury, a third toxic chemical in e-waste, can damage the nervous system and cause other health problems (Grant et al.). Mercury is used in laptop screen shutoffs, LCD screens, and monitors. PCBs are toxic chemicals that can cause cancer and damage the immune system (US EPA).

In Guiyu, similar to the case in Ghana, e-waste is often processed in small workshops using primitive methods, such as burning wires to extract copper and acid baths to remove the gold. These methods release toxic pollutants into the air and water, leading to high levels of lead and other heavy metals in residents' blood. Other than that, hundreds of thousands of local and migrant workers who extract copper, silver, gold, platinum, and other resale materials often burn or use acid baths to separate the elements of interest. As they process e-waste, workers are exposed to lead, cadmium, brominated flame retardants, and other toxic chemicals, many of which present developmental risks. Exposure to e-waste can occur through inhalation, skin contact, and ingestion. Inhalation of toxic chemicals and microorganisms can cause respiratory problems, headaches, and fatigue (Nriagu, 2016). Skin contact with e-waste can cause irritation and rashes (Decharat and Kiddee). Ingestion of e-waste can cause stomach problems and damage the liver and kidneys (Yan et al.). E-waste exposure can also have negative impacts on the environment. Improper disposal of e-waste can lead to the release of toxic chemicals into the soil and water, which can contaminate the food supply and harm wildlife (*E-Waste*).

Aimin Chen, an assistant professor at the University of Cincinnati College, works in Guiyu with Xia Huo, a professor at Shantou University to study the impacts of e-waste recycling on pregnant women and their children in Guiyu. The joint study enrolled 600 pregnant women from Guiyu and a control site. The researchers measured exposure to various metals, birth outcomes, and long-term effects on the infants' neurobehavioral development. Although the research is still being prepared for publishing, previous studies have confirmed that serum in

children and pregnant women contained many contaminants in e-waste (Chen et al.). Specifically, pregnant women who lived in areas with high e-waste recycling activities had significantly higher levels of lead, cadmium, and mercury in their blood and urine compared to those who lived elsewhere (Chen et al.). The investigators associated adverse birth outcomes in neonates with concentrations of serum and umbilical cord chemical compounds and did find significant associations (Grant et al.). These findings have important implications for the e-waste recycling industry and public health in Guiyu. The study highlights the need for proper e-waste management and disposal practices to protect the health of residents and workers in e-waste recycling communities. It also calls for more research to investigate the long-term health effects of e-waste exposure and to develop interventions to reduce exposure and mitigate health risks.

In addition to the health risks, the e-waste industry in Guiyu has also had a significant impact on the environment. The town's rivers and streams have been heavily polluted, and the surrounding farmland has been contaminated, making it difficult for local farmers to grow crops. In response to these issues, the Chinese government has taken steps to address the e-waste problem in Guiyu. Since 2013, the government banned the import of e-waste and shut down many of the small workshops in the area. Specifically, the Comprehensive Scheme of Resolving Electronic Waste Pollution of Guiyu region of Shantou City was approved by the Guangdong Province government (“Electronic Waste in Guiyu”). Part of the scheme involves the construction of a designated industrial ecology park, wherein most of the workshops are to be centralized and relocated. Zheng Songming, esteemed leader of the Guiyu Township government, has issued a decree that promises supervision and fines for violations.The implementation of this regulation has led to the eradication of over 800 coal-burning furnaces, and has yielded a remarkable improvement in the air quality, elevating it to Level II, rendering it safe for human habitation (“Electronic Waste in Guiyu”). Despite the government’s commendable efforts, the challenge of eradicating informal e-waste processing persists. The vast number of workshops, coupled with the lucrative profits associated with this industry, have made it exceedingly difficult to enforce the aforementioned ban.

Equipment Shortage During COVID Crisis

E-waste is not only a threat to the environment, but complacency with electronic waste also artificially prevents people and businesses from accessing the technology they need, leads to

a widening digital divide, and exacerbates socio-economic inequalities. During the COVID-19 pandemic, this threat was a matter of life and death for many afflicted patients.

In 2020, hospitals and healthcare facilities in the United States faced an increased demand for ventilators. Hospitals could not respond to the challenges posed by the pandemic at its peak due to a shortage of reliable ventilators. There were an estimated 62,000 full-featured ventilators in the US during the initial wave of COVID in 2020, which was insufficient compared to an estimate of 535,000 acute care beds and nearly 97,000 ICU beds filled (Dar). The severity of the shortage could have been mitigated, because an additional 100,000 ventilators were accounted for with partial functionality (Ranney).

