Friends of the Dunes

Rapid Compost

ENGR 215 Team 6:

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1 Problem Formulation

The problem formulation contains the objective statement and Black Box Model of the project. The Black Box Model (Figure 1-1) illustrates the impact of the completed project.

1.1 Objective

The objective is to construct an efficient method of recycling waste generated from onsite restoration projects while educating volunteers about Friends of the Dunes at the Humboldt Coastal Nature Center.

1.1.1 Black Box Model

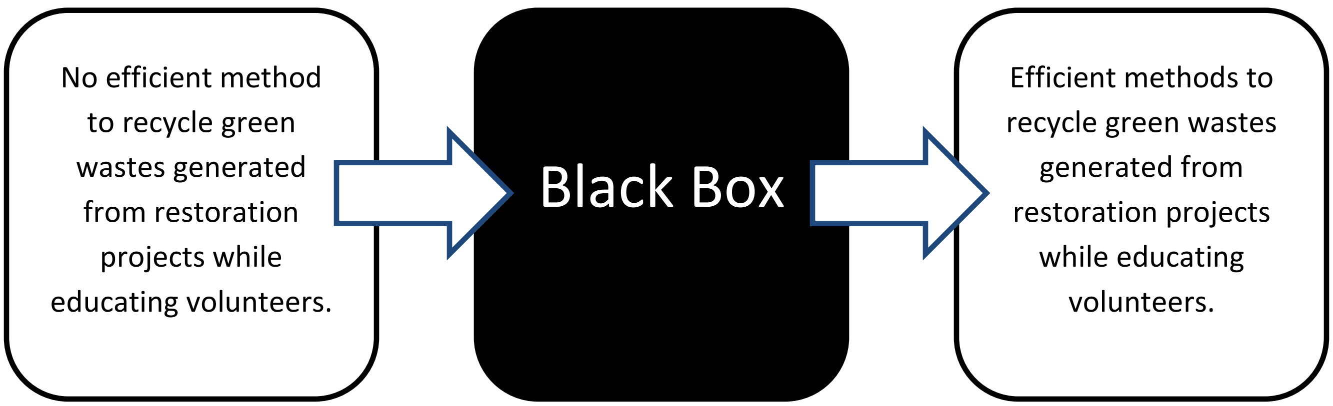

Figure 1-1: Black Box Model illustrating impact of project.

2 Problem Analysis

The problem analysis identifies and explains the criteria and constraints specified by the client. Use, production volume, specifications, and considerations are also discussed in this section.

2.1 Specifications

Specifications are factors that are required elements of the final product. Without exception, the project must:

- Include and educational board.
- Maintain 50% moisture content in the compost, with a 10% margin of error.
- Maintain a 30:1 carbon to nitrogen ratio, with a 1 unit margin of error.
- Have a consistent supply of oxygen to prevent anaerobic decomposition.
- Located in proximity to a clean water supply with a pressurized hose.

2.2 Considerations

Considerations are assumptions that are inferred from a general knowledge of the problem that may influence the final product. Such considerations are as follows:

- The system will be maintained by untrained volunteers.
- The system will primarily be used for green wastes.
- The climate may have adverse effects to the composting process.
- The system may be located in very close proximity to the Nature Center.
- Local building materials will be incorporated when available.

2.3 Client Criteria

The client criteria are required components of the system that were specified directly by the client. The criteria and constraints, located below in Table 2-1, will later shape the design of the final product.

Table 2-1: Client Criteria and Constraints.

Criteria	Constraints
Cost	Less than $400
Ease of Use	Useable by untrained volunteers
Educational Value	At least volunteers learn more about rapid compost systems
Effectiveness	Must be able to process about 6’x6’x6’ of yard waste every 14-21 days
Labor intensity	Cannot require more maintenance than 1-2 times a week for 2-3 hours each day
Availability of Amendments	Bought locally and cheaply
Aesthetics	More professional than a tarp
Safety	Non-toxic and will not spontaneously combust
Durability	Stable for at least one year

2.4 Usage

The compost system will be used to process a 6’x6’x6’ volume of yard waste generated onsite once a week. Variance will occur only slightly.

2.5 Production Volume

One or two appropriately sized compost systems will be built to withstand the usage requirements. An education board will stand next to the compost system to teach and train volunteers.

3 Literature Review

This literature review will provide an appropriate background of information necessary to begin the design process. The following topics will be discussed: client information, compost projects, compost systems, compost basics, compost laws.

3.1 Client Information and Specifications

3.1.1 Friends of the Dunes

Friends of the Dunes (FOTD) is a 501(c)3 non-profit organization. FOTD began at the Stamp's house, which is now located at the center of 113 acres donated as multiple land trusts. This slot of land is now recognized as the Humboldt Coastal Nature Center. FOTD has lived up to their mission statement by, "conserving the natural diversity of coastal environments through community supported education and stewardship programs (FOTD, 2012)."

On Friday, February 17, 2012 there was a meeting with the client Carol Vander Meer, the Executive Director of Friends of the Dunes, to discuss the criteria for the rapid compost system. Notes were taken by Lucas Holland. The results of the meeting are detailed below.

3.1.2 Client Specifications

The rapid compost system:

- Will be processing biomass generated from the weeding and landscaping around the Humboldt Coastal Nature Center.
- Does not necessarily need to incorporate beach grass into the construction.
- Will be processing material weekly and should have a volume of roughly 6'x6'x6'.
- The operation must simple enough to be maintained by volunteers.
    - Systematic, easy to follow steps.
- Must include a board educating the public about the compost process that will accompany the composter.
- Will be located by the site manager, John St. Marie.
- Must achieve temperatures necessary to destroy the seeds of the plants put into the composter.
- Will be sampled for a biological assay of the different weeds on site; the California Native Plant Society can help with species identification.

3.2 Basics of Compost

3.2.1 Uses and Benefits of Compost

Good compost increases topsoil biodiversity and water-holding capacity. Composted materials add nutrients that can be absorbed by plants. Composting cycles nutrients that would otherwise be lost and destroys disease creating organisms, insect eggs, weeds and weed seeds.

Compost that is properly made, with the correct mix of carbon and nitrogen, will reach an internal temperature of 135°F in 24 hours, which will continue to rise to 150°F in 72 hours (Lowenfels and Lewis, 2010). The sustained high temperatures will denature proteins in pathogenic microbes, insect eggs and weed seeds, neutralizing them.

Bacteria secrete biofilms (a matrix of sugars, proteins and DNA) as a means of propulsion or protection from desiccation. These biofilms work as glue that stick soil particles together, increasing the number of sites where water can hydrogen bond and reducing porosity of the soil so water is slower to percolate(Lowenfels and Lewis, 2010).

3.2.2 Chemistry

Yard wastes tend to lack the necessary nutrients vital for rapid decomposition. This problem is usually managed by the addition of nitrogen. Microbial synthesis must have the perfect carbon to nitrogen (C/N) ratio to properly function. The C/N ratio ranges from 15 to 30 parts of carbon for each part of nitrogen (Haug, 1993).

One example of decomposition is a microbe that degrades starch (with glucose as the base monomer) as a source of energy (Haug 1993). The equation representing this is:

$x(C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy})$

This entire reaction yields 180 moles of energy

The following reaction uses the free energy from the above reaction to drive the formation of $C_5H_7O_2N$ (which requires about 113 moles of energy).

$5CO_2 + 2H_2O + NH_3 + \text{energy} \rightarrow C_5H_7O_2N$

Assuming a net yield of 0.1g cells/g glucose, the moles of energy reaction per moles of synthesis reaction can be calculated as such: $\frac{1}{[x(180)]} = \frac{0.1}{133}$

X = 6.3, about 6 moles/mol

Multiply the energy reaction by 6 and add to the synthesis reaction

$6C_6H_{12}O_6 + 31O_2 + NH_3 \rightarrow C_5H_7O_2N + 31CO_2 + 34H_2O$

From this final equation we can see 36 moles of carbon are used for every one mole of nitrogen.

From here, we must multiply by the respective molecular weights and create the C/N ratio.

$\frac{36(12)}{1(14)} = 30.9C/N$

If the assumed cell yield were 0.2 rather than 0.1, the C/N ratio would come out around 15C/N (Haug, 1993). The cell yield can be determined from chemical knowledge on the substrate being used.

3.2.3 Compostable Materials

Not everything can be composted and even if the material does no degrade, the byproducts can be harmful to people, the air, and other still living plants on the site (Raabe, 2005). To ensure positive results the EPA released a list of materials that should and should not be composted. Table 3-1, below, displays various materials that can and cannot be composted.

Table 3-1: Compostable Materials.

Can be Composted	Cannot be Composted
Manures from herbivores	Manures of carnivores
Green waste	Charcoal ash and soil
Food scraps	Diseased plants
Paper products	Yard trimmings treated with chemical pesticides
Other fibrous products (hair, rags, etc.)	Meat

3.2.4 Flora and Fauna in Compost

Compost is a diverse world of soil organisms. The groups of organisms most important to compost are bacteria, archea, fungi, algae, slime molds, protozoa, nematodes, arthropods, gastropods, and earthworms.

3.2.4.1 Bacteria

There are many different kinds of bacteria that are important in soil ecology, but we are most concerned about pathogenic bacteria and decomposers. These bacteria can be further categorized into two functional groups: anaerobic and aerobic. Bacteria are important in the immobilization, retention and horizontal movement of nutrients in soil systems (Ingham, 2000).

