Technological Recycling of Used Electronics

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Problem Statement:

How might we increase the amount of electronic waste collected in the Southeastern United States?

Problem

Who: All consumers who regularly purchase and dispose of electronics contribute to the problem in small parts, but as a whole, they create a grand challenge. The improper disposal of electronics affects anyone living in the areas surrounding informal disposal sites around the world.

What: Used electronics are either not being disposed of or are being improperly disposed of, leading to environmental damage and health problems.

When: The problem has existed ever since the rise of consumer electronics, but the problem worsens annually as consumers purchase and dispose of more electronics.

Where: The lack of collection of e-waste is a problem in several regions of the United States, especially the Southeast, while the environmental damage and health problems are significant in China, India, and many developing countries.

Why: When electronics are disposed of improperly, they release heavy metals and other toxins into the air and the surrounding groundwater, causing numerous health problems. In addition, the increase in consumer electronic use and planned obsolescence are causing the problem to grow exponentially, so existing solutions cannot keep up.

Significance

Improperly disposing of e-waste can irreparably damage the environment and can put the lives of both disposers and innocent bystanders at risk. One of the most common informal disposal methods is burning electronic waste to reclaim precious metals, a process that releases dangerous toxins (e.g. cadmium, lead, copper, nickel, mercury, dioxins, and hydrocarbons) into the air and the ground (Hieronymi, Kahhat, & Williams, 2013). These toxins can affect local resources and contaminate groundwater (Hieronymi, Kahhat, & Williams, 2013). If they find their way into the human body, the toxins can lead to cancer, lead poisoning, reproductive disorders, and other health problems ("About e-Waste," 2016). As an example, the residents of Guiyu, one of the world's most prominent e-waste recycling sites, have experienced digestive,

neurological, respiratory, and bone problems. In fact, a study found that “80 percent of Guiyu’s children experience respiratory ailments and are especially at risk of lead poisoning” (McAllister, 2013).The toxins that pollute the soil and air can also contaminate plants, including food crops ("About e-Waste," 2016).

In addition to causing health and environmental issues, the improper disposal of e-waste represents a missed economic opportunity. Electronics often contain both precious metals (e.g. gold, silver, and platinum) and rare earth metals (e.g. neodymium, praseodymium, and terbium), which are in increasingly high demand and short supply. By not properly recycling e-waste, these resources are quickly being consumed without being adequately reclaimed ("Recovery of Rare Earths," 2015), leading to a significant potential loss. For example, in 2014, about 300 tons of gold were estimated to be in e-waste (Balde, Wang, Kuehr, & Huisman, 2015), valued at about $11.7 billion. Combining that with the other valuable metals and plastics found in e-waste, a total of roughly $54.1 billion could have been reclaimed from e-waste in 2014 (Balde et al., 2015).

What are the possible causes of the problem?

Part of the problem lies in the policy regarding e-waste — or rather, the lack thereof. In the U.S., there is no federal legislation regulating e-waste recycling; any legislation that has been implemented is on the state level. Even then, only 27 states have passed any kind of e-waste legislation, and the nature of those laws varies from state to state. The Southeast is one of the worst regions in the country in terms of their lack of e-waste legislation ("E-WASTE: The Exploding," n.d.). In addition, the U.S. is one of two countries not to ratify the Basel Convention, an international treaty that aimed to stop the export of e-waste to developing countries ("Parties to the Basel," 2011).

Some of the problem stems from the culture regarding electronics and their lifespans. Electronics manufacturers have increasingly implemented planned obsolescence, a business strategy in which manufacturers frequently release new products that make their older models obsolete. As a result, people throw out electronics at a higher rate than ever before. Also, some products — for example, many Apple products — are manufactured in a way that makes them unrepairable when key components such as batteries and screens fail, leading to an even higher number of electronics that must be disposed of ("Quickly Obsolete," n.d.).

Finally, the lack of consumer education about e-waste and the effects of improper disposal contributes greatly to the lackluster collection in the U.S. Many consumers do not recycle their electronics because they are not aware it is an option, while others find it too inconvenient to justify. In some cases, consumers do not have

easy access to e-waste recycling resources. As a result, people tend to either throw their electronics out or hoard them ("Old Gadgets," n.d.).

How would society be improved if this problem were better addressed?

If the collection of e-waste increased in the U.S., less e-waste would end up in developing countries, and thus the environmental and health problems that result from improper disposal would decrease in severity (McAllister, 2013). In addition, the U.S. and other countries could save significant money on rare earth metals and prevent environmental damage by reclaiming those metals from e-waste ("Recovery of Rare Earths," 2015).