This situation emphasized the need for biomedical equipment technicians, intended to fix obsolete equipment and therefore minimize the shortage. Yet, original equipment manufacturers imposed contracts, software locks, and intellectual property protection on medical equipment. These measures, as well as restricted access to training and repair information, prevented biomedical technicians from maintaining ventilators during the pandemic. Although manufacturing companies often hire their own technicians, travel restrictions from the pandemic hindered their ability to address such an overwhelming demand for repair. Hospitals also had rules in place to prevent non-hospital employees and non-patients from entering their facilities during the pandemic to prevent the spread of COVID. The problems only worsened whenever hospitals possessed equipment from multiple manufacturers and had to juggle solutions to different restrictions on top of regular work (Tur-Sina). The following logistical nightmare, constructed by an insistence to maintain company ownership, continues to exacerbate COVID's death toll on the United States, which, at the time of writing, has exceeded one million.

Systemic Perpetuation of Electronic Waste

While these case studies come from very different parts of the world, they are all united by the fact that electronic waste does harm to vulnerable communities—whether those are workers in Ghana who need to keep working with hazardous materials to keep food on the table or patients in the United States suffering from severe COVID symptoms. The case studies of Agbogbloshie, Guiyu, and the legal barriers surrounding ventilators are examples of broad systemic inequalities being exacerbated by the inconceivable amount of electronic waste produced daily. We will now transition from studying the effect of e-waste on specific

communities to analyzing how this issue is being addressed and portrayed to consumers, and how large tech companies promote it, and how all of this contributes to a systemic enforcement of violence.

Media Portrayal

The media has given some attention to the problems caused by electronic waste. There have been highly-regarded short films, photo journals, and plenty of articles published on the topic (Andersson). However, media representations of electronic waste constantly struggle with appropriately expressing the scope and importance of the problem. In his article "Where Technology Goes to Die: Representations of Electronic Waste in Global Television News," Linus Andersson describes the tendency to portray dump sites like Agbogbloshie and Guiyu as the "toxic sublime" with scenes so otherworldly and almost beautiful in their monstrosity that the viewer cannot help but perceive these places as distant and disconnected to their lives (Andersson). A photo journal from *The Guardian* titled "Agbogbloshie: the world's largest e-waste dump - in pictures" is perhaps the most apt example of "toxic sublime."

Old monitors are used to build bridges

("Agbogbloshie: The World's Largest e-Waste Dump – in Pictures")

This photograph in particular, where a bridge crossing the Odaw River that runs through the dump site is constructed out of old computer monitors. This depiction of e-waste recycling is so out of the ordinary for a first-world country that it is almost reminiscent of a fictional depiction of a dystopian society. Another photo of cows with open wounds grazing on the dump site is so gruesome that a viewer may convince themself it isn't real in an attempt to gain distance from the situation at hand.

When the media attempts to depict the raw severity of electronic waste, they often end up alienating the situation altogether. The modern, sensationalized media landscape has the opportunity to convey the gradual buildup of electronic waste as the fundamentally slow and systemic issue that it is, but regularly ends up further from the truth of the issue than where it began. The result is that in the countries most responsible for the production of e-waste, there is little to no mainstream effort being made to effectively connect the audience with the issue in a way that emphasizes the audience's relationship and contribution to the problem, which results in electronic waste being considered a secondary problem and being treated with less importance, which in turn allows the problem to continue its slow growth unimpeded.

We acknowledge that our attempts to convey the impacts of electronic waste may fall into some of the same pitfalls. However, despite the danger of becoming distracted by the toxic sublime, it is still important not to avoid how severe the impacts of e-waste can be. In order to convey the slow and systemic nature of e-waste and emphasize the reader's connection to the problem, the rest of this paper will investigate the major motivations and processes contributing to the problem as well as solutions. We hope that this shift in focus will result in the lasting imagery of this investigation being personal connections, rather than the distant toxic sublime.

Planned Obsolescence

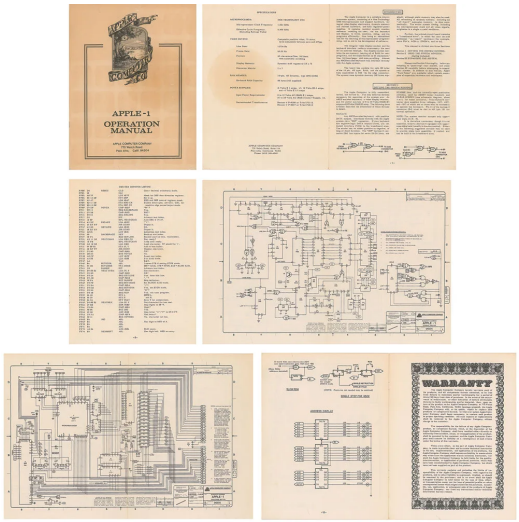
Electronic waste as a problem is deeply tied to the media, not just through portrayal, but through the ties between social media, marketing, and consumer culture that contribute to the increased production of electronic waste. In order to understand this connection, we must start with the companies responsible for electronics production. There is a single term that dominates most discussions regarding how the actions of these companies contribute to electronic waste: planned obsolescence.