Pathogenic bacteria are responsible for plant diseases and degrade soil health. (Ingham, 2000) One of the goals of our process will be to minimize the presence of pathogenic bacteria in our composted product.

Decomposers are vital to the consumption and cycling of carbon compounds in soil (Lowenfels and Lewis, 2010).

Anaerobic bacteria live in the absence of oxygen, and are important for decomposition where oxygen cannot penetrate, for example, the soft tissue of organic matter (Ingham, 2000). Anaerobic decomposition rates are slower than aerobic decomposition rates and give off putrid greenhouse gasses (such as H_2S, NH_4, CH_4 and acetic acid) (Lowenfels and Lewis,2010) so our project will seek to limit the growth of anaerobic bacteria and promote aerobic decomposition conditions.

Aerobic bacteria live in the presence of oxygen and are important for rapid decomposition. Aerobic decomposers are important to the degradation of pollutants and complex carbon molecules in composting materials (Ingham, 2000).

3.2.4.2 Fungi

Fungi are eukaryotic organisms and are the main decomposers in nature. Fungi share some functional overlap with bacteria in soil ecosystems (Lowenfels and Lewis, 2010) and are evolutionarily selected to decompose cellulose and lignin, two very complex structural carbohydrates that make up a large portion of dead organic matter. Fungi are also essential for the mycorrhizal relationships they form with plants, which increases the surface area of the plant’s roots, increasing water and nutrient absorption (Ingham, 2000).

3.2.4.3 Algae
Algae are broadly defined from single celled organisms to large multicellular seaweeds and kelps (Ingham, 2000). In compost, algae are important for the binding of aggregates into larger soil particles and as primary producers that are eaten by larger organisms (Lowenfels and Lewis, 2010).

3.2.4.4 Slime Molds
Slime molds are coenocytic organisms that inhabit damp, rotting organic material (Ingham, 2000). They are similar to fungi but differ in the way they consume food. In compost ecosystems, slime molds ingest bacteria, fungal spores and small protozoa, keeping these populations in check and immobilizing nutrients. These organisms act as food for larger organisms that are also important in compost bionetworks (Lowenfels and Lewis, 2010).

3.2.4.5 Protozoa
Protozoa are small, heterotrophic eukaryotic organisms that obtain their sustenance from eating bacteria (Ingham, 2000). Protozoa participate in the decay process by ingesting small amounts of organic matter and breaking them down to become available to bacteria and fungi. Small enough waste products such as ammonium ions become plant-available nutrients that can be absorbed directly by roots, a process known as mineralization (Lowenfels and Lewis, 2010). Protozoa are the main constituent of the earthworm’s diet, and their presence is an indicator of a healthy biological community in the compost (Ingham, 2000). Our process will attempt to maximize the number of protozoa present in our final composted product.

3.2.4.6 Nematodes
Nematodes are non-segmented blind roundworms that participate in compost ecosystems similar to protozoa. Both are important for nutrient mineralization, where nutrients immobilized by bacteria and fungi are consumed and excreted as waste products that are made available for plant roots to absorb (Lowenfels and Lewis, 2010).

3.2.4.7 Arthropods
Arthropods are segmented insects that are essential for nutrient cycling in compost. These large insects dig through and shred organic material, making it available to bacteria, fungi or protozoans. As they dig, they shred and expose more material to oxygen, effectively aerating the compost. Their waste also contributes slightly to mineralization as a small amount of the waste can be taken up directly by plant roots (Lowenfels and Lewis, 2010).

3.2.4.8 Gastropods
Gastropods are more commonly called slugs and snails. These organisms function similarly to arthropods in compost in that they shred and aerate organic materials they consume (Lowenfels and Lewis, 2010). The presence of large numbers of gastropods is not desirable, and our project must attempt to limit the numbers of gastropods present in our final composted product.

3.2.4.9 Earthworms
Earthworms are segmented worms that are essential for composting processes. Soils with large numbers of earthworms are bacterially dominated and their presence is an indication of large

communities of fungi, nematodes, and protozoa (Ingham, 2000) Earthworms are classified as shredders that dramatically alter soil composition after consumption, making more organic matter available for bacteria and fungi to devour and mineralizing nutrients that can be taken up directly by plant roots. Burrows created by earthworms act as channels for air and water to infiltrate deeper into the compost (Lowenfels and Lewis, 2010). Our composting process will attempt to maximize the number of earthworms present in the final composted product.

3.2.5 Amendments and Bulking Agents

To maximize decomposition rates, compost requires a 30:1 ratio of carbon to nitrogen, about 50% moisture content, and sufficient oxygen. If the ratio of carbon to nitrogen is below 30:1, the organic matter will decompose rapidly but valuable nitrogen will be lost to the atmosphere as ammonia (NH_4). If the ratio is above 30:1, the decomposition rate will be too slow. If the ratio shifts above or below the desired value, carboniferous or nitrogenous materials need to be added accordingly. There are numerous lists online of what can and cannot be added to compost, and knowing the nutrient content of your amendment is essential before adding it. When made properly, the only thing needed to be added to compost after its initial compilation, when the material dries out (Raabe, 2005). Oxygen is added to compost by turning the pile, which aggregates the material and exposes areas of low oxygen. If materials being composted are too compact and moist, a fluffing agent should be mixed in to increase the exposure of oxygen (Lowenfels and Lewis, 2010).

3.2.6 Spatial Requirements

Compost piles are limited in size by the availability of space, the amount of material needing to be decomposed, the composition of that material, the composting method of choice, and the labor available to tend the pile.

A minimum volume of 36”x36”x36” will ensure rapid decomposition of organic materials in compost (Raabe, 2005). Piles can be larger, but increased size creates more work when piles need to be turned and aerated to keep from turning anaerobic. Tending to compost can be labor intensive and requires strength to turn wet materials. Compost piles need to be limited to a size that is reasonable for the people who need to tend them. Unless assisted by mechanical equipment, piles should not be larger than 6’x6’x6’ (Lowenfels and Lewis, 2010). Compost will also require enough open space beside the pile to allow for turning and aeration.

Compost will be more compact if the material is finely chopped before stacking, and will decompose faster due to greater surface area (Raabe, 2005). The material’s pH, temperature, and the availability of nutrients for microbial digestion will dictate how fast decay will take place, so the spatial requirements for the compost can be reduced if the material is processed and analyzed before being decomposed.

Compost bins create a compact, isolated area for organic matter for deterioration and are limited in size by the materials they can be constructed out of. Bins have the added benefit of insulating the material to keep in heat generated from cellular respiration, reducing exposure to rain and nutrient loss from leaching and reducing the chance of an animal rummaging through the pile (Raabe, 2005).

3.2.7 Factors That Influence Detention Time

The effects of heat, moisture, and mixing on the detention time for various compost systems will be analyzed in the subsections below. Most information will be based around green waste systems. If these three factors are carefully maintained, a 2 week detention time can be achieved (Raabe, 2005).

3.2.7.1 Heat

Temperature, insulation, and size of enclosed compost bins are vital to maintain a high rate of decomposition (Raabe, 2005). Microorganisms used for rapid compost are most efficient at about 160°F (71°C) and if the temperature within the compost system is unstable, a consistent rate will not be achieved. Proper insulation will reduce outside temperature fluctuations while bins larger than 3ftx3ftx3ft will reduce heat loss within the system (Raabe, 2005). Figure 3-1 (right), displays the relationship between temperature and rate of decomposition.

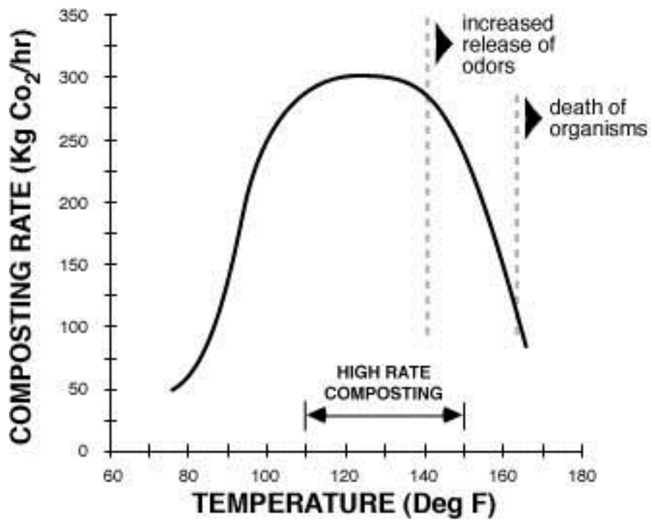

Figure 3-1: Temperature vs. Composting Rate. The Composting Process. <http://ohioline.osu.edu/b792/b792_2.html>

3.2.7.2 Moisture

Moisture control varies greatly on the substrate. Green (or “wet”) wastes require 50-55% moisture (of total weight). If the moisture content is too high, straw or rice hulls can be added to absorb excess moisture (Haug, 1980). Newspaper and dried organic materials (leaves, grass) may also be incorporated; however adequate shredding must take place ahead of time. If the amendment (newspaper or leaves) is not separated with the compost materials, clumping will occur and this may result in a slower process (Raabe, 2005).

