LAFAYETTE COLLEGE

Mapping the E-waste Cycle

EGRS 451: Capstone Seminar on Engineering & Society

Duncan Brady
Nicolas Hoffman
Dawei Zhang

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Content

Introduction

Electronic waste (e-waste), the discarding of electronic devices, is one of the largest growing forms of waste in the world. The United States produces a large portion of this e-waste, together with China accounting for over a third of worldwide e-waste (Casey, 2015). Our project seeks to rectify this problem in the Lafayette College community, and our work will hopefully inspire other projects to remedy this issue in other communities. The Lafayette community provides an excellent example of the mentality, particularly in the United States, that propagates growth in the e-waste pile-up. Currently, there is an extensive program laid out on the college's website on how to recycle the e-waste. The program, while still finding its footing, creates different routes to reuse, donate, or recycle "All college-owned computers and electronic devices that are being replaced (Electronics Recycling, its.lafayette.edu)." However, beyond Lafayette's Electronics Recycling Day (Recycling, sustainability.lafayette.edu) during Earth Week in April, the college does not have any system in place for students to understand how to recycle their electronic waste. Students are constantly in possession of smartphones, laptops, and televisions all possess rare and valuable materials that continually go to waste at Lafayette College. To raise awareness of electronic waste build up at Lafayette College and to help students understand why e-waste is a serious problem that deserves attention, our project seeks to map the electronics lifecycle in the Lafayette College community and to do so in a way that will best stimulate change in how students prioritize proper disposal of their own electronic waste.

To best appeal to the Lafayette students, we decided to focus on mapping the life-cycle of the iPhone, most closely focusing on the iPhone 6s. The iPhone is the most common smartphone at

Lafayette, carried by 84 percent of students surveyed, and Apple is an dominant presence in the consumer electronics arena (Mapping the E-Waste Lifecycle, 2017). The iPhone 6s was the world's highest selling phone in 2016 (Apple iPhone 6s Crowned World's Best-Selling Smartphone, Forbes). We believe this is the product will generate the largest interest in our work. The large image of the iPhone should quickly draw the eye, as the smartphone is likely the most commonly used electronic device on campus, considering the average person checks their phone 110 times a day (How often to do check your phone, dailymail.co). The raw materials in an iPhone are also very similar to the materials in the average computer, and many are commonly found in electronics everywhere.

Our map will be modelled in part after a technical cost model of economic analysis, an approach through which a product is broken down into its basic components and analyzed as such. Similarly, we are mapping the lifecycle of each of the three products from their raw materials, to the centralization and assembly of its components, distribution and sales, average usage and lifetime, and disposal or recycling. The goal is not to advise students on how to deal with their own devices. Campaigning what students are doing wrong would not only be hypocritical, it would be ineffective because it would students defensive about an issue they have no idea how to rectify. We found that 57 percent of Lafayette students surveyed do not know what e-waste is, let alone what to do with their own (Mapping the E-Waste Lifecycle, 2017). Our goal is to inform them of the issue and how they contribute to the e-waste problem. We will make suggestions in our report for the Office of Sustainability, or possibly another capstone project, to move forward with addressing student e-waste.

Solely researching and documenting our findings is not enough. Students at Lafayette, and consumers in general, are unlikely to read a paper about a seldom talked about issue that does not provide a simple and direct academic or economic incentive. Students at Lafayette also receive daily emails from Calendar of Events, informing them of multiple lunch talks and presentations that will be occurring in the coming days, and unfortunately a talk on electronic waste is unlikely to stand out as a must-attend event. Besides just a general lack of knowledge on the subject of electronic waste, there is also a lack of proper motivation to learn about this project and its resulting findings. This important challenge has sparked our idea of creating a physical map for the e-waste lifecycle at Lafayette, focusing almost completely on the iPhone. By creating a separate display that physically "maps" the life-cycle, we believe the information will catch the eye of students. The display that we will produce will be large, colorful, and minimalist enough to convey the relatable ideas on the posters, hopefully drawing in the busy student. Though fitting enough information on the display will be challenging, compelling images and minimal description should be able to convey all necessary information if done on large displays.

Our student survey on electronic waste provides more background information on how Lafayette students dispose of and interact with their electronics. The survey questions are as follows: Do you know what e-waste is? What brand of cell phone/computer/tv do you have (if any)? Which electronic device do you use the most? How often do you replace each electronic device? Do you know how to recycle your electronic waste? How well do you know Lafayette's policy on electronic waste? What do you usually do with each of these electronic devices when you are done with them? Do you know about electronics recycling day?

Upon speaking with the Marie Fechik-Kirk, the Director of the Office of Sustainability, we have come across another problem, which is that even though Lafayette's system seems well organized from the site description, it is not so in practice. The Office of Sustainability is a new department, relying heavily on student contribution rather than administrative help, and is still working on centralizing many different pockets of passionate recycling initiatives across campus. This pertains to our project in that obtaining information on how the school deals with its e-waste is difficult without a centralized understanding of who is performing what function. There is no way to solve the problem other than waiting for centralization to occur. We recommend that future groups seek to gather information through the involved departments, such as The Office of Sustainability, Information Technology Services, Plant Operations, and the organizations through which the college recycles. For Electronics Recycling Day, the organization is Responsible Recycling Services, and the green bins used for batteries and ink cartridges are taken care of by Big Green Box.

This project will not be able to serve its purpose if it does not change how students think about their electronic waste. Our goal at this step in the process is to provide a jumping off point by simply mapping the e-waste life cycle at Lafayette, not changing it. We hope for our display to be visible in all academic buildings, and our structure for the posters should make them both eye-catching and informative. By surveying students, we have also not only made the information more applicable to the Lafayette community, but we have made the students participate in mapping the life-cycle, which should create more interest in the topic as a whole. We will also make sure to provide information that will be gripping, such as the ambiguity in Apple's sources for tantalum, a rare metal mined in the Democratic Republic of the Congo and Rwanda.

Through mapping the electronics lifecycle, we hope to lay the groundwork for developing a system to address student e-waste at Lafayette College. This project will educate students about e-waste while providing necessary research as to how the college can create a system to manage it. Through our suggestions, based on internal analysis as well as successfully implemented programs of other academic institutions in the United States, Lafayette can create a model to serve as an example for how the rest of the country treats its electronic devices.

Social Context

The central social context that contributes to the issue of America's ever-growing e-waste is that of planned obsolescence. In short, the principle of planned obsolescence is such that an item does not last as long as it potentially could, meaning that consumers are prompted to replace old items more frequently than would be necessary had the manufacturer not intentionally shortened its life cycle. For example, textbook publishers frequently publish new editions of their textbooks with ever so slightly altered practice questions and definitions to diminish the used textbook market and force students to obtain the newest edition of the book even though most of the material carries over (Iizuka 2004).

Although it is easy to dismiss planned obsolescence as a product of corporate greed in a capitalist society, it is important to understand what causes manufacturers shy away from producing durable goods. When a product is successful its market becomes saturated but producing more durable and long-lasting products lengthens the repeat purchase cycle, retarding growth. So too does the second-hand market, raising the level of competition between new and used goods while simultaneously lowering the price of replacement goods. Increasing the frequency with which users replace their products stimulates market growth, limits competition from the used market dragging down profit, and increases the value of replacement goods (Guiltinan 2009). Adult smartphone ownership in the United States has jumped from just 35 percent in May 2011 to 77 percent in November of 2016 (Pew Research Center, 2017), meaning there are more soon-to-be obsolescent electronics in our country than ever.