Stakeholders

Individuals: According to a World Health Organization report on children's environmental health, children are "especially vulnerable to the health risks that may result from e-waste" as they develop. The effects of the harmful toxins found in several varieties of e-waste can be seen consistently throughout developing countries, India, and China, specifically in areas where improper and informal e-waste recycling takes place. Luckily, WHO has recently taken initiatives with other humanitarian organizations to tackle the problem in these targeted areas ("Electronic waste," 2016), but there is still significant room for improvement.

E-waste companies: E-waste companies, such as eWaste ePlanet and Electronic Recyclers International, Inc., are capable of processing substantial amounts of e-waste, but the problem lies in insufficient collection. Most of the states in the Southeastern United States do not have state-wide legislative policies regarding the collection and disposal of e-waste ("U.S. Legislation," 2016). In addition to helping the environment, collecting more e-waste would generate more profit for these companies.

National governments: Governments have an obligation to protect their citizens, and in the case of countries that receive and improperly process e-waste, governments need to work to eliminate the health and environmental problems associated with e-waste. The American Environmental Protection Agency (EPA) has been cooperating with the United Nations' Solving the E-waste Problem (StEP) initiative as well as other national governments from Ethiopia and China to coordinate and better manage the flow of e-waste as well as exchange ideas on how to improve e-waste collection and processing ("Cleaning Up," 2015).

Activists: Individuals who are highly environmentally active often take their own initiatives, such as with ecoATM ("About ecoATM," 2016) or push for legislation to be passed that would allow the current solutions and recycling infrastructure to better handle the increasing amounts of e-waste generated worldwide. In these cases, the individuals are intrinsically motivated to help the environment, so they would support any promising effort to reduce the impact of e-waste.

Context and Existing Solutions

The amount of e-waste generated worldwide is massive, and it's growing. An estimated 41.8 million tons of e-waste were generated in 2014, with a predicted 4-5% growth rate leading to the possibility of about 50 million tons of e-waste in 2018 (Balde et al., 2015). In the United States alone, the average inhabitant generated 22.1 kg of e-waste in 2014, with the country as a whole generating 7.1 million tons of e-waste (Balde et al., 2015) — more than one-sixth of the global total. To make matters worse, collection is insufficient in the U.S. In 2012, only 15% of the e-waste generated in the U.S. was officially collected (Balde et al., 2015), with the rest either being thrown out with normal garbage or unofficially collected. Because the U.S. did not ratify the Basel Convention, it is likely that most of the unofficially collected e-waste was exported to other countries.

There are four main possibilities for the disposal of e-waste (Balde et al., 2015):

(1) Official take-back systems

Government services, retailers, or commercial collection companies collect e-waste, usually as a result of official legislation. From there, the waste goes to pre-processing companies, where the waste is physically broken down and the toxic components are separated. Afterward, the waste goes to end-processing companies, where it undergoes various refining and recycling processes to recover any potentially useful materials. Whatever cannot be recovered or recycled is incinerated or put into landfills (Balde et al., 2015).

(2) Unofficial collection in developed countries

Private collectors and collection companies collect e-waste, and they often refurbish and resell the e-waste. In some cases, they export e-waste to developing countries, and in other cases, they do some pre-processing before sending them to end-processing companies. This kind of collection is difficult to track, since it is based on the free trade of e-waste rather than official, regulated processes (Balde et al., 2015).

(3) Unofficial collection and informal recycling in developing countries

Motivated by the income e-waste recycling provides, individuals collect e-waste door-to-door or from imports. Once they have the e-waste, they recycle it using hazardous methods without proper training, leading to health problems and pollution (Balde et al., 2015).

(4) Disposal in mixed waste

Individuals put e-waste in normal trash containers, and the e-waste is collected through municipal waste collection services. From there, the e-waste is generally not separated from other waste, so it ends up in landfills, where it can leach toxins into the soil (Balde et al., 2015).

The distribution of e-waste between these four pathways varies depending on the country and its e-waste recycling policies and infrastructure. In the U.S., about 15% of e-waste was officially collected in 2014, but the countries in the European Union were able to officially recycle 40% of their e-waste due to their more progressive e-waste policies (Balde et al., 2015).