Planned obsolescence is the artificial limiting of the lifespan of a product. When one hears the term used today, it is most frequently associated with poor quality materials, rushed production, and products designed to fail in order to encourage future consumption. All of this leads to products having much shorter lives than their older counterparts. However, even if planned obsolescence in this sense is a genuine phenomenon, it is hard to find concrete evidence of it being intentionally used in practice. There is a historical precedent for deliberate design choices limiting product lifespans. From 1925 to 1942, several lightbulb manufacturers deliberately limited the lifespan of their bulbs to 1000 hours, in order to make more money (Albrecht). This "Phoebus Cartel" included companies from the U.S., the U.K., and Germany, and is widely considered the first instance of planned obsolescence when journalists started investigating the situation (Hadhazy). This case illustrates two major ideas. The first is the reasoning that manufacturers have to limit product lifespans: the sooner a consumer needs a new product, the sooner they will be paying more money back to the same company. The second is that the origins of electronic waste are just as much a global problem as their impacts.

Despite the historical precedent for deliberate shortening of device lifespans, many modern companies are adamant that they do not contribute to this practice. Apple's website states that "Apple devices are designed to be long-lasting. They are made of durable materials that are heavily tested in our Reliability Testing Lab" (Apple). This statement demonstrates that consumers prioritize the durability of their machines enough that Apple's team was compelled to add a dedicated statement on their website affirming that long-lived machines are their priority as well. These statements must be taken with some skepticism, however. Tech companies intentionally promote that they want to help consumers in the long run, not hurt them. However, this is not without some degree of evidence, as well-cared-for devices by companies like Apple can last long past their warranty. As a part of this project, we are working with a Macbook Pro from 2009 that is still fully functional thanks to some careful thinking about how to take care of old devices.

The long-standing use of Apple devices from the 2000s shows that these statements from Apple are not without some degree of truth. However, Apple has discouraged consumers from reusing or repairing their devices increasingly over the years. Aaron Perzanowski illustrates that, in the case of smartphones: "Every year, fifty million people in the United States break their smartphone screens… replacing the screen requires tools, skills, and confidence many consumers

lack. In comparison, Apple currently [2022] charges $279 for this fairly straightforward repair, a fee that often makes purchasing a new phone more attractive. And Apple further entices customers by offering discounts on new phones if they trade in their existing device instead of fixing it," (Perzanowski). Additionally, instructions on how to repair Apple devices have not always been restricted. The earliest Apple computers came packaged with detailed instructions on how they work internally, ways to repair them, and diagrams that demystify their internal components.



Apple 1 Operation Manual, 1976

Despite reassurances from Apple that they are not participating in planned obsolescence, the lifespans of electronic devices continue to dwindle. A Dutch study showed that between 2000 and 2010, almost all appliances produced towards the end of the decade had shorter lifespans, and the researchers believe that this data can be applied to countries outside of the Netherlands (Huisman).

In order to fully understand the phenomenon of planned obsolescence, we must turn our focus away from design and toward marketing and consumers. Companies like Apple don't need to build devices that break down in a few years if consumers will buy new devices anyway once their current ones are perceived to be outdated and out of style. Some of this "perceived obsolescence" is caused by direct marketing from companies, but it is also deeply ingrained in our consumer culture (Soke). This phenomenon results in a popular culture that places value on what is new and in doing so, tells consumers that the right thing to do is to spend money on the latest piece of technology rather than sticking with the old until it begins to struggle. This is part

of a broader impulse within consumer culture in which "the brands [are] perceived as cultural icons of consumption…that goes beyond their physical characteristics, their functionality or their economic value, by proposing meanings or lifestyles that are shared socially by a society" (Fondevila-Gascón). These marketing strategies appeal to the consumer's need to fit in. In a culture where technology is just as much an accessory as it is a tool, marketing new tech as "cool" compels consumers to discard old electronics that would now mark them as other. This impulse effectively invalidates Apple's statement that "the longer you use your device, the better it is for the planet" (Apple). While the company publicly says that it supports long-term use of products, the environment they have created through marketing tells consumers the exact opposite, which is the impulse that they will follow.

Planned obsolescence is not a singular force limiting device lifespans through deliberate design choices, but rather includes social and cultural forces that are just as effective in limiting product life spans as built-in hardware and software limitations. Limiting planned obsolescence to the design room is ultimately harmful. Doing so encourages the belief that the causes of electronic waste are purely on the shoulders of design teams, and just as easily allows companies to dissuade consumers that anything sinister is happening through statements like the one on Apple's website. In addition, doing so closes the doors to many potential solutions to the problem that focus on changing how people perceive and interact with older electronics. In order to fully understand the problem of electronic waste and move toward effective, encompassing solutions, planned obsolescence must be understood as a complex series of overlapping forces that contribute to the effect of shortened device lifespans together.

The rapid rate of technology obsolescence benefits the consumer, who is ensured to always have a new product available when they need one, and the manufacturer, who gets increased profits (Hadhazy). However, this beneficial relationship is relegated to those involved who participate in the consumer culture of primarily first-world countries. When a device is deemed obsolete, both consumers and manufacturers can forget about it and move on. The same cannot be said for the workers at electronic waste dump sites such as Guiyu and Agbogbloshie, where these devices are disposed of at the end of their lives. The faster a device is deemed obsolete, the faster it will end up contributing to the ecological and health hazards at e-waste dump sites.