As it pertains to the issue of electronic waste in the electronics life cycle, planned obsolescence occurs in three forms: limited functional life design, design for limited repair, and design aesthetics that lead to reduced satisfaction. In that first case, manufacturers deliberately limit a product's life cycle. This is illustrated in 1924, when the Phoebus cartel of light bulb manufacturers standardized that light bulbs should last one thousand hours, even though up until that point light bulbs regularly lasted up to twice that duration (Krajewski, 2014). Similarly, users of inkjet printers frequently experience similar falsities with computer chip-equipped ink cartridges. These chips are coded to stop providing ink to the printer when the ink within the printer reaches a certain level. However, in the case of the Brother HL-2140 Toner cartridge, covering its sensor after receiving an "out of ink" prompt will yield the user an additional 200 pages (Aladeojebi, 2013).

Second, some products are manufactured in such a way that they become prohibitively costly to repair when they break, prodding the consumer to replace a product as opposed to seeking repair. This principle is particularly present in Apple's line of products. One particularly offensive example finds Apple charging $49 for a battery replacement for its iPod Shuffle, which coincidentally retails for $49 (Aladeojebi). More pressing to the Lafayette community however is a construction feature of Apple's laptop computers.

According to our survey on e-waste administered to 135 Lafayette students across all four class years, 71 percent of students owned a laptop manufactured by Apple (Mapping the E-Waste

Lifecycle, 2017). The late 2013 MacBook Pro and the MacBook Air of the same generation feature batteries secured with industrial strength glue and hard drives soldered to the computer's logic board. These features, in combination with Apple's usage of proprietary screws and Apple-specific tools needed to open the computers' casings make these laptops near impossible to repair without doing so through the parent company. Repair costs out of warranty can approach the cost of a new computer, encouraging the consumer to replace instead of repair. Given that the majority of students surveyed replace their laptop computers every 5-6 years, it is likely that many members of the Lafayette community use computers that were manufactured with this construction (Mapping the E-Waste Lifecycle, 2017).

Thirdly, some products are designed in a way such that they wear quickly and appear aesthetically dated just in time for the new product to roll of the assembly line. Quick production of a new version of a product gives the consumer the perception of quality in the new product, and minute details like a new color finish or a slightly different camera bezel design are enough to give the impression that a consumer's old smartphone is no longer current. Automobile manufacturers generally make slight aesthetic changes for a model's mid-cycle refresh—usually three years into the model's life cycle—to prompt lessees and buyers to trade in for the newest model even though the vehicle is often mechanically identical.

This planned obsolescence is not just the fault of companies that produce these products. At Lafayette College, 57 percent of students replace their cell phones every 2 years or less (Mapping the E-Waste Lifecycle, 2017). These phones are more often than not still usable. The iPhone is still able to operate using data, to search through the web using wireless internet, to hold music, to call and text, to take pictures, etc. The iPhone X features a new shape, face recognition software and many other features through a new camera, though none of the necessary functions of what makes it a smartphone have changed. However, the iPhone X is currently priced at $999 (apple.com) and “a new research note from reputed analyst Ming Chi-Kuo relays that iPhone X production during the current holiday quarter will fall somewhere in the 25-27 million range… production is set to increase by upwards of 45 percent during the first quarter of 2018 (Heisler, 2017).” A new operating system does not constitute a $1000 purchase for a new device to put in one’s pocket. The consumer’s desire to have the newest piece of technology is a big part of what drives planned obsolescence.

At Lafayette College, the social context that precludes proper e-waste disposal, reuse, or recycling is lack of awareness of the problem. And amounting e-waste is in fact a problem. Electronic waste amounted to 41.8 million tons worldwide in 2014. This figure, amassed of 12.8 million tons of small equipment, 11.8 million tons of large equipment, 7 million tons of temperature exchange equipment, 6.3 million tons of screens and monitors, 3 million tons of small IT, and 1 million tons of lamps, is expected to reach 49.8 million in 2018 with an annual growth rate of 4-5 percent. The United States generated 11.7 million tons of that e-waste, about 28 percent of the world total. Ironically, though nearly all electronic waste is recyclable, only about 29 percent of e-waste in the United States is actually recycled, and only 15-20 percent is recycled worldwide (E-Waste Recycling Facts and Figures, The Balance).

At Lafayette and in the world as a whole, we can attribute much of the lack of recycling to a lack of awareness of the problem and how to remedy it. As a result of our survey we found that 89 percent of Lafayette students have little to no knowledge of the school's program for dealing with its electronic waste (Mapping the E-Waste Lifecycle, 2017). One reason for this gap in knowledge is likely that the Office of Sustainability was created only last year, appointing Marie Fechik-Kirk as its first director in November, 2016 (Kevin Gray, news.lafayette.edu, 2017). Since its founding the Office of Sustainability has been expanding programs such as the student run "Eco-Rep" program, Green Move Out, and their current administration's e-waste program, which will be discussed in more detail in the political context.

This project is meant to provide a context for the Office of Sustainability through which to expand its work into student e-waste, and we will continue to work alongside them when creating our physical maps. If the school were to have a good buy back program of electronics waste, students would likely use it. Most students see reselling or saving electronics, such as smartphones, as their only real options. Many students (we will confirm this with surveys) would likely donate their phones, or at least sell them back to the school, if they knew that the school gave e-waste to non-profit organizations to be utilized properly. In fact, as most students save their phones just in case their new phone breaks, they would likely rejoice at the convenience of selling their old phones to the college at a low price.

This illustrates the lack of availability as another social context aspect that must be addressed to properly deal with electronic waste. There are Big Green Boxes in some academic buildings that allow students to recycle items such as batteries and empty ink cartridges, but there are no real e-waste recycling options for students. Even as it pertains to the school's most publicized e-waste recycling option, Electronics Recycling Day during Earth Week, only 9 percent of students surveyed said they were aware of the event and its ongoings (Mapping the E-Waste Lifecycle, 2017). Until the Office of Sustainability implements a program, there are few options that could actually appeal to students. One potential incentive that could appeal to students is informing them of when a product (such as an iPhone) is about to decrease in value, giving students the urgency and incentive to sell back their phones before they become obsolete.

Political Context

Due to constant changes and improvements regarding living standards and technical capabilities, the use electronic products is increasingly widespread. Consequently, this means that variety in types of e-waste is growing as well. Unlike domestic waste, electronic waste is complicated in composition. It contains substances that are harmful to both human health and to the environment, such as heavy metals and recyclable materials like precious metals and resins. Proper disposal of electronics to better protect the environment and save resources has become a major issue facing human society.