The existing official recycling system forms a pyramidal structure with three parts: collection at the bottom, pre-processing in the middle, and end-processing at the top. There are only a few prominent end-processing companies, while there are more pre-processing companies and an even larger number of collectors ("Recovery of Rare Earths," 2015). As a result, previous solutions have generally fit into those three divisions, and most end up working with collection because of the lower cost and resource barriers.

One such collection-based solution is ecoATM, a private collection company that utilizes automated kiosks to collect cell phones, MP3 players, and tablets ("About ecoATM," 2016). The kiosks determine the identity and condition of the device, look up the market value, and return cash to the customer ("About ecoATM," 2016). These kiosks are located exclusively in malls, large retailers, and grocery stores ("About ecoATM," 2016). The collected devices are either reused or sent to end-processing facilities ("Going Green," 2016). ecoATM has been successful within their target market, but they only collect three types of used electronics, leaving out laptops, computer monitors, and other types of electronics larger than tablets but small enough to be easily collected and recycled. In addition, their locations are not as conducive to collection, since many people do not regularly visit malls and relevant retailers. Even if people frequent stores and locations containing ecoATM kiosks, it is unlikely they would think to bring old electronics with them, especially when the presence of the kiosk is not heavily advertised.

BlueOak Resources, another existing solution, takes a unique approach based in small-scale post-processing. BlueOak Resources is a startup that began out of Mountain View, CA in 2010 ("BlueOak Team," 2016). Their solution is to create “mini-refineries” that use plasma-arc refining technology to extract valuable materials

from pre-processed e-waste — in particular, circuit boards ("BlueOak Team," 2016). They currently have one facility in the small town of Osceola, Arkansas. The facility costed approximately $35 million to construct, and it only recently began operating (Noyes, 2014). Their solution, while extremely effective in terms of recovering value from electronics, is too expensive and technology-intensive to implement on a large scale. In addition, it only covers one division (albeit an important one) of e-waste by focusing on circuit boards, and it does nothing to improve collection rates.

The negative aspects of these existing solutions reveal a need for further innovation and open up a place for our team to add value to the solution space. In the Southeast, e-waste legislation is virtually nonexistent, so there is no official residential e-waste collection system. As a result, there is a large market that has yet to be tapped to its fullest potential: collecting e-waste directly from consumers. As long as we can find a way to innovate sufficiently and improve upon solutions like ecoATM, we can make a significant impact in the amount of e-waste collected in the Southeast. Even though increasing the amount collected does not guarantee that the e-waste will never end up in a developing country, it slows down the international flow of e-waste to a more manageable level. In addition to being beneficial to the environment, such a solution would be a potentially profitable endeavor, especially given our connection with eWaste ePlanet, a well-established e-waste collector and reseller.

Why is it still a problem?

The sheer scope of the problem is one of the largest obstacles. Managing the disposal of e-waste, where it is sent, and how it is processed is much easier said than done, especially when considering the countless permutations of e-waste destinations and disposal methods. Additionally, there are obstacles in how electronics are designed, since many manufacturers utilize planned obsolescence to phase out their old electronics and increase their own profits. The issue of planned obsolescence is made even worse by the fact that some manufacturers make electronics that are difficult to modify. However, perhaps the most prevalent obstacle is the one we are tackling: motivating people to recycle their electronics instead of hoarding them or throwing them out. This has its own set of obstacles that range from finding the right incentive to actually implementing the solution in a way that is feasible and profitable ("The Problem," n.d.).

Proposed Work

Goal

Our goal is to create an innovative e-waste collection receptacle that will increase the amount of electronics recycled by individuals in the Southeast. In doing so, we aim to find a unique way to motivate people to donate electronics that they would otherwise hoard or throw away with mixed waste. If this project is successful, there would be a noticeable reduction in the amount of e-waste that is sent overseas and improperly recycled. In turn, this would decrease the severity of the health and environmental problems prevalent in areas where e-waste is informally recycled. In addition to the direct impact on the flow of e-waste, our solution would raise public awareness of the problems associated with e-waste, with the eventual goal of making e-waste recycling as common and convenient as paper and plastic recycling.

Objectives

Modeling the Receptacle

The first objective is to model the receptacle. This will allow us to solidify the details and specifications for our design, which is necessary because it gives us a clear idea going forward. It will also allow us to understand the features and applications of our solution and how it can be implemented to solve our problem. The result would be a working model that allows us to showcase a more finalized version of our product when presenting our ideas. In addition, having a model will serve as a good reference on the progress of our project, and it will allow us to have a platform to modify and adapt our idea. This is essential because this solution is adaptable and our model must be able to reflect any changes so that it reflects our current goals.

