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Assessment of the Feasibility of a Composting Facility for the Cantera Community

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Abstract

This report, prepared for Compañía para el Desarrollo Integral de la Peninsula de Cantera (CDIPC), Puerto Rico, is to evaluate the feasibility of a composting plant and raise environmental awareness in the Cantera community of Puerto Rico. The following document addresses necessary background, research methods, and findings. Through evaluating community waste habits, physical composting, and researching of composting and recycling systems, we established the best future options for the Cantera community. We hope that composting will have an effect on the recycling of the community and help it become more sustainable.

Acknowledgements

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We would like to thank ***Carmen Mendoza Rivera*** of the San Juan Municipality and ***José Alsina*** of Vivo Recycling for providing information that developed our project further.

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Executive Summary

Background

Global waste generation is expected to triple in the next hundred years according recent evaluations of the increasing production of garbage (Goto 2013). Without drastic efforts to decrease generation, recycle and reuse, these levels of improperly handled waste will overwhelm populations around the world. Currently less than 4% of the solid waste stream is recycled in poverty stricken communities (Hoornweg & Bhada-Tata, 2012). Efforts to increase this percentage of recycling have the potential to contribute towards a solution to these garbage problems by repurposing waste to create new resources. In Puerto Rico, an island territory with limited waste disposal options, average waste production amounts are 1.2 times higher than average U.S. mainland residents. Problems that result from improper management and lack of recycling of these large volumes of waste are amplified in regions with high poverty levels and poor infrastructure. There is evidence of this relationship in the Cantera Peninsula where substandard living conditions exist.

The Cantera community struggles with both high poverty levels and insufficient infrastructure for waste management and utilities. Sections of resident houses were constructed on unstable land that was created by a buildup of trash dumped in what used to be the flowing Martín Peña Canal. The canal's natural flow has been significantly hindered since the 1980s resulting from a long standing habit of negligent waste management practices. These habits have created a reputation of Cantera as an area to dispose of unwanted waste; outside individuals frequently use the region as a dumping ground. These practices have lead to many negative

effects on the environment due to pollution and the disruption of the natural flow between the ocean and the lagoon that should be connected by the Martín Peña Canal.

To address these issues, we investigated how composting can improve waste management issues in Cantera in collaboration with the Compañía para el Desarrollo Integral de la Península de Cantera (CDIPC). The CDIPC is a government organization that strives to improve the environmental, social, and infrastructural conditions throughout Cantera. Our project is a continuation of previously developed plans for the implementation a waste collection facility from a 2014 IQP: *Evaluation of the Feasibility of Establishing a Waste Collection Facility to Serve the Community of Cantera*. Building off of this past project and using new methods aimed at collecting data on the current waste disposal practices and opinions in the area has allowed us to establish the feasibility of a composting plant in Cantera.

Methodology

Our goal for this project was to determine the feasibility of a composting plant that will improve waste management habits to support the CDIPC's efforts to create a more sustainable community. We achieved this goal by completing three main objectives:

1. Create a plan to connect with the community and gain their support for a composting facility by educating about sustainability and composing.
2. Investigate other composting efforts to gain knowledge about the composting process and how to make a profit from it.
3. Develop protocols for the successful operation of a composting facility in Cantera.

To create a plan for community involvement we evaluated the current attitudes on waste management and waste disposal habits of the community. We did this through a tour of the community, meeting with local middle school students, and participating in a local event. The tour was led by Alfredo Zapata, a CDIPC employee who has created strong connections throughout Cantera. He was able to highlight issues that residents are currently dealing with and their willingness to accept new sustainability efforts. Next, we met with local middle school students to generate methods to reach out to the community and gain support for new ideas. From student feedback, we developed informational sheets to provide basic knowledge about composting. The effectiveness of this material was then tested at a local event, the December 6, 2015 Bike Day.

To determine the feasibility of a composting plant, we met with community stakeholders and other composting operations in Puerto Rico. Community stakeholders included other CDIPC employees, with experience on the conditions in Cantera, and the San Juan Municipality. The Municipality was especially beneficial because their representative expressed interest in a potential partnership with a composting facility. The other composting operations we observed and participated in were the industrial composting operation at Vivo Recycling and a small garden compost process at the local middle school. Our visit at Vivo Recycling was a great opportunity because it is a successful business built around composting, which we hope to be able to repeat in Cantera.

After the feasibility was established, protocols for the operation of the facility were planned out by researching, observing, and identifying the basic steps of the composting process. We started by researching the fundamentals of composting. This was used to create a system to

compare various compost organization methods that were identified and determine the most applicable method for Cantera. By observing the process at the local Vivo Recycling composting plant we were able to recommend a similar type of facility for Cantera. The next step was meeting with the local San Juan Municipality to understand what kind of partnership the facility could have with already established waste collection systems and what kind of legal permits are required. From the collected information, we were able to set up an efficient and reliable composting plan for a new facility in Cantera.