Many countries regulate and promote the recycling of e-waste through legislation and the establishment of relevant policies and systems. Many developed countries and regions such as Europe, the United States, and Japan have established relatively systematic legal systems concerning the scrapping and disposal of electronic products, involving the collection of electronic waste disposal fees and the recycling of electronic waste. In the 1990s Japan and many european nations began to create legislation addressing e-waste. Japan promulgated and implemented special laws and regulations and accumulated a great deal of experience in discarding the legislation on electric and electronic products. (Ministry of the Environment, Government of Japan)

One example of a European country at the forefront of e-waste regulations is Germany. Germany is an industrially developed country and any production and living activities are based on the principle of giving priority to environmental protection. In 1991, the German government enacted the "Electronic Waste Ordinance", which stipulates that the manufacturers and importers of electronic products shall assume the responsibility of accepting the return of the electronic waste. The 1996 Law on the Confinement of Materials and Circulation and Waste Management established that manufacturers of electronic products bear the responsibility of "producer responsibility." That is, they should bear the responsibility of reducing waste generation and waste disposal. In order to further implement the EU WEEE directive, in 2005 the German Bundestag passed the "Regulations on Sales, Recycling and Environmentally Sound Disposal of Electrical and Electronic Products" to promote the recycling and reuse of electronics, thus reducing the need for disposal of hazardous substances in e-waste. (WEEE, no. 3, European Parliament)

The German collection system for electronic products covers collection points set up by public waste management agencies, commercial collection points, and producer collection points. The government set up the Waste Electrical Register (EAR) to manage the Waste Electrical and Electronic Equipment Industry Fund in Germany. (WEEE full-service website) Funds come from the producers to pay the foundation responsible for the collection of unified collection and payment of electronics disposal costs. Under the EAR system, the fees charged by the manufacturer mainly include the registration fee, capital guarantee fee, transportation fee, handling fee, etc. In addition, there are a small part of the EAR agency administrative expenses.

Rather than just legislate, Japan has really created a lasting model for e-waste recycling. The Japanese government has guided the establishment of a "recycling-oriented society" through the

"Basic Law on the Promotion of a Recyclable-type Society." A "recycling society" is a society that reduces the consumption of natural resources and reduces the environmental load by reducing the amount of waste, reusing recyclable resources, and appropriately handling them. (Japanese government, ministry of environment)

In order to achieve the strategic goal of "recycling society," the Japanese government has enacted two comprehensive laws: the Waste Disposal Law, which focuses on appropriate disposal of waste, and the Effective Use of Resources Promotion Law, which promotes the efficient use of resources. On the basis of these two comprehensive laws, a series of recovery laws for various types of waste was further developed. In 2001, Japan began to implement the "Redemption of Certain Household Appliances" ("Home Appliance Law"), clearly stipulating the responsibilities of manufacturers, importers, sellers and consumers of electronics and electrical appliances. Manufacturers and importers should handle e-waste recycling, the seller should handle the transportation of recyclables, and consumers should handle the costs borne from the recovery and transportation of the products. The implementation of the "Home Appliances Law" has not only improved the utilization rate of resources but also reduced the disposal pressure on landfills. (Government of Japan, Ministry of Economy)

In the disposal of e-waste processing fee management model, Japan did not set up similar to the German set of recovery and disposal funds. The processing of funds is required by consumers, and the flow of funds is from the consumer directly to the hands of enterprises. Its advantages save the government's management costs. However, due to a monopoly of the market by a few businesses, high processing costs result.

There are currently policies in the United States that focus on electrical wastes. The Resource Conservation and Recovery Act (RCRA) for example, aims to control the baneful waste. “The statement of the ‘Resource Conservation and Recovery Act (RCRA)’ gives EPA the authority to control hazardous waste from the ‘cradle-to-grade.’ This includes the generations, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of the non-hazardous solid waste.” (EPA website)

The purposes of the RCRA are to protect human health and environment, conserve natural resources, reduce or eliminate the generation of hazardous waste and ensure the safe management of hazardous waste. Hazardous waste regulations were designed to control the management of hazardous waste from “cradle to grave,” i.e The wastes go from generator to transport, and then to storage and finally treatment and disposal. Other agencies responsible for the RCRA include the Department of Labor, Department of Transportation, and the United States Nuclear Regulatory Commission. U.S Coast Guard and Coast Guard Reserve, U.S Food and Drug Administration and Centers for Disease Control and Prevention are also responsible for the RCRA. Part of the RCRA is defining electronic waste as “any garbage, refuse, sludge… and other discarded material, including solid, liquid, semisolid and contained gaseous material resulting from industrial, commercial, mining and agricultural operations.” Under this definition, the e-waste is also part of the solid waste. Discarded material refers to abandoned, recycled, military ammunition and anything considered “inherently waste-like.” Abandoned material refers to materials that would be disposed, burned, incinerated, accumulated, stored, or treated before or in lieu of being abandoned.

There are ways for the RCRA to identify whether the material is hazardous waste. As for the electrical waste, the wastes could be the excess material from electroplating and toxic metal finishing operations, dioxin bearing wastes, and byproducts from the production of certain chlorinated aliphatic hydrocarbons. As e-waste are potentially be flammable, reactive, and toxic, materials can be considered hazardous if they exhibit one or more of the above characteristics. RCRA would therefore take control on the wastes from abandoned and disposed electronics, thus mitigating the hazardous effect of e-waste.

The Commonwealth of Pennsylvania Act 108 also refers to the e-waste in Section 510 titled, “Electronic Materials Recycling Account”. Under this section, the literature reads “(a) Establishment.--The Electronic Materials Recycling Account is established as a restricted account in the General Fund. All proceeds resulting from the manufacturer's registration fees, renewal fees, penalties and judicial actions shall be deposited into the account. (b) Uses. --The department may expend the moneys of the Electronic Materials Recycling Account only to carry out the duties imposed on the department under this act.” The policy focused on the registration fee of manufacturers and regulating the electronic wastes from the manufacturing side. (2010 Act 108)

The National Strategy for Electronics Stewardship (NSES) is enforced by the EPA (Environmental Protection Agency). “The National Strategy for Electronics Stewardship provides four overarching goals, the action items under each goal and the projects that will implement each action item. By implementing the recommendations presented in the Strategy, developed by an interagency Task Force, the federal government will lay the groundwork for improving the design of electronic products and enhancing our management of used or discarded electronics. This Strategy provides a roadmap of how the federal government can use its authorities and leverage resources to seize this opportunity.” The NSES was aimed to achieve the following goals. (epa.gov)

1. Build incentives for design of environmentally preferable electronics and enhance science, research, and technology development in the United States.
2. Ensure that the federal government leads by example.
3. Increase safe and effective management and handling of used electronics in the United States.
4. Reduce harm from U.S. exports of electronics waste (e-waste) and improve handling of used electronics in developing countries.

Different schools also have different regulations and policies relating to the management of the electronic waste. University of Chicago for example, uses an on-demand e-waste recycling service to serve the campus community. By 2025, the university aims to reduce the greenhouse gas emissions by 20 percent. The University of Stanford has locations for the disposal of all electronic devices for students. Students could choose their housing based on the drop off locations of the electronic wastes. This policy says that "Only small, non-capital equipment may be placed into these collection containers. For large volumes of these wastes and disposal of larger components (i.e. computers, monitors, printers, etc.), you are required to coordinate disposal through your Department Property Administrator." (ehs.stanford.edu)

University of Michigan and the Ann Arbor Public School system have co-sponsored a community-wide e-waste recycling event every spring since 2008. Materials accepted include computer systems and accessories, two-way radios, office equipment, home theater equipment, and cellular phones. In terms of what happens to the recycled e-waste, organizers state that, "All equipment is destroyed and recycled in an environmentally sound manner by a fully licensed recycling facility in North America. Equipment is manually and mechanically disassembled; shredded into small pieces of metals, plastics, and glass; and separated into reusable commodity streams used to manufacture new materials. The facility is also Responsible Recycling Practices (R2) certified. Responsible Recycling Practices (R2) is recognized by the EPA as a third-party certification for electronics recyclers to ensure the proper disposal of used electronics." (sustainability.umich.edu)

At Lafayette College, we are now processing policies that focusing on electronic wastes and hazardous materials as well. In the "Hazardous Waste Management Plan" that enacted by the public safety, Lafayette College focused on the management of hazardous chemical wastes that are generated at the college. Among the chemical wastes there are some overlaps with the electronic wastes. Therefore, the college are undertaking the electronic wastes in the hazardous waste management plan. In Lafayette, there are also electronic policies that applies to college-owned computer and electronic devices that are being replaced. The three possible dispositions are “reuse, donate and recycle.” The following is the summary of the policy that relates with the disposition. (its.lafayette.edu)

- Reuse: the machines still have value to Lafayette and will be reused on campus.
- Donate: the machines are of no value to Lafayette but may be usable by an outside non-profit agency; we will donate them to those qualifying organizations that have requested used equipment.
- Recycle: the machines have no value, and must be recycled by an e-waste processor.