In order to successfully model the receptacle, we first need to have a finalized list of features and design details. Then, we need to sketch the receptacle in order to get an idea of the general shape of the receptacle. Before we start CAD, it is important to dimension the sketch and add features so that we have a better idea of what design process to take when starting to model. Then, we can model each of the different parts in CAD. Once all the parts are modeled, we can assemble the complete receptacle on CAD. Throughout this process, we should make sure the model is easily adaptable and can be changed using proper modeling techniques.

We hope this model will allow us to present our receptacle and receive input from various sources. Presenting the model to potential participants such as organizations and community centers can determine the success of this solution. If there is a positive response to the model, we are more likely to continue along the same solution path. However if an overwhelming amount of potential participants object to the model or a

particular feature, our team will have to adapt our solution to match our target participants' needs and wants. We would also like to present the model to focus groups of electronics consumers in order to get a better idea of the public response to different features of our receptacle. The model would also be unsuccessful if there are problems in modeling or assembling the components that cannot be fixed in CAD. If we cannot successfully model the solution, we will not be able to build or implement it, and we will have to adjust our design.

Anticipated problems for this objective include dimensioning or assembling errors and negative responses from the focus groups or organizations. Design dimensions and features need to be clearly specified. As a team, we have struggled to pinpoint exactly what features we want our receptacle to have, and this is very important when modeling the receptacle. Without this information, not all the features and details will be accounted for in the final model. In order to properly assemble the modeled parts, we need to account for potential interference and other design malfunctions when assembling in CAD. This is a very common problem especially among inexperienced modelers. The biggest anticipated problem is a negative public response to our model and general solution because, without their support, our project will ultimately be unsuccessful, and we would need to consider alternate solution paths.

Building the Receptacle

Building a prototype of the receptacle is crucial to truly developing a solution in our problem space. As we are testing the feasibility of different models of various solutions, we cannot truly do so without a working prototype. Without a working prototype, we have nothing to test and thus have no way of proving the validity of our solution.

In order to build an effective receptacle prototype, we must plan for what the receptacle will look like and what features it will have. After careful planning, we must build the receptacle and conduct research to determine the most ideal locations for the receptacle to be placed. Upon placing the receptacle, it will be crucial to collect and assess data to determine how the receptacle may be implemented optimally.

Measurable outputs to determine the successes or failures of our solution will include our observations of the long-term data we collect upon building and implementing the receptacle. First, upon building the receptacle, we will be able to consider the amount of receptacles we will be able to produce and distribute based on the cost of the receptacle itself and all of its features. Upon placing the receptacles in various locations, we will be able to gather data to determine helpful information such as which locations recycle the most e-waste using our receptacle.

Anticipating complications and developing backup plans is vital to developing a successful solution. A few possible issues we may face include complications with

marketing the receptacle, giving the receptacle appealing features to incentivize its use, and developing a feasible plan for the transportation of the collected e-waste. However, with careful planning, we can anticipate these issues and have an effective and efficient plan when they arise.

Testing the Receptacle

It is important for us to have all of the necessary support in place for the implementation of the receptacle to work. We also need to test the receptacle to make sure that it is operational and that people will use it. This is valuable information to know so that the work we do on the receptacle will not go to waste if there is something that will prevent it from working outside of its production.

In order to test the effectiveness of the receptacle, we will utilize a focus group to evaluate our receptacle. To do this, we must find a representative group of people to gain insights and opinions on the use, placement, design, and effectiveness of the receptacle prototype. We will ask the group if they would use the receptacle and what they would personally do to improve the receptacle before they would use it. During the focus group we will also have the group use the receptacle to see if it is easy and convenient to for customer usage.

In order to properly collect and transport the e-waste in the receptacles, we will partner with an existing organization: eWaste ePlanet. In addition to gaining access to their resources, we will gain insight from our mentor Wilson Kieffer at eWaste ePlanet on how we might improve the receptacle and collection strategies. Because of his expert opinions, we may be able to see our solution from different angles and will be able to fix any potential flaws. We will then establish a collection system by fitting in with their current collection routes. To make sure that these collections work, we will have to make sure that the receptacle's sensors work so that those collecting the e-waste know when the receptacle is full.

In order to have places to put our receptacles, we will need to find community centers or other sites that are willing to host the receptacle. To do this, we will call up local YMCAs, churches, and other various organizations and businesses to see if they would be willing to host the receptacle. Lastly, we will need to gain community acceptance by getting the community involved in our solution. Through the placement of the receptacle and advertisement of the receptacle by the host center, we will gain exposure to the problem of e-waste and the availability of our recycling service.