3.2.7.3 Mixing

The speed of degradation and quality of product yielded from three types of household compost mixing were investigated: no mixing (CO), manual mixing (MA), and mechanical mixing (ME) (Illmer and Schinner, 1997). Four of each type of composter were tested three times. The composters were only tested with green waste. The following results were obtained (Illmer and Schinner, 1997):

- ME and MA both attracted less flies and emitted less (if none at all) bad odor. This is presumably due to better aeration within the system.
- ME displayed the highest reduction of wastes, followed closely by MA. Each method (CO, MA, and ME), however, successfully reduced the initial waste to 4% of the original concentration.
- ME proved to yield the best C/N concentration (15-25), where MA and CO both contained concentrations that were too high to maximize plant growth and health.
- ME also resulted in higher rates and “more complete degradation of organic wastes.”

Illmer and Schinner concluded that mechanical mixing of household compost systems resulted in the best quality compost with the shortest detention time. Mixing decomposing materials will also prevent the pile from overheating or suffocating the microorganisms. If the microorganisms are killed in the process, the entire system must be restarted with new microorganisms (Raabe, 2005).

3.2.7.4 Aeration

Supplying oxygen to compost has three main purposes: fueling microorganisms, regulating temperature, and regulating moisture (Haug, 1993). Without proper aeration of the compost system, vital reactions will not occur, resulting in an unfinished product.

The amount of O_2 required for proper yard waste degradation is a 1:1 ratio of grams of O_2 to grams of yard waste. Here is how the ratio was calculated:

The chemical composition of most typical yard wastes is $C_{27}H_{38}O_{16}N$ (Haug, 1997).

$2\ C_{27}H_{38}O_{16}N + 39\ O_2 \longrightarrow 54\ CO_2 + 35\ H_2O + 2NH_3$

The molecular weight of O_2 is 32.00 and the molecular weight of yard waste is 632.58.

So, $\frac{39(32)}{2(632.58)} = 0.9864\text{g } O2/\text{g yard waste}$

This oxygen/gram of yard waste ratio will stabilize temperature and moisture and provide a healthy environment for microorganisms to function. If the oxygen content exceeds this ratio, the compost will dry out. Conversely, if there is not enough oxygen, the moisture will cause the compost to plaster together, halting all chemical processes. In both cases, the microorganisms will die and have to be replaced upon restarting the process (Haug, 1997).

3.3 Compost Systems

As seen in Table 3-2, four compost systems are evaluated in regard to the client's criteria specified in the previous section, Problem Analysis.

Table 3-2: Evaluation of Compost Systems.

System	Pros	Cons	Process
Passive Piles	Low labor intensity and cheap/free	Requires perfect environmental conditions and is a very slow process	All waste is left to degrade in a pile
Turned Windrows	Can be used in or outdoors and cheap	Is a very slow process that requires perfect environmental conditions	Same as passive piles system, but stirred or agitated once or twice a week
Aerated Static Piles	Efficient with both yard and municipal wastes and takes up little space with low labor intensity	Not cheap and may require mechanical aeration	An enclosed space that is aerated to speed the decomposition process
In-vessel Systems	Fast decomposition rates and requires little space	Involves mechanical parts and is not cheap	An enclosed space that is mixed and aerated

3.4 Compost Projects

3.4.1 Arcata Marsh Compost

The biosolids that are treated at the Arcata wastewater treatment plant are poured into drying beds where evapotranspiration kills the biosolids. Once the biosolids are dry they are mixed with amendments to create the right ratio of carbon and nitrogen, which is: one part biosolids, two parts green waste, and three parts wooden waste. The mixture is then piled, and a pipe is inserted at the middle to add or reduce oxygen to increase or decrease the temperature to kill any pathogens.

3.4.2 Humboldt State University Compost Program

The Humboldt State University Compost Program's goal is to compost 100 percent of the Humboldt State's organic waste by December 2012, which would deflect one third of the school's waste from ending up in a landfill. The organic waste is being collected by the Dining Services and in compost bins around campus. Once the organic waste is collected it will be taken to food digesters to create soil. The HSU Compost Program also utilizes the byproducts from the composition process. One of the those byproducts is methane that is used to create electricity that is used in Eureka's wastewater treatment plant and the surplus methane gas is sold to Pacific Gas & Electric Company (PG&E).

3.5 Compost Regulations

Organic Material composting regulations are controlled by the states rather than the federal government (EPA. 2011). These are the regulations from Article 6, Composting Operation Standards, of the California regulations (Cal Recycle, 2011).

- "(1) Operators shall ensure that all personnel assigned to the operation shall be trained in subjects pertinent to operations and maintenance"
- "(2) All handling activities shall be conducted in a manner that minimizes vectors, odor impacts, litter, hazards, nuisances, and noise impacts; and minimizes human contact with, inhalation, ingestion, and transportation of dust, particulates, and pathogenic organisms."
- "(5) Unauthorized human or animal access to the facility shall be prevented."
- "(6) Traffic flow into, on, and out of the composting operation or facility shall be controlled in a safe manner."
- "(7) All compostable materials handling operations and facilities, that are open for public business, shall post legible signs at all public entrances. These signs shall include the following information:
    - name of the operation or facility,
    - name of the operator,
    - facility hours of operation,
    - materials that will and will not be accepted, if applicable,
    - schedule of charges, if applicable, and phone number where operator or designee can be reached in case of an emergency."
- "(8) The operator shall provide fire prevention, protection and control measures, including, but not limited to, temperature monitoring of windrows and piles, adequate water supply for fire suppression, and the isolation of potential ignition sources from combustible materials. Fire lanes shall be provided to allow fire control equipment access to all operation areas."

4 Alternative Solutions

To begin the search for alternative solutions, Team 6 conducted a few brainstorming sessions based on the client's criteria mentioned in the previous section. From these sessions, eight promising alternative solutions to the rapid compost system have been developed. In the sections below, each solution will be described and illustrated.

4.1 Brainstorming

As our group grew more accustomed to each other, brainstorming became easier. However the first few sessions before section 3, were a bit of a "tug-o-war." The shyness in our group has since been eliminated and now brainstorm sessions run quite smoothly. After the first few minutes pass by, ideas are being thrown into the mix regardless of how ridiculous. After about thirty minutes, we then eliminate the more outrageous ideas and further develop the more promising ones. In our search for appropriate alternative solutions, we made the decision to run two separate brainstorming sessions, both of which can be seen in Appendix B. The first brainstorm involved taking all constraints and considerations and translating them into materials. It was not until the second brainstorm that we began to compile a list of complete systems.

4.2 Alternative Solutions

Each alternative solution has been evaluated and agreed upon by each group member. Below is the list of alternative solutions that were chosen based on their support of the client's specified criteria:

- Barrel
- Hole in Ground
- Greenhouse
- Chambers
- Silo
- Baker's Bin
- The Earthworm
- Solar Blast Composter 9000

4.2.1 Barrel

The Barrel solution consists of two 30 gallon barrels with a volume of 19" X 19" X 31" each. The barrels will be mounted (as seen in Figure 4-1) on a base similar to a concrete mixer to allow proper mixing. The green waste will be put in one of the barrels by the volunteers. A manual crank will run the length of the barrel and have perforated panels that mix the compost. A door will be fashioned at the end of the barrel to allow for easy placement of compost. To remove the compost, the barrel may have to be turned onto its side, which may prove to be too difficult for some volunteers.

The barrel solution does meet most of the client's criteria. Previous versions of the barrel system have proven that it composts yard waste very efficiently and quickly. Aside from removing the completed compost, labor intensity is rather minimal. Also, the barrel gives a great recycled appearance to the site, in turn meeting the aesthetic requirement. The largest hindrance would be the cost of the barrels. A single barrel can cost upwards of $100 each, and the project would require two. Finally, the compost would have to be stirred 2-3 times a week, which may not be possible, considering volunteers are only onsite on Wednesdays.

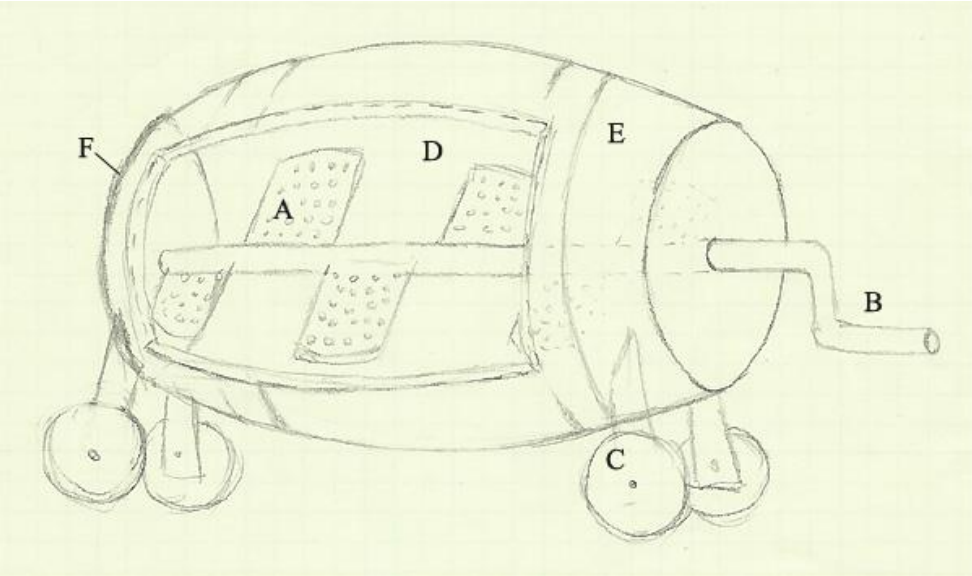

Figure 4-1: The Barrel System. *The features are marked as follows: A) the perforated grate that will allow maximum mixing, B) the manual crank that will turn the perforated grate, C) the stands that will be mounted on wheels for easy transportation of compost, D) a liner that will prevent the decomposition process from affecting the organic wood, E) the outside of the unaltered barrel for a very natural or recycled look, and finally F) the door to the inside of the barrel where the compost will be placed.*

4.2.2 Hole in Ground

The hole in the ground solution is a hole of 6" X 6" X 6" volume that will have plastic lined walls to prevent erosion and mixing between the invasive plants and the natural earth surrounding them. The compost will be dropped into the hole once a week by volunteers. Once the hole is full it will be covered with a concrete door (as seen in Figure 4-2) for safety and to keep unwanted activity to the compost. Mechanical aeration may have to be incorporated, as covering the hole will cause a lack of oxygen necessary for rapid compost.