In this project, we are concerned with the sustainability office and our goal is seeking the right policies for the electronic wastes in campus. By learning from the policies all over the world and other universities, Lafayette College is seeking for a better policy that is sustainable and effective.

Chart for e-waste programs at liberal art colleges

College name	office	Program	websites
Occidental College	● Sustainability Office in Facilities ● Sustainability Committee ● Green Revolving Fund	● Composting ● Release-to-Print ● Eco-Clamshell Program ● Hand Dryer Installation ● Sustainable ReCycle Sale ● FEAST Organic Garden	https://www.oxy.edu/sustainability/campus-sustainability/waste

		Compost Pile ● Department Recycling	
Austin College	unknowns	Austin College Thinking Green The great day of service	http://www.austincollege.edu/e-waste-recycling-a-success/
Luther College	Facilities management office	Dynamic recycling	https://www.luther.edu/its/blog/?story_id=501389

Technical Context

The technical context that comes with mapping the life cycle of electronic waste is a grand portrait of the technologies we chose to analyze, bisected by the comparatively brief period of time during which the user interacts with the product. Though often absent from the mind of the consumer, what happens before and after the user's time with the device is crucial to understanding a product's life cycle.

For instance, Apple's iPhone 6s is composed of much more than the handsome aluminum case and glass screen that users interact with. Within that aluminum casing lies the powerhouse of Apple's smartphone, its lithium cobalt oxide battery which contains aluminum, cobalt, graphite, and lithium . Aluminum can also be found in elements of the smartphone's screen. The micro-electrical connections within the phone utilize different elements for different applications. For instance, silver is used in areas of the device that require maximum conductivity, though gold connections are in place where longevity is of the highest priority, as gold never tarnishes. Copper and tungsten are utilized as well in electrical applications. Apple's A9 processing chip is composed mainly of silicon, though it is treated with a variety of other elements to idealize its electrical properties (Desjardins, 2016).

Ethics are part of the conversation when it comes to the composition of micro-capacitors present in the iPhone 6s and various electronics across the market. Tantalum, the element used in manufacturing the micro-capacitors that control energy flow inside modern electronics is extracted from a dull ore called coltan. In 2013, 44 percent of the world's tantalum came from coltan mined in the war-torn regions of the Democratic Republic of the Congo and Rwanda (Papp, 2015). The DRC is a perfect example of a country that has suffered from what is known as the resource curse. When a nation rich with resources begins profiting from those resources, those profits have a tendency to provoke and sustain internal conflicts as different groups fight over control of said resource (NGRI, 2015). A series of civil conflicts has made the DRC one of the most violent places in the world. More than five million have been killed in the DRC since 1998, and rape and slavery are far from uncommon (Browning, 2015).

Apple made a claim in 2014 that they had audited all smelters of tantalum in its supply chain, and that none of those smelters used tantalum mined from high-conflict areas of the Democratic Republic of the Congo (Browning, 2015). That being said, given the context in which coltan is mined in that area of the world, it is difficult for Apple or any electronics manufacturer to be sure that none of that material makes it into its products. Because tantalum ore is sold not through easily monitored commodities exchanges but through a network of undocumented dealers, regardless of the confidence with which Apple insists their tantalum is conflict free, it is impossible for them to say for sure.

Once consumers dispose of their electronics, we are faced as a society with a multitude of problems. There is far too much e-waste that is difficult to process, and e-waste presents enormous potential risks, though properly recycling e-waste presents enormous potential benefits when properly taken care of. Therefore, it is crucial that engineers and scientists find out how to treat these e-wastes wisely and efficiently. There are different approaches toward separating the valuable and potentially hazardous materials present in the electronic waste. For metals, methods are fusion, refinement, and electrolysis. For non-metals, methods are landfill, burning, and pneumatolysis.

E-waste is composed mainly of metals, ceramics, glass, resin fiber, plastics, rubber, semiconductors, and composites though the proportion of useful materials is higher than other forms of waste. (Kong, Liu, Zeng, 2012) Raising the percentage of e-waste that gets recycled would greatly reduce the amount of waste avoid additional environmental pollution. Some materials are harmful to the human body, some being extremely toxic. When the material is sent to a landfill or burned, the heavy metals therein penetrate into the soil, rivers, and groundwater, which will cause pollution to local soil and groundwater. Materials post-incineration release harmful gases such as highly toxic dioxins, furans, and polychlorinated biphenyls.

As the goal of recycling electronics is to recover the raw materials within their components, we sought to highlight the elemental raw materials in our visual representation of the life cycle of the iPhone of a typical Lafayette student. Reading left to right, our visual representation will include three stages of that life cycle: before use, during use, and after use. The raw materials will be representing the early stage of the life cycle on the left side of the poster, with a sublist of the components in which those raw materials are used. In the center of the visual will be an image of an assembled and functioning iPhone in the form that users are most familiar with during use. The right side of the poster will be broken into three subsections representing three possible routes for an iPhone past its traditional life span. Those subsections are donation, recycling, and waste.

Below are charts showing the data relating to the E-waste recycle. Chart 1 shows the percentage of different components in several typical electronic devices. It provides a few examples from a computer to a dishwasher. The second chart shows the elemental breakdown of a wasted circuit board. The data reports the composition of a circuit board regarding different metals, oxides, and plastics. Chart 3 shows the process of the way in which society deals with electronic waste today. From the chart, we can see that we could be recycling the electronic elements, purified metals, plastics, and glasses. Following are the charts for the e-waste treatment-related information. The chart is cited from a Chinese version of paper by Chen and the following chart is a translated version) (Chen, 2013)

Chart 1 several typical electronic devices' components (percent) (Recycle model)