Slow Violence

Slow violence is a term used to describe "the often hidden ecological damage that poor communities are increasingly burdened with over the long term," and is used within the context of the impacts caused by globalization (LeBel). In the case of electronic waste, communities where recycling is conducted find themselves trapped with an increasing amount of waste, as the rate at which electronic devices are thrown away outpaces the rate at which they can be recycled. Electronic waste is "the fastest growing waste stream in the 'developed' world" (LeBel). The shortening lifespans and growing amount of electronic devices in the world mean that the amount of them that become waste continues to grow at a rapidly increasing rate. Comparatively, only 13% of e-waste produced in a year is recycled in that same year (Andeobu). In order to effectively recycle electronic waste, we would need to recycle it at over ten times the rate to make up for what has already accumulated. With these rates the way they are now, the steady increase of electronic waste in dump sites is inevitable.

As mentioned in the previous case study in Guiyu, electronic waste is extremely hazardous, posing significant and often mortal threats to those who are exposed to it. Therefore, the fact that nothing continues to be done about this problem is an act of violence, as it directly harms the vulnerable communities where e-waste is disposed of.

Electronic waste is certainly considered a global problem, but the truth is that the lasting, negative effects of electronic waste simply aren't felt by wealthy, Western individuals. The movement of electronic waste is a product of globalization, with new transport technologies and regulations brought about by globalization shaping where electronic waste moves to and from (Reno and Alexander). These patterns also align with those of colonization, with first-world countries dumping their waste in those of the "Global South" (Menon). This system, in which dangerous waste flows out of first-world countries and to Africa, Southeast Asia, and China reflects colonialist sentiments that the economic benefits of these choices outweigh the harm that they do to the environment and people they impact.

The choice to export electronic waste to countries in the Global South despite their small contributions to electronic waste overall is one made both out of a disturbing lack of care for the people who live in these countries, and a clear desire to maintain the economic dominance of the west as part of colonialist structures. As such, the environmental and health hazards caused by electronic waste are being used to enforce the pressures of colonialism. The system as it stands

allows for anyone who is privileged enough to be divorced from the impact to simply ignore the problem, like Summers and other economists who prioritize profit over human impact and participants in the U.S. consumer culture who can throw away their old phones with no consequence, while those who are impacted are faced with a problem that grows greater in scale as time goes on.

The problems created by e-waste do not exist in a void. Electronic waste is just one of the many social problems that have arisen in the modern world due to the rise of electronic goods. The impulses that lead to the overproduction of electronic waste, such as planned and perceived obsolescence, have other negative effects on society. The most prevalent among these is the digital divide, a term referring to the access gap between people who have access to communication technology and those who do not (Lythreatis). The digital divide is a growing social problem due to how useful communication technology can be: having online access gives access to information, communication, and more. Access to these resources should be a right, but right now, due to social, economic and demographic factors, it is a privilege. The first phase of remediating the digital divide involves getting internet access to everyone, but recent studies have shown that in countries where internet access is nearly universal, like the United States and the Netherlands, the ability to maintain devices and their peripherals becomes the major contributing factor to the divide (van Deursen). Similar to the case of hospital ventilators, the same lack of supporting structure and profit-motivated choices result in a need not being met, resulting in a violation of rights, whether that is the right to access the powerful tools of the internet or to live. The digital divide is also made more frustrating in the face of the ever-growing stream of electronic waste, many devices still usable, being produced by the developed world. Since social impulses dictate some technology to be more obsolete than it actually is, that technology is discarded without a second thought instead of giving it a potential second life with someone who needs it. Not only does electronic waste contribute directly toward global systems of oppression, but it is connected to other structures like the digital divide that also contribute to systemic inequalities.

The structure and attitudes surrounding electronic products and electronic waste are products of a global, colonial, and deeply unequal system. Discarded electronic products are sent to countries that should not be responsible for them, where they cause great harm to both the environment and the people who live there. The rate at which this waste is generated continues to

outpace the rate at which it can be recycled, so as time goes on the impacts that this waste causes will only grow as it is left to pile up. The lack of support necessary to allow devices to have longer lifespans disproportionately impacts those who do not have the funds necessary to buy the newest products or pay a licensed technician. The excess of technology that is produced does not contribute to narrowing the gap in technology access in the case where it can still be usable, but rather is thrown away without a second thought. It is necessary to define the electronic waste problem as violence. Doing so acknowledges the harm that it has caused and continues to cause to the communities it impacts, and fights against the impulse to label the problem as unimportant simply because it is happening on a slow scale, and allows for effective solutions to be found.