Success in this part of our process would mean that we would receive positive feedback from the focus group and adjust the receptacle's specifications based on any negative feedback. It will also be successful if we are able to secure the use of eWaste ePlanet's collection system and if we are able to secure locations in which to place the

receptacle. Our ultimate success would be if we are able to gain the involvement of the community, which would be evident if our receptacles get filled with e-waste.

During this phase of our project development, we may face many problems including having to alter minor or major aspects of our project and design, having difficulty gaining a collection service for our receptacle, having difficulty gaining admittance to community centers, and having difficulty capturing the community's attention.

Project Team

With a group of seven people, it is important for us to dole out specific roles and responsibilities in order to make the best use of our talents in a collaborative environment. As a result, we have decided to divide our responsibilities into seven specialized positions, each of which makes use of major-related expertise and skillset.

When working on our project, our team realized that it was a necessity to split up the leadership role into an organizer/motivator and an enforcer role. Over the last semester, we found that not splitting the leadership role into these two components was harmful to the group's productivity and morale. By splitting up this position into roles, we improved the balance of responsibilities within our group, and were able to boost efficiency and enthusiasm. The **General Manager** will assume the responsibility of keeping the group engaged. This person must be diplomatic, passionate about the project, and able to work well with others and maintain a healthy work environment. The **Team Supervisor** also serves to keep the group on task but takes a more direct role in holding group members accountable for their work and enforcing deadlines. This person must be confident, respected, and must be willing to enforce the responsibilities of each individual group member. In separating the **Team Leader** position into two specialized roles, we hope to have good group synergy.

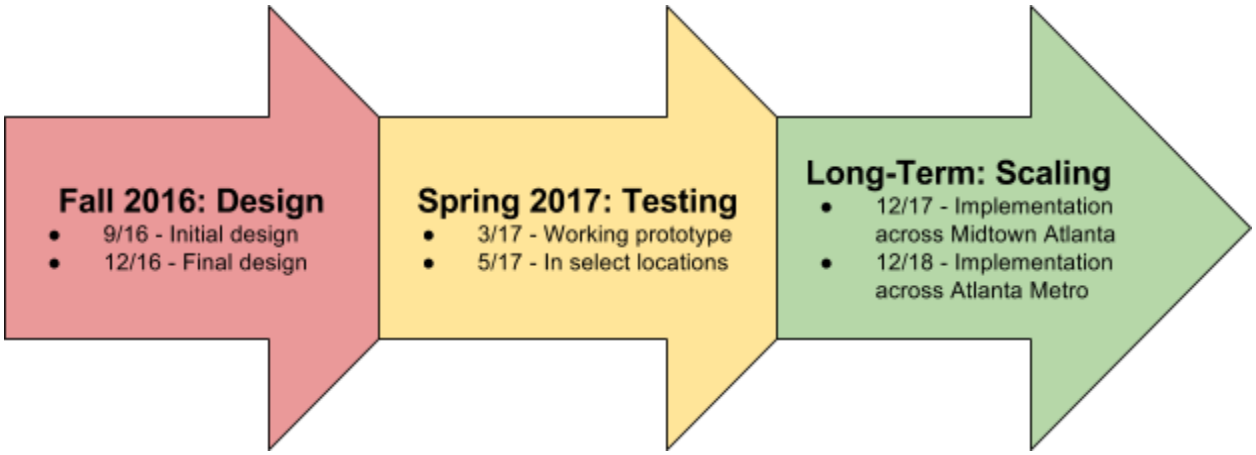
The **General Manager** and the **Team Supervisor** positions organize the group from within, but it is the duty of our group's **Public Relations Manager** to be the ambassador to the outside world. This person will need to be good at networking and a confident public speaker to function as an effective face for the group. Responsibilities of the role include interacting with potential locations that might host our product, companies that we might sell our product to, and any other sponsoring parties that might be willing to fund our project. The **Financial Manager** will be responsible for allocating the funds that our group receives to ensure that everything goes to good use. This position will require a member who is honest, organized, and good with numbers and record keeping.