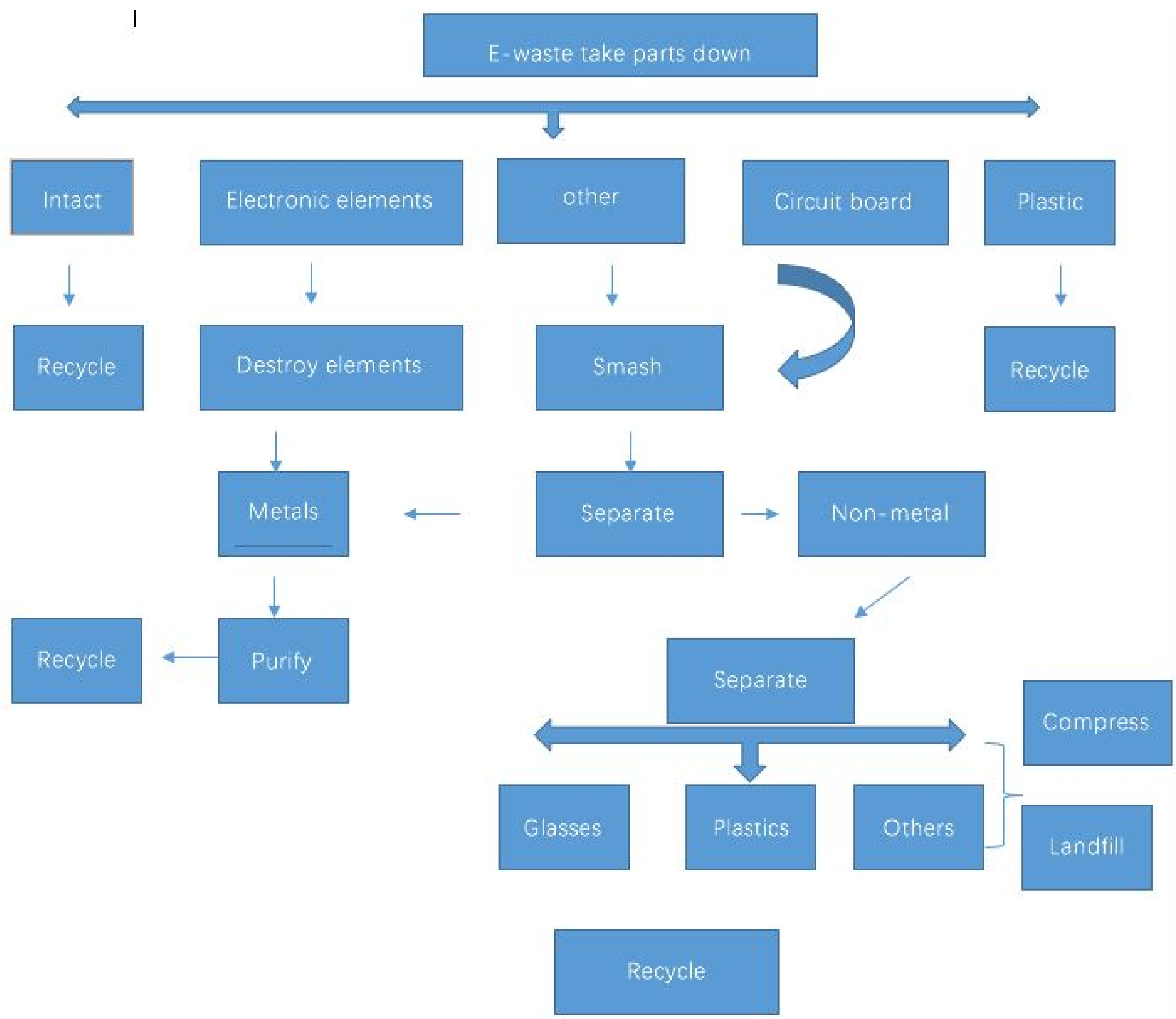
type	Black metals	Non-ferrous metals	plastics	glass	circuit
computer	32	3	22	15	23
telephone	<1	4	69	NA	11
tv	10	4	10	41	7
dishwasher	51	4	15	NA	<1

Chart 2 Wasted Circuit board's typical component(percent)

component	percent	component	percent
Cn	20	Si	15
Zn	1	Al2O3	6
Al	2	Alkane earth metal	6

		oxides	
Pb	2	Other oxide total	3
Fe	2	Nitrogen containing polymers	30
Sn	4	C H O	1
Other	1	Halogen	25
Total	40	Plastic total	30

Chart 3 Process (Kun, 2006)



Even though there are sources of e-waste, there are commonalities in their materials. E-wastes are typically split into the printed circuit board, cable, wires, picture tubes, and other common components. How to recycle these materials has been a problem for a long time because if its complexity. During the 1970s, e-waste recycling was focused on the recovery of precious metals. But as the technology developed, we could also recover ferromagnetic material, non-ferrous metals, and organic substances. Many countries have performed research on the “disposal study” and developed ways to recover useful components, stabilize or remove harmful components, and reduce the impact on the environment. The current methods of disposal of electronic waste are chemical treatment methods, heat methods, mechanical treatment methods and electrochemical methods, or a combination of several methods.

Mechanical Treatment

The mechanical treatment of electronic waste involves utilizing the physical properties of components in sorting, demolition, crushing, and other steps. Following this process, we can access metal, plastic, glass and other renewable raw materials. This method boasts benefits of low cost, simple operation, and low secondary pollution. It is easy to achieve the advantages of a large-scale treatment process. Thus many countries are focusing on the development of mechanical treatment.

Disassembly of electronic waste is usually handled manually for recycling so useful electronic components can be collected. But due to a large number of components and the complexity of the devices hand-processing efficiency is very low. Japanese companies developed a set of automatic disassembly device that can separate these components. These devices mainly use infrared heating and in a two-stage (using vertical and horizontal impact force respectively), to perforate surface elements off. As a result, they will not cause any damage to the electronic elements. German companies use the automatic assembly of the circuit board which is the opposite principle of disassembly. They first put the wasted circuit board into the heated liquid and then melt it, then use a mechanical device to sort out available components based on their shape.

Breaking or crushing is a more efficient way to achieve the separation of electronic waste monomers. The key to making a device "Broken" is the choice of degree of fragmentation because it not only affects the energy consumption of crushing equipment but also affects the subsequent sorting efficiency. A device can be "Broken" through some methods, such as impact crushing, cutting, and crushing. Also, there is wet crushing and low-temperature crushing. The typical equipment involved in crushing includes hammers, choppers, rotary crushers, and many others. To improve e-waste crushing effects and reduce energy consumption for different materials we must choose the right way to crush, which depends on varying characteristics of materials.

The mechanical separation of electronic waste mainly draws on the physical differences between substances, such as density, electricity, magnetism, shape and surface characteristics, etc. Selecting the appropriate sorting method will greatly improve the efficiency of sorting, and reduce the difficulty of subsequent processing and improve recovery efficiency.

Mechanical treatment is currently the most widely used method of recovering precious metals from electronic waste. The snow treatment method is based on the physical characteristics of the material, such as density, conductivity, magnetism, and toughness. Mechanical treatment methods include manual or mechanical disassembly, crushing and sorting techniques.

E-waste can be rich in many types of precious metals. Among the existing methods for leaching metals such as gold, the cyanide leaching process is often applied. However, the toxicity of cyanide is extremely harmful to the environment and human health, greatly limiting the usage and net benefit of this method (Samantha Boh, 2016)

Thermo-metallurgy

By definition, "Metallurgy is a domain of materials science and engineering that studies the physical and chemical behavior of metallic elements, their intermetallic compounds, and their mixtures, which are called alloys." Thus, thermo-metallurgy means using the heat and fire to study the chemical and physical properties of metals. The basic principle of pyrometallurgical metallurgy furnace is the use of high-temperature heat stripping of non-metallic materials, precious metals fused to other metal smelting materials or molten salt, and then be separated. Non-metallic substances are mainly organic materials on the printed circuit board, generally separated and removed from the scum, while precious metals and other metals were out of the state of gold, in the refining or electrolytic treatment. Metallurgical pyrometallurgical extraction of precious metals is simple, easy to operate and high recovery rate, but due to the presence of organic pollutants in the incineration process produces secondary pollution caused by harmful gases, a low recovery rate of other metals and processing equipment, and other shortcomings, the current method has been Gradually eliminated. (Thermal, Metallurgical and Mechanical Phenomena in the Heat Affected Zone)

Hydrometallurgical technology

The fundamental principle of hydrometallurgy technology is to utilize the chemical properties that allow precious metals to be dissolved in nitric acid or other reagents, separating precious metals from other substances and to recover them from the solution. The most commonly used in hydrometallurgy is nitric acid.