Solutions

While the connections between electronic waste and colonialism, the gap in technology access, and other relevant social issues might seem as though they worsen the problem, these connections are key to moving towards solutions that can benefit everyone. To fix this problem, change needs to happen on a global and governmental scale, but lots of good work is being done by small communities and individuals that should not be overlooked. During our research on this project, we have been exposed to sustainable, tangible solutions occurring in our local communities, and work being done by governments particularly in the EU to address the issue. Inspiration can be taken from these case studies for potential resolutions to some of the broader problems of electronic waste.

Free Geek

Free Geek Twin Cities is a nonprofit organization located in Minneapolis, Minnesota that takes in residential donations of old electronics and either breaks them down to safely hand off to a recycling company, or restores them to sell in their thrift store with the help of volunteers. Their goal is to create a community where old technology is not perceived as outdated and uncool, but rather a source of historical, cultural, and technical knowledge and a cheap and effective way to gain access to the indispensable tools of the internet. By doing so, Free Geek is able to both provide affordable options for people in need of technology and help give electronics that would otherwise be bound for the landfill a second life. In their approach to

electronic waste, Free Geek understands that the digital divide is a related issue, and they are able to both extend the lifespans of electronics otherwise bound for dump sites and address the digital divide by providing a place where people can obtain both devices and their peripheries at a reasonable price. While they do not offer repairs for devices, their enthusiastic and helpful attitudes towards volunteers encourages volunteers to learn repair skills that can be used on their own devices as well.

Working with Free Geek, it is obvious how much their staff, volunteers and store visitors care about old electronics, and their attitude is infectious. Free Geek does very little advertising: their operation is supported by word of mouth within their community. While Free Geek is a relatively small operation, what they are doing is a breath of fresh air. Electronic waste is a complicated issue, tied up in many global systemic and cultural issues, and because of that it can feel like an insurmountable challenge. However, Free Geek shows that with the right people, these attitudes can be shifted. Change on a global scale might be slow, but in the meantime small, community oriented organizations like Free Geek are an extremely effective solution, working hard to keep devices out of landfills in a way that is fun, interesting, and builds a community.

It is hard to accurately quantify the impact of such an organization, but we have been working closely with Free Geek to implement some data collection strategies that could be useful. Our data collection process is fairly low-tech, because Free Geek already has a very efficient workflow that we do not want to disrupt. We have gained interesting data such as how long it takes devices to get processed, what models of devices are most commonly donated, and how many devices ultimately end up in the retail thrift store. While the precise definition of Free Geek's impact is still a work in progress, it is clear to see that they are making a tangible impact in their community when you look at how many donations they get each day. Most donations to Free Geek are residential, but they also get the occasional school, business, or organization that no longer has a need for certain technology. When these donations roll in, the volunteers at Free Geek—whose participation is fueled by compassion for others, care for sustainable recycling practices, and a general curiosity about technology—greet visitors with kindness and warmth. They have a great relationship with clients, customers, and donors, and have ultimately formed an amazing community surrounding the repair and recycling of electronic waste.

Potentially the most sustainable aspect of Free Geek is the attention to detail within their workflow. It is rare that a device ends up somewhere it shouldn't, and even if it does it is

properly assessed to be dismantled, recycled, or passed along to the store. No matter where a device ultimately ends up, it is being properly and safely taken care of. In this sense, Free Geek is environmentally and socially responsible because they take precautions to keep harmful chemicals out of waterways, bodies, and the trash.

As outsiders to Free Geek, it has been an enormous task to approach the organization, dutifully study their system and flow, and help them achieve their goals of data collection all within the span of six months. Nonetheless, it has been an inspiring experience to work so closely with individuals who have devoted their livelihoods to reducing the negative impacts of electronic waste.

Carleton College

In addition to investigating Free Geek, our research also encompasses academic institutions to gain a comprehensive understanding of responsible e-waste recycling practices in the vicinity. Carleton College, a private liberal arts college situated in the Midwest, has implemented distinctive strategies to manage electronic waste. Our selection of Carleton College as our educational institution of choice was influenced by a variety of factors, one of which is its reputation for demonstrating a strong commitment to environmental stewardship. We were drawn to Carleton's active and ongoing efforts to promote sustainable practices and reduce its ecological footprint, which aligns with our own values and aspirations. As students from Carleton, we are motivated to investigate at our school, as we want to compare the academic institution to the community institution like Free Geek. As a hub for academics and research, the institution produces significant volumes of e-waste from students, professors, and staff. To ensure proper disposal, the Information Technology Services (ITS) department carefully monitors all old electronics, including computers, monitors, projectors, and printers owned by the school. Such initiatives taken by Carleton College indicate the growing awareness and responsibility towards sustainable e-waste management practices.