When it comes to actually creating our product, our team will need to have a **Designer** and a **Programmer**. Preferably, the **Designer** will be one of our group

members who is majoring in Mechanical Engineering who is proficient at design software (e.g. AutoCAD or Solidworks) and proficient with the tools in the Invention Studio that we might be able to use to make a functional prototype of our product. The **Programmer** (ideally majoring in Computer Science) would be responsible for programming the electronic components of our product, which might include an interactive display, a variety of sensors, and potentially other features. The person in this position would need to be capable to code in a variety of languages and work with the microcomputer(s) (Raspberry Pi or Arduino) that will drive our device. The **Operations Expert** is responsible for conducting research on how our product is performing and which features help and hurt its effectiveness. This person will need to be good at weighing costs and benefits as well as data collection and analysis and will play a major role in keeping our product as profitable as possible.

Our entire team will also have a **Team Mentor** who works in the e-waste recycling industry. Wilson Kieffer, the owner and CEO of eWaste ePlanet in Norcross, GA, has offered to fill this position and help our team along the way. One of our team members, Conner Reinhardt, will be interning for Wilson at his collection facility over the Summer of 2016.

Timeline



Budget

- Materials and Supplies
  - Arduinos
    - $25 per unit
  - Raspberry Pi

            - $40 per unit
        - Sensors (to measure when the containers are full)
            - Load Sensor - $10 per unit
    - Equipment
        - 3-D Printers
            - Available in the Invention Studio
        - Soldering irons
            - Available in the Invention Studio
        - Welding equipment
            - Available in the Invention Studio
    - Services
        - Storage space
            - $60/month
    - Travel
        - How many trips are necessary and why?
            - Few trips outside of conferences - our team mentor is located in close proximity to Georgia Tech.
            - E-Scrap 2016 Recycling Conference
                - September 20-22, 2016
                - New Orleans, Louisiana
                - Flight necessary
                    - $80-$150 per person

Ideas for Innovation

Right now, we have a general idea of the nature of the receptacle, but we still need to add one or more innovative elements in order to set our solution apart from existing solutions and increase its effectiveness. The following list is a compilation of some of the potential innovations we could pursue:

(1) We could provide food-based incentives for people who put their electronics in our receptacle. This would likely be implemented in the context of restaurants (especially fast food), where customers would receive some kind of meal voucher or coupon in exchange for their electronics. Restaurants might be open to this idea because it would make them seem more environmentally friendly, and customers might be more motivated to donate electronics, especially if they are regular customers.

(2) Our receptacle could be mobile, whether in the form of a receptacle that can be transported on a truck or simply the truck itself. This would result in a more “drive” based campaign, where e-waste would be collected in a

specific area over a limited period of time before moving to the next area. This would likely cover a broader range of customers, and customers might be more motivated to recycle their electronics immediately, since the receptacle would not be there forever.

(3) The receptacle could double as a way to educate people and spread the word about the e-waste problem. For example, it could include an interactive display that provides information about what happens to e-waste when it is recycled as well as the damage caused by improper disposal. It could also give the customer a sticker, wristband, or something else small to act as a way to spread the word and make the customer feel as though they are making a difference (similar to the Livestrong wristbands or the stickers people get after voting).

(4) Some of the electronics we collect could be donated to people who need them, whether in the U.S. or elsewhere — though if the electronics are given to people in developing countries, we would have to ensure that those electronics would not be improperly recycled once they were there. This altruistic element could motivate more people to donate their electronics.

(5) Instead of providing communities or every individual with rewards, we could offer people who donate their electronics the chance to win a larger prize by pooling some of the profits into a periodic lottery. This might motivate people to donate more than if smaller rewards were provided to every individual, since they would have the chance to win a much more significant amount of money.

All of these potential solutions would require significantly more research and experimentation to determine whether they are viable, but they are all ideas we are considering to take our solution to the next level.

Expected Outcomes and Future Directions

Over the next two years, our group expects to work extensively on our recycling receptacle. We are not sure exactly what features our product will have, but we plan on conducting extensive research and testing to create the most profitable and useful e-waste collection device possible. We hope to be able to create a digital design of the receptacle using AutoCAD and prototype it using 3D printers and microcontroller kits by Spring 2016. Once we have built our prototype, we will test it in a variety of community locations, such as schools, churches, and YMCA's, and run focus groups of the people who used our device to get feedback that we can use to improve the receptacle. Our partnership with eWaste ePlanet will initially provide us with access to funding,

expertise, and other testing locations. Eventually, our goal is to create an independent business and sell our recycling unit to e-waste collection facilities (like eWaste ePlanet). In the long term, we believe the project can make a significant impact on the amount of e-waste that collection facilities are able to collect and process.

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