Hydrometallurgy takes place in three steps: pretreatment, leaching of the element, and precipitation. Select electronic waste containing precious metals is broken with a crusher to a certain particle size and then heated to 400 degrees Celsius to remove organic matter. The pretreated parts are immersed in a certain molar concentration of a nitric acid solution and heated. The precious metal, base metals, and metal oxides are dissolved in hot nitric acid and filtered to obtain a nitric acid solution containing the precious metal and other non-ferrous metals. Continue to soak plate with aqua regia, gold, palladium, and platinum dissolved in aqua regia solution, filtered, the filtrate after evaporation concentrated sodium sulfite or oxalic acid, formic acid, ferrous sulfate and other reducing agent precipitated gold in the filtrate, and then extract or ammonia precipitation Palladium and platinum in solution.

Compared with pyrometallurgical hydrometallurgy, hydrometallurgy has the advantages of less exhaust gas emission, easy extraction of precious metal residues, and significant economic benefits. The main disadvantage of hydrometallurgical technology is the expensive chemical reagents, complicated process and a large amount of waste water, which is hard to handle. At present, hydrometallurgy technology is still improving and developing. (Hydrometallurgy). The following equations show the chemical process of hydrometallurgy. (Progress of Electronic Waste Treatment) (Wu, Guo, 2006)

Hydrometallurgy Chemical Process

$Ag+2HNO_3= AgNO_3+NO_2\uparrow+H_2O$

$Au+4HCl+HNO_3=HAuCl_4+NO\uparrow+2H_2O$

$3Pt+18HCl+4HNO_3=3HPtCl_6+8H_20+4NO\uparrow$

$3Pd+18HCl+4HNO_3=3HPtCl_6+8H_20+4NO\uparrow$

$2HAuCl_4+3Na_2SO_3+3H_2O=2AU\downarrow+3Na_2SO_4+2HCl$

$H_2PtCl_6+Na_2SO_3+H_2O=H_3PtCl_4+Na_2SO_4+2HCl$

Microorganisms

The use of microorganisms is a new technology. The use of microbial activity makes gold and other precious metal alloys and other non-precious metals oxidized into the solution and making metals to uncover themselves to collect easily. Biotechnology to extract gold has the advantages of simple process, low cost, and simple operation, however, the time for leaching is long. (NUS study)

Design Principle

1. Easy to disassemble

Hazardous components are easily separated; Fasteners are reduced; Plastic and alloy types are reduced

2.Do not need to disassemble

Materials that are not easily disassembled Select materials of the same kind or materials that are compatible with each other so that the entire assembly can be recycled without disassembly

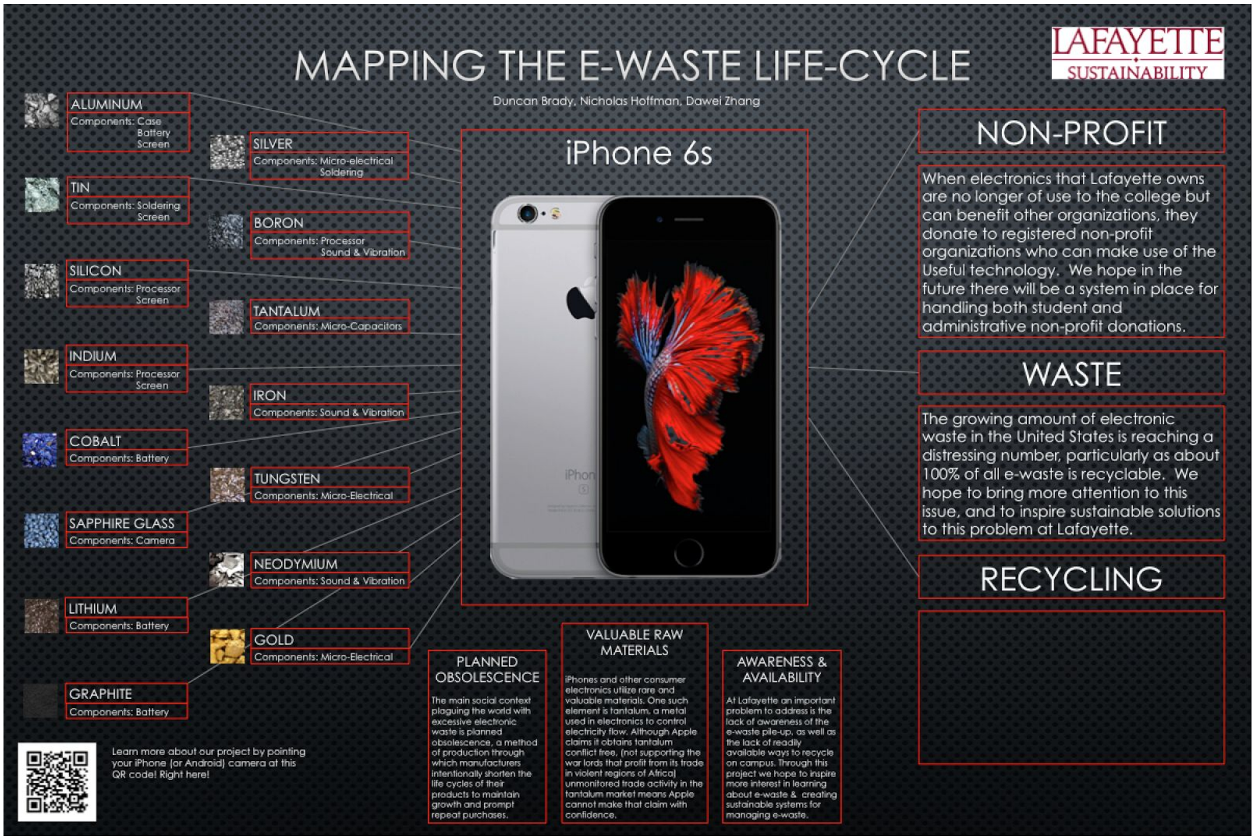
3.Easy to heat treatment

Plastics used in the manufacture should ensure high purity, create conditions for micro plastic sorting and heat treatment

4.Green design

Use environmentally friendly materials and recycled materials (Disassembly and Recycling)

Our representation of the e-waste lifecycle at Lafayette will focus specifically on that of the iPhone 6s, released in September of 2015. Of students surveyed at Lafayette College, 85 percent owned a cell phone in Apple's line of iPhones (Mapping the E-Waste Lifecycle, 2017). We feel that in order to have the most effective visual representation of the life cycle of electronic waste, it is necessary to focus in on a device that students are familiar with. Additionally, in researching the elemental breakdowns of smartphones, laptop computers, and high-definition televisions, we found that from an e-waste perspective these devices are largely the same. Therefore, an image of a 2015 model iPhone 6s will be the centerpiece of our diagram.



Information will be presented left-to-right, with the elemental breakdown of the phone on the left representing life before student ownership, and short paragraphs describing different potential paths for life after student ownership. We decided to present the information for before ownership based on the elements that make up components in the phone, rather than structuring based on the components themselves. Presenting the elements as the most important aspect of the pre-ownership life cycle emphasizes that these are the potentially valuable but also potentially harmful materials inside an iPhone that are so important to recycle or dispose of properly.