Carleton College's efforts to regulate electronic waste focus primarily on the recycling of computers, which are a significant source of e-waste on campus. With approximately 800 computers distributed for personal use and over 200 lab computers attached to specific hardware in various classrooms and labs, ITS is responsible for the management of a large number of devices. To ensure safe disposal, ITS has implemented strict life cycle guidelines, whereby

computers distributed to faculty and staff are deemed to have a four-year life cycle, and computers for lab usage are considered to have a five-year life cycle. The prevailing norm in the desktop computer industry stipulates a lifespan of approximately 4 to 5 years. While extending the lifespan of electronic devices can indeed reduce the generation of electronic waste, this approach is limited by the rapid pace of technological advancement. As technological progress marches inexorably forward, electronic equipment can quickly become functionally outdated. This obsolescence is characterized by a range of issues, including noisy fans, lengthy startup times, poor multitasking capabilities, and most importantly, outdated security features. These complications can prove particularly detrimental to researchers and professors, whose work depends heavily on the accurate and efficient functioning of their equipment. Given these challenges, the adeptness of balancing the lifecycle of computers displayed by Carleton in managing electronic obsolescence is both reasonable and commendable.

Once these computers have reached the end of their life cycle or have broken down, ITS will recollect them and send them to be either disposed of or recycled. Based on estimates, ITS will replace approximately 200 computers annually, making a significant contribution to the reduction of e-waste on campus. To promote sustainability, 75% of the computers collected for recycling will be sent to Think Dynamic, a reputable e-waste recycler, and 25% may be reused after the hardware has been cleared and the software updated. The computers that are deemed suitable for reuse will be directed towards the Laptop Loaner Program at Carleton. This program, which emerged from the Low-Income and First-Generation Working Group, is dedicated to providing laptops and computers to students who may lack the financial resources to obtain such equipment on their own. Students only need to request the computers by filling up a form explaining their need for a loaner laptop, the ITS department and the Dean of Students Office will consider providing them the refurbished laptops. By redirecting these devices towards this laudable initiative, Carleton is not only contributing towards the democratization of education by promoting equal access to vital technological resources, but also towards a more sustainable future by refurbishing and reusing electronic waste.

The 75% of Carleton's electronic waste that is recycled is sent to the Think Dynamic company, a full-service electronics and materials lifecycle management corporation specializing in electronics recycling, product refurbishment, materials recovery, and data security. They will take over the computers, monitors and various electronics from Carleton. The innovative

recycling process employed by Think Dynamic involves breaking down electronic devices into their constituent parts, thereby generating small fragments that can be repurposed for the creation of new materials. Once the initial recycling phase is complete, the resulting waste is transported to the end-stream processor on a monthly basis for further processing. Here, the non-metal and metal fractions of the electronic waste are subjected to additional procedures, resulting in their further decomposition and destruction. Through this comprehensive and sustainable approach, Think Dynamic exemplifies an unwavering commitment towards safeguarding the environment and reducing the ecological footprint of electronic waste.

The process from Carleton College ensures the proper disposal of electronic waste to prevent possible harm to the environment and human health. Both colleges and large communities, Think Dynamics and Free Geek, follow local, state, and federal regulations for the proper handling and disposal of e-waste. They all have designated staff or departments responsible for the management of e-waste. Both Carleton and Free Geek use a combination of recycling, reuse, and disposal methods to handle e-waste. They prioritize data security and take steps to ensure that sensitive data is removed from electronic devices before they are disposed of or recycled. However, there are also differences in how they process these devices. Larger community processors like Free Geek may have more complex e-waste management systems—such as sorting and processing equipment—to handle larger volumes of e-waste. Smaller communities like Colleges may be more likely to involve students and faculty in e-waste awareness campaigns and recycling programs, as part of their sustainability initiatives.

DIY Art

Free Geek is not the only community to grow around the idea that outdated machines can be used to make something new and beautiful. DIY art networks provide models for how technology can be used more sustainably. The repurposing of obsolete technology breathes life into otherwise forgotten devices, and the creative reuse of technology and computing resources provides new techniques so that retro devices remain applicable to the next generation's art.

One early example of this culture is the demoscene, a community of computer enthusiasts that organized in the late 20th century. The demoscene has its origins in "cracking" video games, which involved the removal of the copy protection from commercial software, making it available to the public. Similar to traditional graffiti, it became customary to "tag" the title screen

with visuals, animation, or even music. As the tags became more elaborate, it became more common for enthusiasts to make audiovisuals divorced from existing games. These "demos" were a way to demonstrate their technical prowess and claim some semblance of ownership over machines that were otherwise restricted to intended use.

Over time, the creative spirit of the demoscene branched into a music movement called micromusic, established in 1999, which utilized the devices commonplace in the demoscene in order to make a more explicit statement about how low tech technology could be used to give people a voice, adopting the phrase “low tech music for high tech people,” (micromusic). This enthusiasm simultaneously gained traction in the United States. Labels such as 8bitcollective, also founded in 1999, would say in their mission statement: "born out of an appreciation for the unique aesthetic character of early-generation computers and video game systems, and the belief that hardware has a lifetime measured in decades, not months. Like the subculture we seek to represent, we reject intended use and planned obsolescence — champions of forgotten tech, hijacking the future," (8bitcollective, Nullsleep) Together these movements evolved into a broader "chiptune" culture.