This could be a great solution for a rapid compost system as it is cheap and durable, however because it will be located underground, the physical demand on the volunteers may be too great. Erosion and mixing are two very dangerous situations that should be avoided at all costs, and this system may put the local ecosystem in danger. There are very serious precautions that must be made before attempting to install this system.

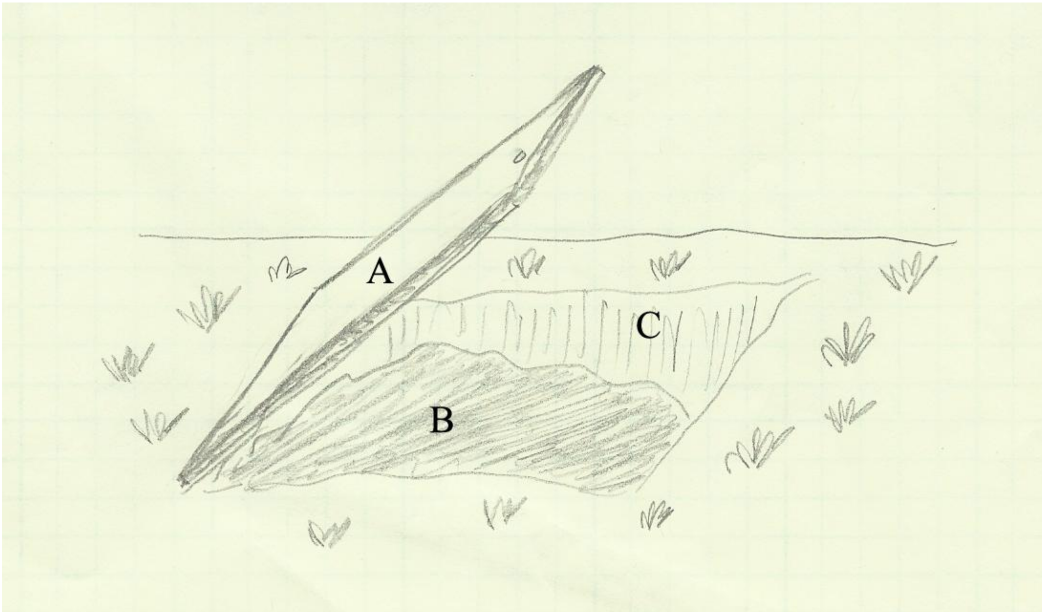

Figure 4-2: The Hole in Ground Solution. *The very simple design does not require much explanation. The key features of this solution are as follows: A) the concrete door for protection, B) the composting material that must be mixed with a shovel, C) the sturdy plastic liner that will prevent the invasive plants from spreading.*

4.2.3 Greenhouse

The Greenhouse solution (in Figure 4-3) is designed as it sounds, as a greenhouse. The structure is built out of a thick clear plastic that can allow sunlight in while trapping the heat. The Greenhouse design provides a roof that will protect the compost from the harsh weather experienced at the nature center including wind and rain. When compared to the criteria, the greenhouse falls short in some areas including ease of use, size, and cost. The compost needs to be turned frequently and being confined inside a building would not allow the space needed for the volunteers to move around enough to adequately mix the compost. The compost also needs to be moved to make room for fresh waste and if the only way to get the compost out is through a small door, that would cause difficulties for the volunteers as well. Also the Friends of The Dunes predicted to be producing approximately 6’x6’x6’ of waste that needs to be composted per week. That much waste would take a large structure that might not be possible with a greenhouse. If the greenhouse is too big then building codes and ADA regulations apply. Also, with a closed structure air will need to be supplied to the compost, perhaps by putting PVC pipes in through the ground or adding some kind of powered fan. The final pitfall is cost. Finding alternate materials other than a greenhouse kit or sheets of plastic, which is difficult to find and according to Costco.com the cheapest greenhouse kit they provide is close to $1,000.

While the Greenhouse solution doesn’t meet some of the criteria, it does meet safety, aesthetics, and educational value. Having all of the compost in a secure structure will keep children and animals away from the compost and out of harm’s way. As far as aesthetics go, the greenhouse provides insulation but it looks better and is more reliable than a tarp and it will keep any odor under control. The clear plastic structure not only appears much more professional, but it also allows for volunteers to see the process as will be described on the education board.

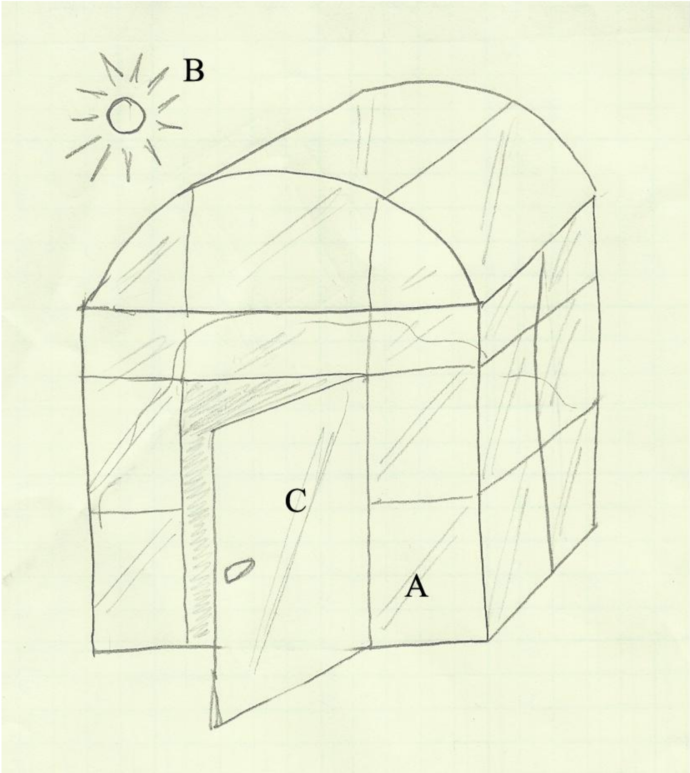

Figure 4-3: The Greenhouse Solution. *The simple design is durable and aesthetically pleasing. The features are as follows: A) the glass or sturdy plastic panels to allow sunlight in and heat to be trapped inside the system will surround the entire volume of compost, B) the sun will supply the heat to regulate the temperatures necessary inside the system to rapidly decompose materials, which may be difficult to achieve in a climate like Arcata, and C) the door for easy access to the compost for mixing and transporting in and out of the system.*

4.2.4 Chambers

The Chambers solution (Figure 4-4) is designed to have three sections partitioned from each other. Each section will have compost in a different stage of its composting cycle. The first section is for the initial waste still in its plant form, the next week when more waste is to be added and the compost needs to be turned, the compost will be moved into the second section. This process will repeat and the waste will continue to move into the third section where it will stay until it is ready to be used. The most durable and logical material for the chambers to be built out of is concrete. The structure will essentially be a pen with slats or pipes in the ground to add air to the compost. The composter will need a door, which will be made from wood slats with metal backing to protect it from the decomposition processes going on in the composter. When access is needed, the slats will be removed individually. Finally a roofing structure will be built over the chambers to protect the system from rain and animals.

The chambers solution meets most of the criteria including safety, cost, and size. With the inclusion of the wooden slats animals and children will not be able to wander into the composter. It is also made of strong materials that cannot rot or erode over the next few years, so it is not a falling hazard. Most of the materials can be donated, salvaged, or made which leaves little to be bought from the store and lowers the overall cost significantly. With the availability of three chambers the composter should be able to store the 6’x6’x6’ of waste accumulated weekly at the site.

The chambers solution does not meet the criteria for ease of use because it requires a lot of moving of the compost which takes time and the removing and returning of the compost every week. This complication can be minimalized if the compost stays in its original chamber until the end of processing, but the stirring will still be required, if not more rigorously. However this is a problem for most of the solutions simply because rapid composting requires time and energy to run its course efficiently. It also incorporates recycled and scavenged parts that come in all kinds of conditions, which would affect the aesthetics of the final product.