The structure of our design came from research regarding how members of the community respond to data being presented in different ways as well as how we anticipate students interacting with the design. Based on studies to examine how patients make decisions given health care information presented in different ways, people are more likely to make informed decisions when presented with visual cues rather than just a graphical data representation (Peters, 2007). Therefore, we added light gray lines connecting each element to the iPhone they would eventually amass and the same light gray lines connecting the iPhone to the different paths representing the end of its life cycle. This illustrates continuity across the figure, reminding the viewer that the elements on the left-hand side of the figure are the same materials being donated, recycled, or thrown away on the right-hand side. We also consciously avoided filling the poster with numbers and statistics, as information presented numerically can be less effective than information presented in prose. According to the National Adult Literacy Survey, almost 50 percent of American citizens lack the numerical literacy and mathematical skill necessary to process the numbers embedded in printed material (Kirsch, 2002). Although the level of numerical literacy is likely higher at a well regarded academic institution such as Lafayette, it is important that the visual representation of the life cycle be as accessible to the viewer as possible.

For those viewers who are interested in learning more about the details of our project, a QR code will be provided in the bottom left corner of the poster. Upon aiming the camera of an iPhone or similarly capable Android device, software within the device will extract a link from the QR code, prompting the user to visit the web page at that address. The code will link to the Electronic Lifecycle page at the Engineering Studies Fall 2017 Capstone website. There the reader will be presented with well-organized links to the different sections of our report, exploring the different contexts surrounding the issue. This resource will ensure that more information is available to those who seek it out, though it does not guarantee that the information will be current.

In order to maximize the longevity of our project, one section of our poster will remain blank by design. One of the three pathways we chose to highlight for post-ownership electronics is to recycle them as electronic waste. As we found that only 15 percent of students surveyed could confidently report that they knew how to recycle their e-waste, we thought it necessary to include a dynamic section of the poster to accurately report where students can recycle e-waste even as those locations change throughout the years (Mapping the E-Waste Lifecycle, 2017). The Office of Sustainability will be responsible for regularly updating the posters around campus to display up-to-date information on recycling locations.

Economic Context

This project has a broad focus because it contains information involving processes inside and outside the Lafayette College community, focusing on the overarching problem of e-waste buildup in the world, but seeing how this applies to the Lafayette community. This analysis of the economic parameters of this project applies mainly to the Lafayette community, or mainly in the ways that this project applies to the Lafayette community.

One of the most important aspects of completing an effective electronics life cycle analysis is taking into account the cost of the electronics. Particularly, the most important aspects are the materials that make up the iPhone, the cost of the product, and the price or cost to the consumer at the end of its useful life. Taking into account all of these parameters, we decided that a Technical Cost Model (TCM) would be the most effective way to represent the important monetary values at play in this project. A Technical Cost Model breaks down a product into its basic parts and models the costs for those specific inputs and outputs. By collecting this data from the actual life cycle, we can show members of the community the value of what they and the rest of society are paying for.

Technical Cost Model (TCM)

The raw materials were chosen as an economically important aspect of the e-waste life-cycle to the Lafayette community because they are the first and one the last steps in the life of the product. The raw materials are a large aspect of why e-waste recycling is an important topic. As shown in the model, these materials can be very valuable and almost all e-waste is recyclable. The materials include are the main materials, and do not include some rare earth metals that are mainly used for aesthetic purposes. They can also have very interesting backgrounds, as these materials come from all of the world. The origins of these raw materials can create more interest in recycling them, and understanding the stakeholders and value is a key part of that. For example, one such element is tantalum, a rare lustrous metal used in microprocessors to control electricity flow. Although Apple claims that it obtains its tantalum conflict free, as opposed to supporting the tyrants and warlords that profit from its trade in the Democratic Republic of the Congo and Rwanda, the frequency of unmonitored trade activity in the tantalum market means Apple cannot make that claim with confidence. Apple does not make any such claim for gold, tin, or tungsten, similarly conflict-associated materials (Desjardins, 2016).

Raw Material	Price/Unit
Aluminum	$0.97 / lb
Copper	$3.09 / lb
Gold	$18,651.75 / lb
Silver	$246.94 / lb
Nickel	$5.14 / lb
Tin	$9.24 / lb
Iron Ore	$0.03 / lb (dry)
Sapphire Glass	$15-30 / display
Lithium	$9.07 / lb
Silicon	$0.91 / lb
Tantalum	$56.18 / lb
Indium	$135-170 / lb
Neodymium Oxide	$42.84 / lb
Cobalt	$30.39 / lb
Tungsten	$25.52 / lb
Graphite Flakes	$0.45 / lb
Boron (Amorphous)	$907/ lb

Because we focused heavily on the cost of the raw materials themselves, we did not touch on the cost of the components that the raw materials make up. This would have included the manufacturing of the components, and the salvage value. The main reason not to mention this as an important economic aspect of the life-cycle to the Lafayette community is because students are not involved in that process, are unlikely to resell parts of their iPhone, and the components have different resale and recycling values depending on the buyer of the used components. We also do not intend to model the cost of a product's design or that of its software/operating system. For the purposes of this lifecycle map, we are focusing the vast majority of our efforts into the physical aspects of the products, as the software is not the tangible part of electronics that manifests e-waste. Though costs of steps in the overall creation and mass production of widely used products are important to take into account when evaluating costs of bringing the iPhone to market, they are not important in mapping the physical product. This is why such steps as design of the product, design of the operating system, software download and quality assurance, assembly and distribution, are not included in this economic model.

iPhone 6S 128GB
Original Price: $849
Current Price: $549
Apple Buyback Value: $200
Years Available for Purchase: 2

The next part of the TCM is the price of the iPhone. For the purposes of this project, we thought it was particularly important to focus on the cost over time in the model. For this reason, the original price listed for the iPhone in late 2015 is visible, as well as Apple's current price for the same product, and the current listing on Apple's site for the salvage value. As mentioned in the introduction and social context sections, planned obsolescence as a manufacturing ethos is a crucial influencer of the electronic life cycle. Products are meant to have a set lifespan before being replaced by their updated successors. For the most part, Apple produces a new or updated model (i.e. iPhone 6s, iPhone 6s Plus) of the iPhone on a yearly basis. Normally, each time Apple produces a new model, the model that preceded it will decrease in price by $100 (Broida, 2017). Additionally, through a study done in 2013, Usell.com found trends within weeks weeks of the launch. They found that "Two weeks after a new phone launch, old iPhones lose about 11 percent in value. Four weeks after launch, old iPhones depreciate about 15 percent. Six weeks after launch, old iPhones depreciate about 18 percent. By week seven, old phones are worth about 21 percent less (Huddleston, 2014)." As shown in the model, two years after the iPhone 6s was released, its price from its own producer has decreased by $300, instead of the average $100 per year.

The TCM does not, however, include the cost of the actual recycling process. This is because not only Lafayette, but individuals, corporations, other colleges etc., do not participate in the process of physically stripping down old electronics to their raw materials. For our purposes, we are focusing on how Lafayette recycles its e-waste. Our project is not about evaluating the practices of the companies that perform the services laid out in the technical section. We will continue to focus on finding information from the school on the cost of Electronics Recycling Day, now through Information Technology Services. Our focus on these sources of recycling is more aimed at its cost-benefit ratio to the consumer (members of the Lafayette community) as opposed to throwing away or keeping old electronics.