Art movements such as the demoscene and the chiptune scene serve consumers by modeling ways individuals can take ownership of their devices in unique ways, and as a result, extend the lifespan of machines. This phenomenon is especially potent with art, because art’s appeal demystifies the process through which that art is made. A musician’s enthusiasm for taking computers apart and using them to make audiovisual spectacles encourages the audience to consider that act as a valid way to produce something of value.

This effect is enhanced further for DIY art because of its nature as a hobbyist’s medium. Chiptune and DIY electronic music is less a ‘genre’ in the sense that it carries a signature sound, and better described as a hobbyist movement. Musicians diverge widely in the sound of the music they produce, but have a sense of unity when it comes to their values and the spirit of their work. Lauren Flood observes: “among the shared concerns and techniques displayed are an affinity for noise, chance, chaos, and incompleteness; an aesthetic preference for the sounds and acts of repurposing outmoded and discarded materials” (Flood). While the chiptune medium is hardly an organized community, its participants find themselves telling the same messages through the shared processes that they use to generate art. The hobbyist nature of the music further proliferates those social or political messages due to the lack of social distance between

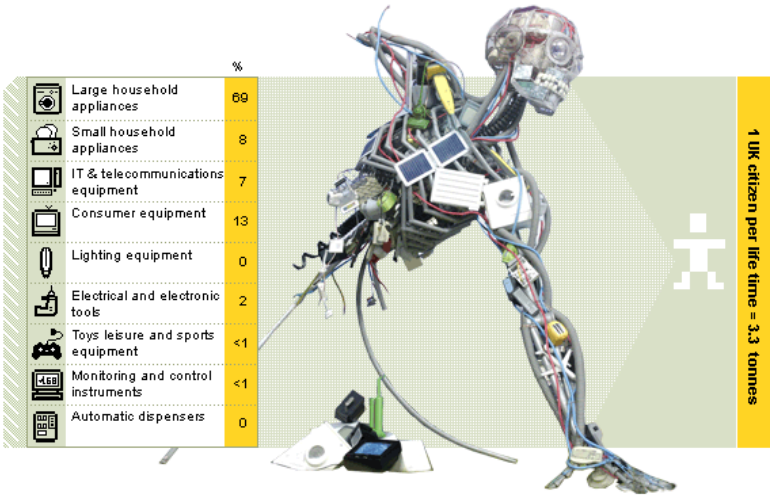
the musician and the listener. The stories told by hobbyist art and the methods through which the art is made feel more accessible to the consumer because of the musician's similar socioeconomic class as someone who makes music as an outlet for their creativity on top of other intersecting lifestyles. This connection between the creator and the listener further enhances the inspirational aspects of DIY works, giving the medium a pivotal role in encouraging individuals to repurpose their own devices, and/or take action on associated issues such as the problem of electronic waste.

Legal Solutions

Electronic waste is difficult to pin down due to its breadth of impacts, and as a result, there's no single legal solution that will entirely fix the phenomenon. Rather, legislation can be used as a tool to treat the harms of electronic waste and mitigate the damage it causes to people and the environment.

The European parliament has taken a holistic approach to legislation on electronic waste since 2003 by legally codifying e-waste, founding of the European Waste from Electrical and Electronic Equipment "WEEE" Directive, and by setting legal pathways to hold manufacturers and sellers accountable for the electronics they provide (Official Journal of the European Union). This approach is exceptional when compared to worldwide norms, where electronic waste is rarely addressed so directly from a legal standpoint.

Aside from legislative advocacy, the WEEE directive also illustrates the problem of electronic waste via a sculpture called the "WEEE Man." The WEEE Man means to represent the average amount of electronic waste a resident of the UK would create in their lifetime: "69% of Household WEEE arising by weight in the UK comes from Large Household Appliances – cookers, washing machines etc. Therefore the predominant weight of WEEE in the WEEE Man is large household appliances. Consumer Equipment (i.e. Hi Fi) accounts for 13%, 8% Small Household appliances such as vacuum cleaners, 7% IT & telecommunications (mobile phones) and so on," (The WEEE Directive). The benefit of state funding allows the sculpture to exceed the hobbyist limitations that come with most art projects which repurpose electronic waste.



WEEE Man Sculpture, The WEEE Directive

Definitions and illustrations such as these allow voters and legislators to better recognize electronic waste as a problem. A shared consensus on the reality of electronic waste is a necessary step in introducing effective legislation to address the issue. One major avenue for legislation is that of the right to repair (R2R), which limits the ways original manufacturers can prevent customers from fixing their devices: “The idea behind the right to repair is simple. You bought the device, you own it, and you should have the right to repair it.” (Montello). The legal recognition of electronic waste has set a foundation for legislation promoting the repair of faulty products. For example, EU consumers have the right to have their electronic products repaired free of charge if it becomes faulty within two years of purchase, as long as the consumer does not drop or misuse the device. If an electronic device breaks within one year, it’s recognized under law as faulty from the start. (Šajn). This guarantee discourages planned obsolescence and the use of fragile materials in the design process.