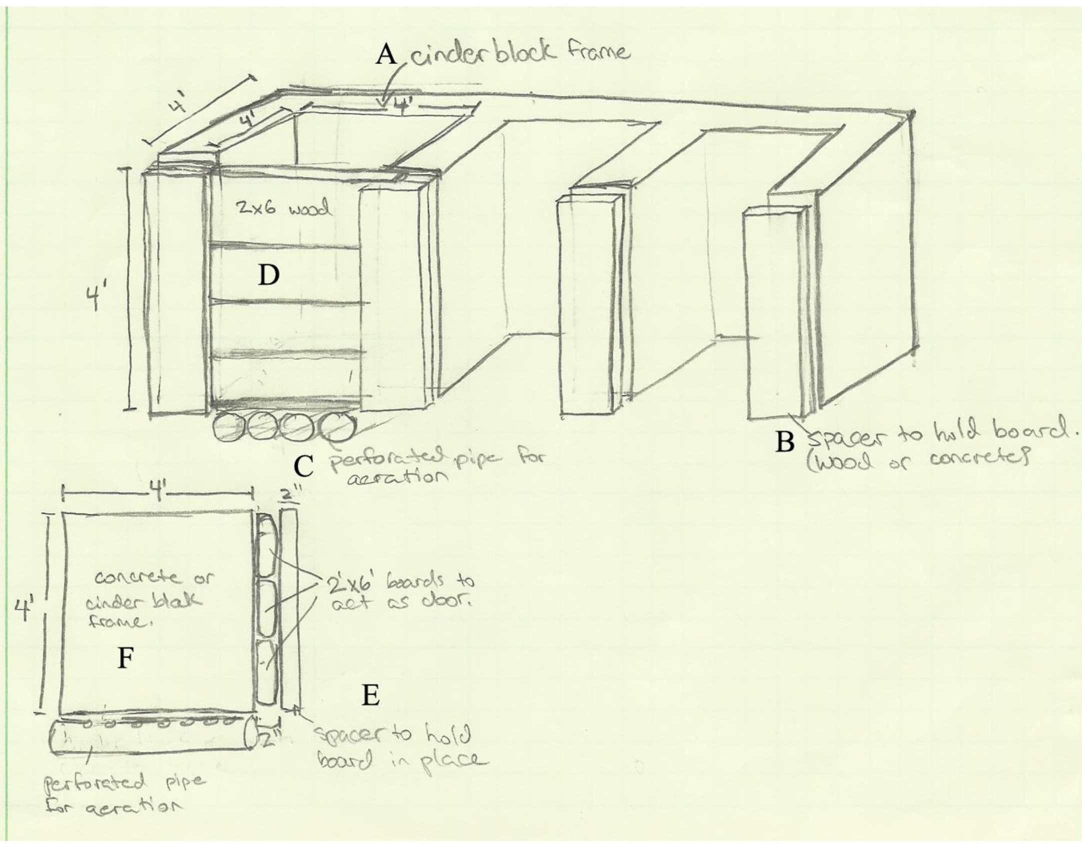

Figure 4-4: The Chambers System. *The feature of the Chamber system are as follows: A) A cinderblock frame will ensure a durable, visually appealing, and well insulated structure, B and E) two views of the spacers that will hold the wood planks in place, C) perforated PVC pipes directly under the compost for proper aeration, D) wood planks that are lined with a sheet of metal or concrete on one side to prevent decomposition, and F) the side view and dimensions of the Chamber solution.*

4.2.5 Silo

The Silo (Figure 4-5) is an upright cylindrical compost system with doors on the top and bottom of the system and a large screw-like crank running the length of the system. The Silo will be made of an insulated concrete. The green waste generated on site will be dropped through the top door and turned once a week by the manual crank. After a two or three week retention time, the finished compost will be removed from the bottom onto a wheelbarrow to be used as fertilizer. Each week when new waste is generated, the green waste can be simply tossed on top. The large crank will eliminate mixing between each separate load.

This system utilizes gravity to lessen the labor intensity. A truth window will expand from top to bottom, which is an excellent source of visual education. As visitors look through the truth window, they will be able to witness the process. The door at the bottom of the system removes the need for other tools, such as shovels. As one volunteer turns the crank and another holds the wheelbarrow, the compost will simply fall out. A set of stairs will lead up to the top door, because the system may be taller than most volunteers. The stairs will also lessen the physical demand of dropping green waste into the system.

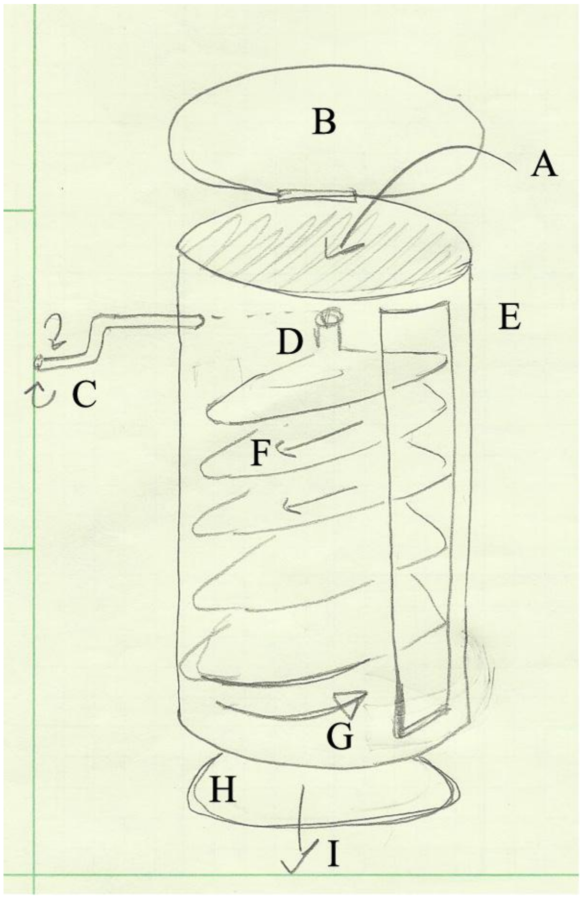

Figure 4-5: The Silo System. *The features of the Silo are as follows: A) the entrance where the compost will be placed, B) the top door, C) the manual crank that will utilize a few durable gears to turn D) the screw-like mixer at a 90 degree angle, E) the truth window will give great educational value to the system, F) the direction of flow of the compost which may be helped by anchoring concrete slabs against one side of the system, G) the direction the mixer will be rotating, H) the bottom door, and finally I) the direction the product will come from.*

4.2.6 Baker's Bin

The Baker's Bin (Figure 4-6) is much like the Silo, but with the crank remodeled much like a push lawn mower. The bin will be rectangular with a door located on the top and bottom of the system. The crank will be horizontal and with dull blades much like those seen on a push lawn mower. A truth window will also be featured on the front side of the system. Two separate chambers may be required, because fresh green waste will be generated faster than the completed compost. Alternating between two chambers will allow the proper retention time for decomposition. Stairs will also be incorporated into the design, as it is necessary to reach the top door. The Baker's Bin will be built from an insulated concrete material.

The top to bottom door system is a great use of gravity to make labor intensity and demand for tools almost nonexistent. The crank running through both chambers may make the turning of compost too difficult to only complete once a week. Turning the compost twice a week may not be possible considering the volunteers only visit on Wednesdays. Further discussion with the client is necessary. Also, by including the crank, there is an increased chance of failure.

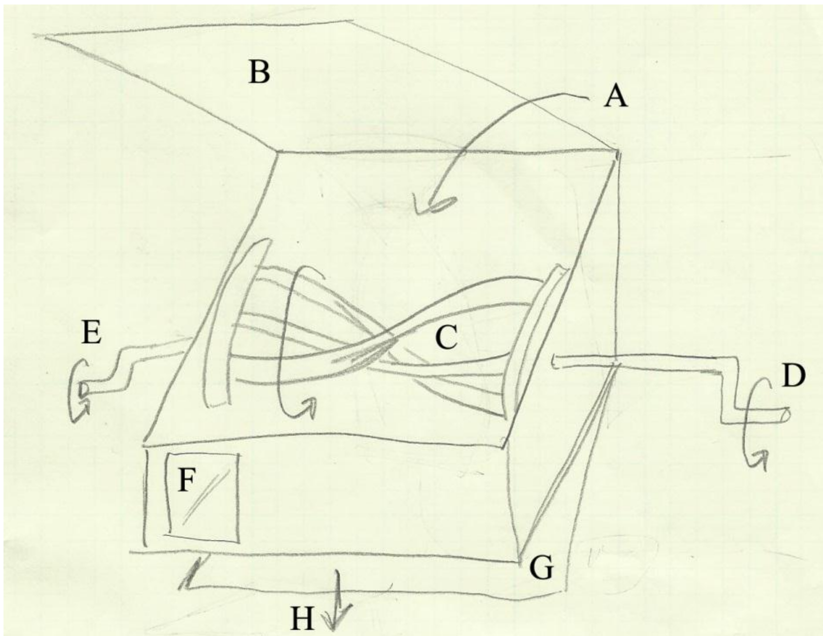

Figure 4-6: the Baker's Bin System. *The features of the Baker's Bin are as follows: A) the direction of the inflow, B) the top door, C) the push lawnmower-like mixer, D) the manual crank, E) an optional second crank to increase ease of use, F) a truth window for educational purposes, G) a bottom door to easily remove the final product, and H) the direction of outflow.*

4.2.7 Earthworm

The Earthworm (Figure 4-7) would be built at the base of a small hill that would be used as a ramp to load material into. By using gravity, the largest input of labor would be the loading of material into the system. At the upper opening, a large mechanical shredder breaks material into smaller pieces for bacteria and fungi to decompose rapidly. The shredder breaks material into the holding tank, an insulated aerated storage vessel that utilizes the principles of aerobic digestion to break down material. Air is pumped into the system by taking advantage of convection currents, mimicking termite mounds and maintaining optimal temperature. Air needs to be exchanged to allow for bacteria and fungi to respire, grow and reproduce. Material is left to decompose and is slowly turned by means of a hand crank that can be turned periodically by a volunteer. A grate at the bottom of the vessel is meant to hold the compost in place and allow for more air to pass under the compost as well. The material is left in the Worm for 2 weeks and turned every couple of days by a volunteer. At the end of the 2 weeks, material is tamped through the steel grate to a a final shredder that breaks the organic matter into small pieces ideal for gardening applications. Advantages of this system are its ease of use and the lower labor inputs of turning a crank as opposed to turning large piles of compost with shovels, and its aesthetics as it would be a contained system with manufactured parts. One of the disadvantages of this system are its high cost as materials may need to be manufactured, such as a sturdy plastic container that can hold the compost. This could be minimized by scouring recyclable materials. Other disadvantages may be the safety of having a top loading system with a mechanical shredding device and also the inherent dangers of large structures in earthquake country.