Cost to School to Recycle
Price of Big Green Box Bins: $63

It also does not include the cost of recycling products at Lafayette. This is because particularly for students, there is not really a system in place to handle e-waste, besides Electronics Recycling Day, which is free for students to participate in. Responsible Recycling Services is the organization that handles Electronic Recycling Day, and could be used in the future if the school wanted to bolster its program. However, the scope of this project is mapping the current e-waste life-cycle at

Lafayette, not to plan and model a possible future system. The current system that is in place for students are the Big Green Boxes. The school uses the company Big Green Box for recycling student and faculty batteries. According to Marie Fechik-Kirk, Director of the Office of Sustainability, the school has about 10 of these boxes out at a time. Each box includes the transportation and disposal costs, and cost $63 each. These boxes hold 43 pounds of batteries (BigGreenBox.com).

Another aspect in addressing e-waste involves tax deductions, the most intuitive being charitable donations. Whether donating money, clothes, or electronics, “charitable donations” to nonprofit and charity organizations are often used for tax exemptions. Deductions of $500 or below are allowed to be self-reported, so individuals can actually report the prices that they believe are at “fair market value.” Values must be reported through a 1040 federal form. Donations exceeding $5000 require written appraisal of the property’s fair market values (On Earth Day, 7 Tax breaks for Going Green). Any of these donations must be to a qualified “charitable organization,” which can be confirmed by the Internal Revenue Service (IRS) Exempt Organizations Select Check. (Phillips, 2017)

Tax incentives for recycling are mainly focused on larger companies rather than individuals. The Environmental Protection Agency (EPA) does not offer any direct credits or rebates. “[The EPA] does keep a listing of state programs that provide incentives to companies. Twenty-five states have some type of program, usually tax incentives or credits, to promote recycling market development. Some states offer a fixed amount of money. Delaware gives $500 towards equipment costs, as of August 2011. Others offer a percentage of value that can range from 10 to 50 percent. (Sanders, 2017). For states that offer percentages, the value of electronics can be significant.

In terms of dealing with electronic waste, Lafayette is an institution that donates its e-waste, which is one potential option to minimize the amount of e-waste that ends up in landfills. In particular we focus on the properly certified non-profit agencies to which Lafayette donates electronics that do not have value to the college, but have value to "qualifying organizations that have requested used equipment (its.lafayette.edu)." After speaking to Marie Fechik-Kirk, we found that the school is listed as a tax exempt organization, so any tax exemptions that may serve as an incentive to recycle e-waste are moot. Lafayette qualifies under section 501c of the Internal Revenue Code of the IRS (Exemption Requirements - 501(c)(3) Organizations, irs.gov) because they are an educational institution. Tax breaks, therefore, are not relevant to the school. Fechik-Kirk also said that any fines for not recycling electronics waste are likely few and do not provide sufficient incentive to the school.

The school does not technically have a strict monetary incentive for bolstering its current recycling program. However, a very important incentive to take into account for doing so is publicity. Implementing sustainable practices throughout an institution is a very hot topic, particularly for schools that have dominant programs in engineering. Marketing a school is therefore very important in bolstering a school's image, and the school's image and rankings are economically very important because it can increase the inflow of applications, overall publicity, and possible donations. Creating a sustainable environment is part of creating a better and more inviting college environment. This bolster ratings which boosts publicity. The average college campus spends about $1190 on marketing per student. About 56 percent have attributed increases in both applicant quality and perceived academic reputation to the work of their marketing functions. (Hanover, 2014) These reputations do matter a lot. For example schools landing in the U.S. News and World Report's Top 25 will experience a 6-10 percent increasing in the volume of incoming applications. Schools making Princeton Review's Top 20 Best Overall Academic Experience will see a 3.2 percent surge in applications. In fact, colleges that move just one percentage point upward in U.S. News rankings will see a corresponding 1 percent increase in applications received. (Tomar, 2016)

Conclusion

This project involved mapping the electronics waste lifecycle at Lafayette. After much research into the raw materials that make up e-waste at Lafayette, we found that because the raw materials were common throughout commonly used electronics (cell phones, laptops, televisions, etc.), that mapping the iPhone was the best method, and that creating a physical display was the most effective way of conveying all of the information to students.

Our map will be printed and displayed in many high concentration academic buildings throughout campus. We have been assured by the Director of the Office of Sustainability, Marie Fechik-Kirk, that they will oversee the placement of the posters and their continual presence in the academic buildings.

The long-term goal of this project other than mapping the electronics life-cycle was to add some form of impact to the Lafayette campus. Lafayette College does not have a system in place for students to recycle their e-waste, and as we later learned, the system on their site is not very well documented or organized in practice. Additionally, the campus community is not educated on e-waste as a whole and how large a problem it is in the world at large. Our display is therefore meant to be a constant, informative, and aesthetically inviting potential solution to this problem.

Additionally, the Lafayette College Sustainability logo is in the top right corner of the poster. By connecting the poster with the Office of Sustainability, we have made the project both a symbol of their department at Lafayette, and part of their responsibility. Beyond our work in this semester, we are not likely to continue working on the project. The presence of the poster is just the first step in making sure this work is complete. This is why we have placed the responsibility on the school.

The poster lends itself to longevity as well. As suggested by Marie Fechik-Kirk, the poster's "Recycling" section is left blank for the Office of Sustainability to periodically update with current locations at which Lafayette students can recycle their e-waste.

Another way in which we focused on student inclusion and longevity is by implementing the surveys. The 135 person survey with at least 30 students from each future graduating class was meant to include students in our work. This survey was meant to initially get students thinking about how they contribute to the e-waste problem at Lafayette, and how they can lead their lives slightly differently in return for more environmental stability.

The survey is also meant to inform the Office of Sustainability. We may have used this survey for our own statistics about how little students know or understand about electronic waste, but the office of sustainability can use the surveys to make their future e-waste program. We have kept all of the surveys and are giving them to the Office of Sustainability, as well as any other useful information we have gathered on the subject. The Office of Sustainability now has information on what students do and do not know. They can use this information to correctly implement a system that has the necessary outreach to students. As shown in the survey, there are a very large number of students at Lafayette who know how to recycle their e-waste on Electronics Recycling Day, the school's one form of campus-wide electronics recycling. Possibly marketing the program more or differently could increase the way that students approach recycling on campus.

The school could market recycling more in many other ways. Marie Fechik-Kirk also brought up putting the Big Green Boxes and our display together in the select academic buildings. This could help students actually understand where to use and how to use that. The school could also send memos about when particular electronics are about to decrease in value due to planned obsolescence, such as when a new iPhone is scheduled to be released, so students are more likely to capitalize on the possible economic value of their older versions of the iPhone.

This project is meant to show that one group of students in their senior capstone class cannot both find and decide a way to reach students and implement an entirely new system that can solve all problems involving electronic waste. This project is meant to lay a foundation through which the Office of Sustainability can work with other interested groups or individuals to create a lasting and effective system to recycle electronic waste. There are many incentives for both students and the administration to do so, and organizations such as Responsible Recycling Services or Big Green Box have already worked with the school, and if nothing else can provide added insight and aid to creating this lasting system on Lafayette's campus. The goal of future work should be to not only make this system sustainable, but to figure out a way to tailor it to reach students, who as shown in the survey, have many sources of electronics that are valuable and almost always readily recyclable.

We’ve taken the steps necessary to ensure the longevity of our project, which will remain visible on campus for years to come. Next semester, whether it be the Office of Sustainability, a future capstone group, or a Sustainable Solutions class, the work we’ve done over the past three months will continue to move forward in bettering the environmental impact of our community.

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