Legal advocacy and awareness by WEEE has also allowed the European Union to focus its efforts on forms of electronic waste which have the most poundage by setting ecodesign requirements for household appliances such as washing machines, dishwashers, and refrigerators in 2019 (EUR-Lex). This targeted effort is in line with the WEEE Man art installation, which demonstrated that household appliances take up the majority of electronic waste generated by the average consumer.

Conversely, R2R laws are relatively rare in the United States, though they are not unprecedented. Massachusetts passed a bill in 2012, which was later extended nationwide, that

required car manufacturers to provide components and manuals to the public to allow people to repair their cars (Montello). Extending these requirements to other electronics would solve many of the issues outlined so far, such as the scarcity of ventilators or the prevalence of planned obsolescence. It would also make the work of DIY artists and refurbishing communities easier, since the tools they need to fix those devices would be more readily available.

While legal treatments are categorized here as a solution to electronic waste, the lack of legal restrictions on manufacturers can also be framed as a major problem that contributes to e-waste, especially in the United States. The European Union's research, advocacy, and legislative efforts can serve as a model for how other major contributors to electronic waste can reduce their footprint in this issue. Furthermore, we hope that the breadth of issues and movements discussed in this paper inspires more potential solutions, legal or otherwise, which reflect the vast effects that electronic waste has on both people and the planet.

Conclusions

Though the topic of electronic waste is expansive, there are bridging concepts that allow for synthesis of such a complex issue. The most prevalent underlying catalysts are the large tech companies that lie at the source of the waste stream. Companies like Apple want to convince you that they are environmentally responsible, while releasing a host of new devices every few years. These companies insist that they do not intend for technology to become obsolete while simultaneously churning out new promotional stunts as fast as they can to encourage purchasing new devices. This technique of convincing consumers that they "need" the newest device is majorly successful. If old or retro technology was given the same type of advertising, perhaps it could be a significant solution to the problem of electronic waste. In a society where trends are defined by the media, retro technology could regain traction if only consumers were taught to be enamored with it.

At places like Free Geek, and in networks of DIY hobbyists, communities thrive on mutual passion and excitement for reusing and repurposing old technology. There, no one is caught up in societal perception or media portrayals of the devices they work on—they do it to do more good, and they feel good doing it. Working on this project has shown us what working towards a tangible solution looks like in real-time, and has motivated us to repurpose old technology to make a long-lasting statement on the effects of electronic waste. Taking inspiration

from the working aesthetic of Free Geek, the importance of the knowledge we gained from exploring how the school we go to handles e-waste, the intention to reject obsolescence of the Chiptune Community, and the educational graphics made by the WEEE Directive, we created an art installation.

3D Model of our Art Installation

Most of the technology used to create the installation comes directly from Free Geek, where some of it was purchased from the store and other parts were saved directly from the recycling room. The clunky, older aesthetic of these devices paired with the working environment at Free Geek inspired us to create a piece that is messy and octopus-like. This visual element both acknowledges the severity of the impact of electronic waste, while also embracing Free Geek's enthusiasm for an aesthetic that embraces the internal chaos of technology rather than the modern, sleek designs associated with newer releases. This installation is located in the 3rd Olin stairwell, right by the Computer Science department at Carleton College. Being responsible and environmentally friendly is an important part of Carleton's identity, and we learned a lot from seeing how seriously ITS handles old electronics. We want viewers of our project to understand that they are part of a community that cares about this issue, and is willing to support them as they learn more about it and try to work against it. A huge part of this project was finding

electronics that could serve our purpose and getting excited about them, with the goal that hopefully we can get others excited about them too. This fundamental idea took inspiration from the Chiptune Community and their ideas regarding using art as a method of subversion to embrace the old in new and exciting ways. Finally, we wanted this piece to contain an optional educational element pushing the idea that these old devices are more than deserving of their second life as a part of this installation. Taking inspiration from the WEEE Man's educational purpose, this piece includes an interactive projection detailing the stories of each component device, particularly how they got to be a part of the piece and where they would likely be otherwise. The goal of this piece is to focus on a specific, tangible solution: embracing older devices in order to help keep them away from dump sites and slow down the e-waste stream. While it is important to understand the tremendous impacts and global scale of electronic waste, we found that, for a public-facing project, it is productive to focus on reasonable, community and individual level solutions to avoid the pitfalls of catastrophizing and distancing oneself from the problem. We hope that by giving an example of what we were able to create using old electronics, viewers of our piece will feel inspired to try and do the same, or at least think twice before deciding a device is at the end of its life.

Electronic waste is a global problem, with tremendous social, environmental, and health impacts that cannot be ignored or understated. However, this is not something to be intimidated by. It is important to acknowledge the harm that electronic waste causes, but in the end, we want to encourage people to take inspiration from Free Geek, the DIY art communities, and participating institutions such as Carleton College, and to learn something new about something old.

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