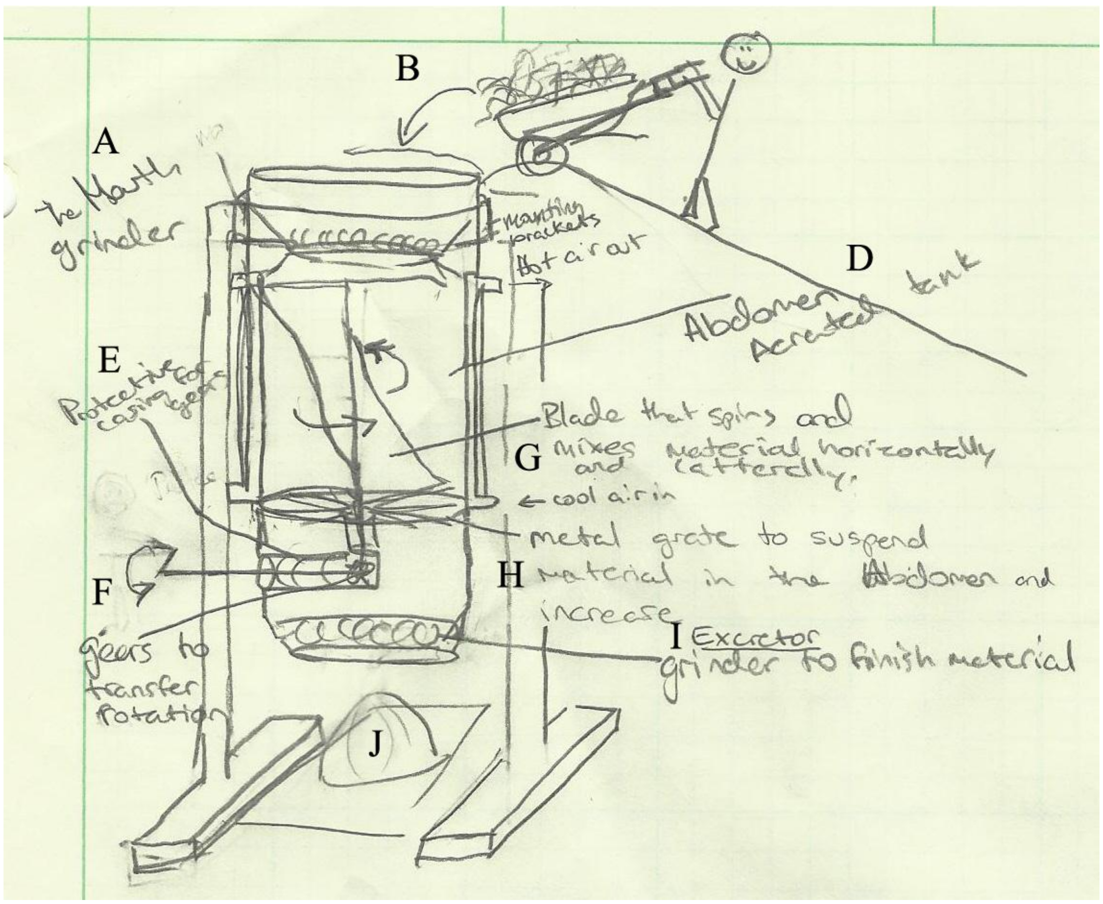

Figure 4-7: The Earthworm. *The features of the Earthworm are as follows, A) the mouth grinder that will grind the green waste into ready-to-compost mulch, B) the opening at the top that will allow for simply dropping the waste into the composting system, D) the aerated tank appropriately named the abdomen, E) protective casing for gears to ensure safety while operating the system, F) the gears that will mix the compost once a week, G) the blade that is turned by the gears to mix the compost both laterally and horizontally, H) a metal grate that will increase aeration inside the abdomen, I) the grinder that completes the process and finally prepares the product (J) to be used as a soil.*

4.2.8 Solar Blast Composter 9000

The Solar Blast Composter 9000 solution (Figure 4-8) is an easy to operate system that disintegrates matter to its constituent elemental components. The system uses a large reflective lens to bend light to heat and rapidly burn organic and inorganic matter. To operate, volunteers will pile organic material from landscaping in the safety zone. The volunteers will then position the lens in place to maximize solar power and set the pile ablaze. When the material has burned to an ash, the ashes can be used for fertilizer. This system utilizes the burn permits Friends of the Dunes (FOTD) obtains to get rid of the large volumes of beach grass generated from volunteer operations. The main advantages of this system are effectiveness (The material would be reduced in a matter of hours instead of days), cost, (a 43”x33” Fresnel lens would be the most expensive component of this system, costing around $250, but still below specification), ease of use, (the lens only need to be placed in the sun and focused on the material and watched while it burns) and aesthetics as this would be a very neat looking object in action. It could also provide some educational value as people learn about light refraction and the power of concentrated sunlight.

A Fresnel lens of this size can boil 12 ounces of water in 60 seconds, and set fire to wood in one second (GreenPowerScience, 2009). This feature would be important because of the high moisture content of fresh material. The material will dry and burn rapidly, destroying weed seeds and reducing the large volume. One of the disadvantages of this system is the fire hazard of burning large amounts of material, but this danger can be minimized by the experience of FOTD staff members that currently use burning to reduce organic waste piles. Another disadvantage of this system is that it does not leave much material to work with, and does not truly compost the material as it does just rapidly disintegrate it.

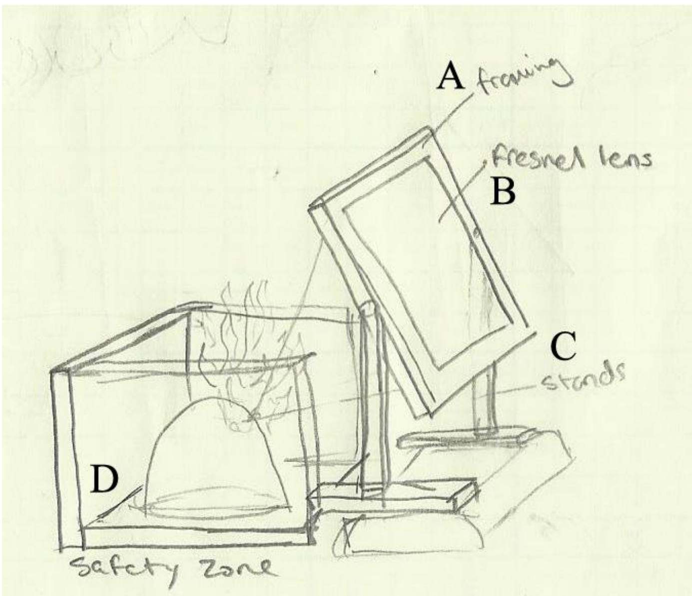

Figure 4-8: The Solar Blast Composter 9000. *Another very simple and very durable design, The Solar Blast Composter 9000 has the features as follows: A) the framing that will hold B) the Fresnel Lens, which will be supported by C) the stands (most likely metal or concrete as wood poses a threat of combustion, and the most important part of the system is D) the safety zone which will prevent and volunteers from being burnt or any wildfire from starting.*

5 Decision Process

The Decision Process evaluates each solution described in Section 4, Alternative Solutions. The compliance with the client's criteria listed in Section 2, Problem Analysis, is evaluated by use of the Delphi Method to find the most appropriate solution. The Delphi Method deciphers how well each solution meets the criteria.

5.1 Criteria

The following criteria, from Section 2, were used in the decision process. Each criterion is defined as follows:

Cost: the price to build and maintain the system.

Ease of Use: the time and energy required to maintain the process of making soil from green waste.

Educational Value: how much physical and visual learning the volunteers and guests will experience.

Effectiveness: the speed of decomposition and quality of the final product as a result of the system.

Labor Intensity: how much physical work it will take to run this system for one cycle.

Availability of Amendments: the cost and proximity of amendments if they must be incorporated into the system.

Aesthetics: the cleanliness and overall structure of the system.

Safety: the limitation of hazards brought on from spontaneous combustion, the structure collapsing, mechanical parts breaking, etc.

Durability: how long the system will run without breaking past the point of repair.

5.2 Solutions

Each of the following solutions are described in Section 4, Alternative Solutions. There are eight total solutions and they are as follows:

1. Barrel
2. Hole in Ground
3. Greenhouse
4. Chambers
5. Silo
6. Baker's Bin
7. Earthworm
8. Solar Blast 9000

5.3 Decision Process

The alternative solution was selected based on the results from the Delphi Matrix (Table 5-1). To begin building the Delphi Matrix, the group had to agree on the weights (or importance) of each criterion. The higher the value, the more important that criterion is to meet. Each group member shared the weights they felt appropriate and discussed why. The final agreed upon weights and their respective criteria can be seen in the first two columns of the Delphi Matrix.

Each solution was evaluated (from zero to fifty) based on its ability to meet the criteria. A low score meant the system did not meet the criteria to the client's expectations. That value (written above the diagonal mark) was multiplied by the weight of the respective criterion to reveal the final value. Those values were totaled at the bottom of each solution's column and compared. The systems with the highest scores were then further evaluated by the group and client to make a final decision.

Table 5-1: The Delphi Matrix.

Criteria		Solutions							
List	Weight	B	HG	Gh	Ch	S	BB	Ew	SB
Cost	4	10 / 40	45 / 180	35 / 140	40 / 160	15 / 60	20 / 80	10 / 40	30 / 120
Ease of Use	7	40 / 280	30 / 210	35 / 245	35 / 245	45 / 315	45 / 315	40 / 280	45 / 315
Educational Value	6	10 / 60	10 / 60	30 / 180	30 / 180	40 / 240	35 / 210	30 / 180	40 / 240
Effectiveness	9	35 / 315	10 / 90	40 / 360	45 / 405	25 / 225	25 / 225	25 / 225	40 / 360
Labor Intensity	5	35 / 175	15 / 75	20 / 100	20 / 100	35 / 175	35 / 175	35 / 175	45 / 225
Availability of Amendments	2	25 / 50	15 / 30	30 / 60	30 / 60	25 / 50	25 / 50	25 / 50	40 / 80
Aesthetics	6	40 / 240	10 / 60	45 / 270	40 / 240	40 / 240	30 / 180	35 / 210	40 / 240
Safety	10	40 / 400	15 / 150	35 / 350	45 / 450	35 / 350	35 / 350	25 / 250	10 / 100
Durability	8	25 / 200	45 / 360	35 / 280	45 / 360	30 / 240	30 / 240	15 / 120	30 / 240
	Total:	1760	1215	1985	2200	1895	1825	1530	1920

Key:
B: Barrel
HG: Hole in Ground
Gh: Greenhouse
Ch: Chambers
S: Silo
BB: Baker's Bin
Ew: Earthworm
SB: Solar Blast 9000

5.4 The Final Decision Justification

The final decision is based on the totaled score seen at the bottom of the Delphi Matrix (Table 5-1). The Chambers solution had the highest score, with the Greenhouse and Solar Blast 9000 clearly second and third, respectively. With safety as the most valuable criteria, the Chambers system is the best option.

6 Specifications

This section will provide a more detailed description of the solution decided on in section 5.4. A cost analysis, implementation instructions, and test results will also be featured in this section.

6.1 Solution Description

The Chamber solution will be a three chamber compost bin with no mechanical parts. The structure will be supported by wood beams and insulated with beach grass bales. To protect the insulating bales from wet weather, a hand mixed lime plaster will seal the walls. The ground under the structure will be compacted thoroughly and covered with wood pallets to prevent the compost materials from contacting the earth. A roof will be slightly larger than the structure to keep rain from soaking through the plaster, and doors will be made from donated wood that slide into place.

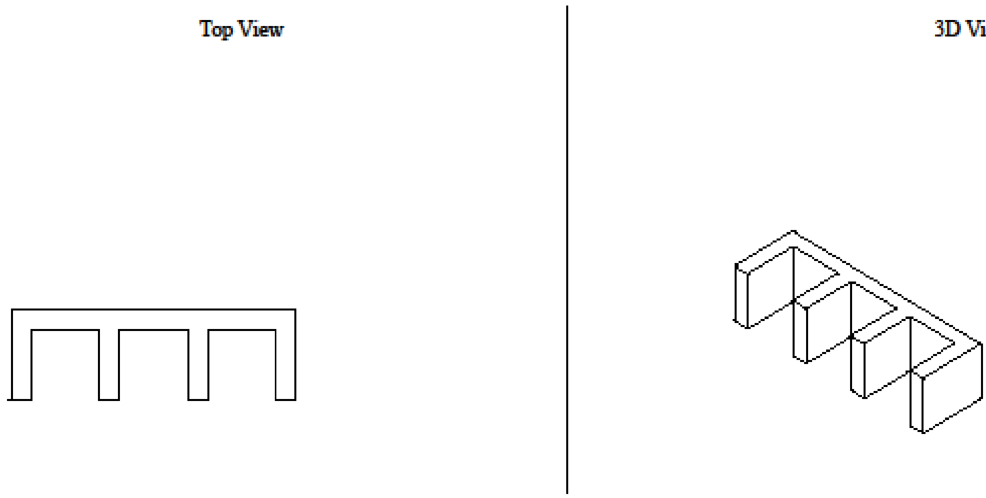

Figure 6-1: 3D Design of Chambers.

6.1.1 Structure

The main structure of the system will feature three chambers lined next to each other with separate doors. As seen in Figure 6-2 below, the floor plan will allow for a 4'x4'x4' chamber where the waste will degrade into usable soil. The walls will be roughly 14" thick because of the dimensions of the bales. Wood will provide the main structure to the system as well as separate the bales from the ground. Wood that will come in contact with the soil will be treated with oil to prevent rapid degradation and rotting.

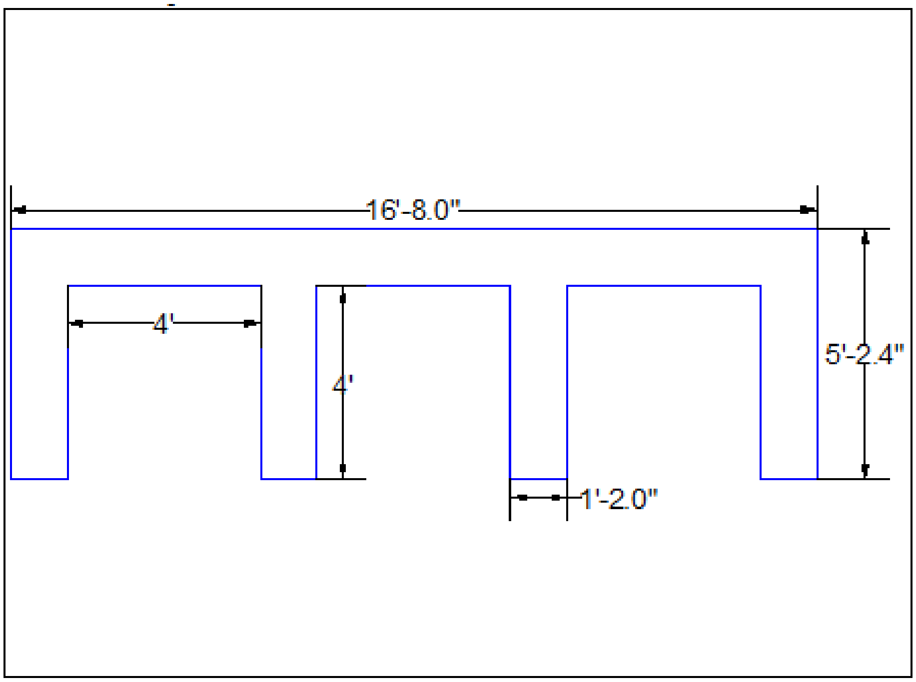

Figure 6-2: Floor Plan of Chambers.

6.1.2 Insulation

Beach grass bales will provide the insulation that is vital for rapid decomposition. The bales are being constructed by peers and will be tightly compacted. The dimensions of the bales will be roughly 2'x2'x2' which will create the thickness of the walls. Pond liner will be draped over the upper layer of bales to prevent water, if it passes the roof, from soaking through the plaster and causing mold. To prevent moisture from seeping up through the ground, treated wood will be placed as a boundary. To secure the bales together, rebar will be inserted into the bales as a nail. Chicken wire will be stapled onto the bales to simplify the plaster process and act as a final structural support. The hand mixed lime plaster will act as a weather shield for the insulating bales. Figure 6-3 displays a beach grass bale that is slightly smaller than the standard dimensions.

Figure 6-3: A Beach Grass Bale.

6.1.3 Roof and Doors

The roof dimensions will slightly exceed the overall size of the structure to ensure rain will not soak through the lime plaster. The roof will be made from corrugated metal that has been adequately sanded on the edges to prevent injury. The back side of the roof will have hinges, much like a dumpster, to provide ease of access for volunteers. The doors will be multiple pieces of wood that are 4’1” long that will be slid into place, as seen in Figure 6-4 below. The wood will be treated for weather protection.

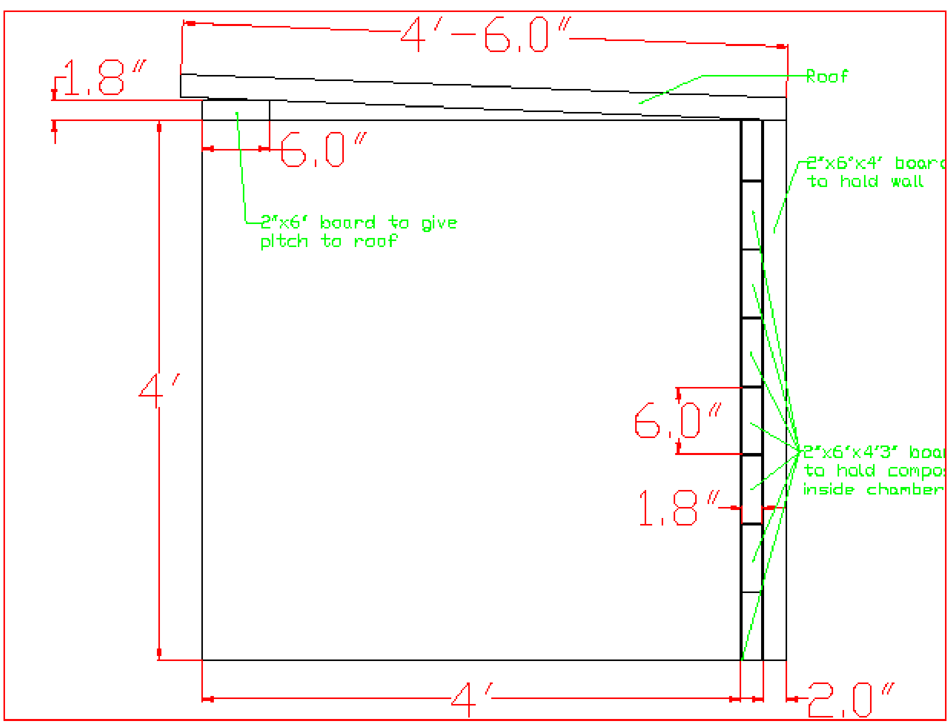

Figure 6-4: Side View of Chambers.

6.2 Cost Analysis

6.2.1 Cost of Materials

Below in Table 6-1, a list of materials and their costs are provided. The potential cost represents what this project would have cost, had donations not been received. Our cost is the price that was paid in this project.

Table 6-1: Cost of Materials.

Material	Potential Cost ($)	Our Cost ($)
Pallets	285.75	Donated
Beach Grass Bales	Free	Donated
Wood	15.00	15.00
Nails and Wire Staples	4.98	4.98
Chicken Wire	24.99	24.99
Corrugated Sheet Metal	10.00	10.00
Total:	339.97	54.97

6.2.2 Design Cost

As seen in Figure 6-5 below, this project (so far) has required 209 hours. This number is added together by each group member's individual time spent on the project. Group meetings were only counted once.

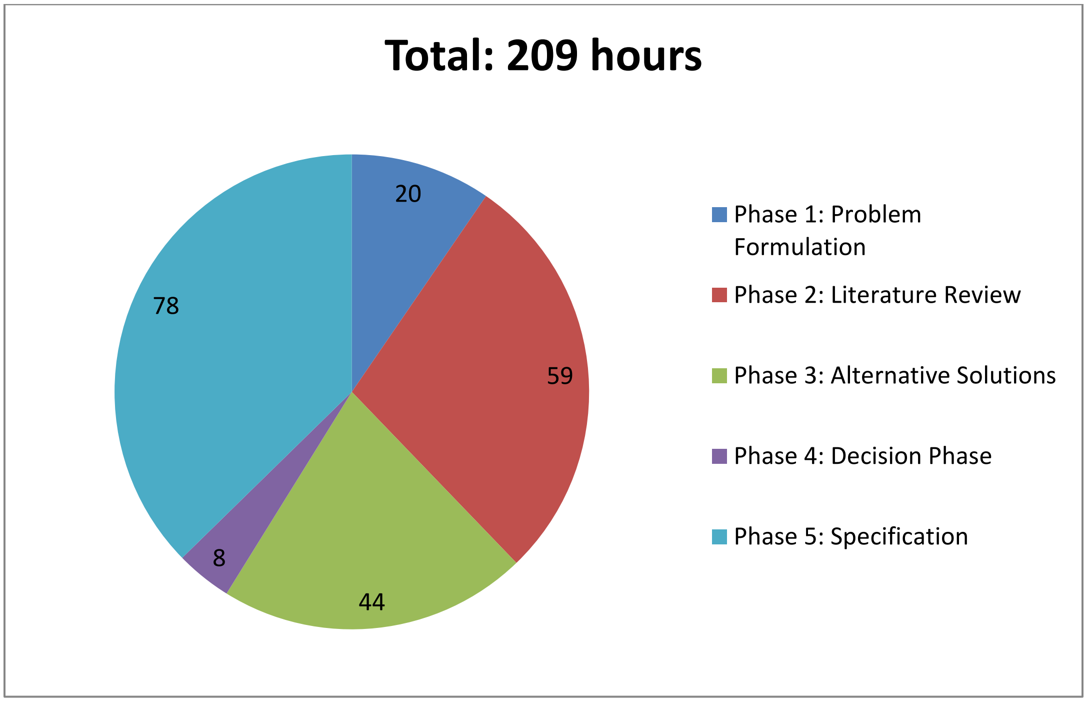

Figure 6-5: Design Cost.

6.2.3 Maintenance Cost

The chamber system is a very durable structure, especially because of the lack of mechanical parts. Maintenance costs of this system may occur because of the exposed wood. Due to the rainy climate, wood may have to be replaced as frequently as every six months. However, there are many local free wood sites available. Therefore, the materials cost of maintenance is minimal. If purchased wood is preferred because of aesthetic value, the maintenance cost may rise to about $10-20 a year.

The durability of this project should allow it to be fully functional and safe for well over a year.

6.3 Implementation Instructions

Follow these instructions unless this is within the first three weeks of implementation. In that case, refer below to the instructions most appropriate for the week of use.

1. Remove the finished compost from the chamber that appears the most processed. This compost may now be used as soil.

2. Following Figure 6-7, carefully layer green waste, then brown straw-like waste in many layers. Do not compact the waste.

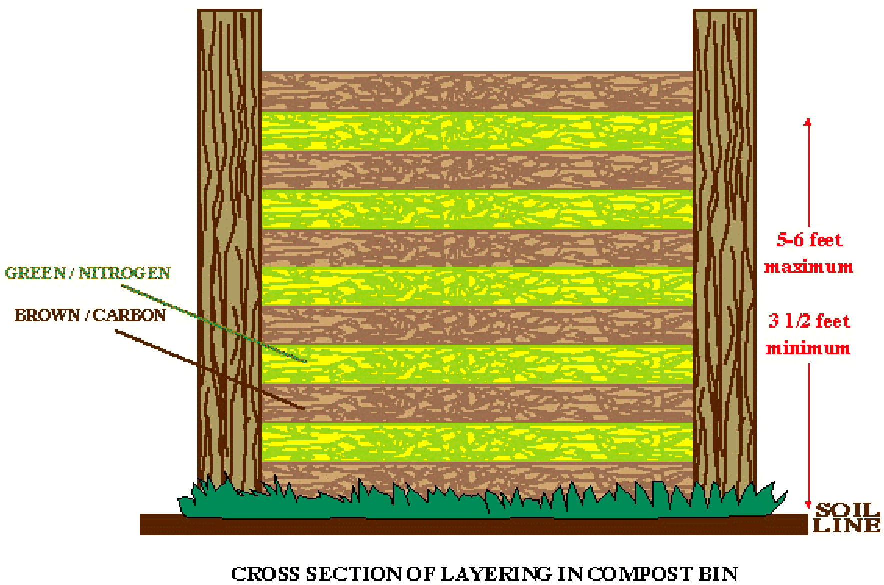

Figure 6-7: How to Layer Compost Materials Properly.

3. Properly close the chamber and make sure system is as sealed as possible.

4. Leave the fresh chamber undisturbed for one week.

5. Thoroughly mix the composting materials in the other two chambers. The best way to mix the compost is to “fold” the materials from the outside to the center. **Do not compact the compost.**

6. Properly close the chambers and leave undisturbed for one week.

7 Appendices

7.1 A. References

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7.2 B. Alternative Solution Brainstorm Notes

Barrel idea

Compost → Barrel → Chamber

Crank system (both sides)

cover, store

~~Celyph~~ wrapping

Burning

Grinding

- Direct, safe

Tubes to airate

Fan

Structurally add air

Tarp

Door / slats

Materials

wood

Glass

Concrete

Adobe

plastic

Bamboo

Pallets

PVC

Isulation

Glass / double pane

Bottles

Concrete

Rubber

Tarps

In a hole

(supply air)

Hole System:

need:	constraint:
Cover	Safety
Lining	Mixing
Fence for safety	Effectiveness
insulation	Taking out
· protect errosion	Ease of use
Mixing
· Screw

Shilloute system

need:	constraints:
Screw
Concrete for structure
Lid
Truth window
~~Death Ray~~ (
Fresno lens
not safe!

Barrel Solution

Need:	Constraints:
Barrel (plastic)	Labor intensive
Lining	Size
Spinning apparatus	Cost
Door for access	Fragile
Wheels for portability

Chambers

Need:	constraints:
concrete	Labor intensive
Protection Roof: Plastic, metal	* safety
Airation system	Cost
· fan, PVC, pallet	Size
Door	Asthetics
· wood with protection
Insulation [at night, etc]
(Look up building codes)