Results

This project includes an assessment of the current waste management situation in Cantera and an explanation of how introducing composting would be beneficial to the community. A plan for a composting facility is also outlined as follows:

1) Evaluation of the current waste management situation in Cantera

From the tour around the Cantera Peninsula, we learned about common practices of open dumping and were able to see the build up of trash in certain areas. Seeing the conditions throughout Cantera showed how the current waste management practices are not effective. We then talked with students at the local middle school and learned about the limited common knowledge about recycling methods, like composting. From our discussions, we learned about the attitudes that residents have and how to best approach changing them. The student's interest in environmental issues, learning, and sharing knowledge showed promise for improvement of the waste management habits in Cantera. Talking with the students allowed us to generate educational materials that will help explain the concepts of composting and how it could be implemented in Cantera. One example of educational material is shown below in Figure 1.

Figure 1: Example of Education Material

2) Assessment of a potential composting facility

Assessing the feasibility of the composting facility was completed through discussions with Vivo Recycling and the San Juan Municipality. Vivo Recycling is an established industrial composting plant located in Caguas, Puerto Rico. Our tour with Vivo helped us identify four factors for a successful composting business. These factors include:

- Community need for organic waste disposal
- Partnership with local municipality
- Distribution of revenue
- On site nursery

Cantera has the potential to build from the presence of these four factors and establish its own facility. This is demonstrated by the interest of the local San Juan Municipality. Through a meeting with a municipality representative we found that there is a need for a composting facility. We learned that they would be eager to work with a local composting plant to revert

recyclable organic waste from its current disposal method: landfills. We found that a facility could create more sustainable habits for the community and maintain a profitable business.

3) Explanation of required composting protocols

In order to prepare for the future facility in Cantera, four steps of composting were identified:

1. Sorting
2. Creating a Pile
3. Maintaining
4. Separating

We designed these steps through research and confirmed them through observing both the Vivo Recycling facility and the local school's garden. We then compared multiple composting organization techniques to choose the most applicable one for Cantera. By comparing the systems, we found the two best methods to be compost piles and holding units. These two organization methods would be implemented during different phases of the three-tiered facility plan. An outline of the three tiers can be seen below in Figure 2:

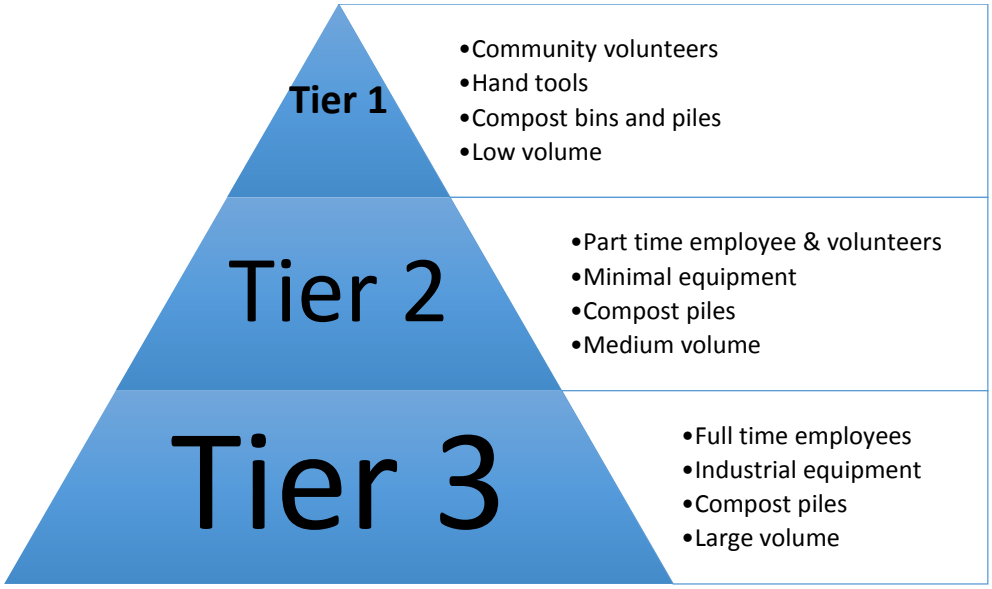

Figure 2: Example of Three-Tier Facility Plan

Recommendations

We identified recommendations to increase the reception of a community-composting plan based on the analyses of our results. We focused our recommendations on the education of composting concepts in Cantera to encourage progress towards the implementation of a composting facility.

- **We recommend disseminating the basic knowledge of composting concepts to residents in the community of Cantera.**

A large importance to the implementation of the composting program and facility is the community understanding the composting process. We created pamphlets and handouts outlined in both Appendix I and Appendix H that would create a basic understanding of the composting process. The informational material should be handed out at schools and community events. The individuals delivering the information need to be established as a trustworthy source with connections to the CDIPC. After interaction with the material, residents' knowledge will then be assessed through interactive activities. Once residents are engaged in the learning of composting, the plan for the implementation of a facility will hopefully gain support.

- **We recommend the implementation of a compost facility.**

This should be implemented by the CDIPC along with a partnership with local community leaders. Some funding for the facility could be generated through a partnership with the San Juan Municipality. The composting facility location will be where the community can come together and work in a common area. The techniques of composting that we have provided will be

utilized at the site. The overall layout of the site will include a learning center, garden, and process of composting. The layout can be seen in Figure 3, below.

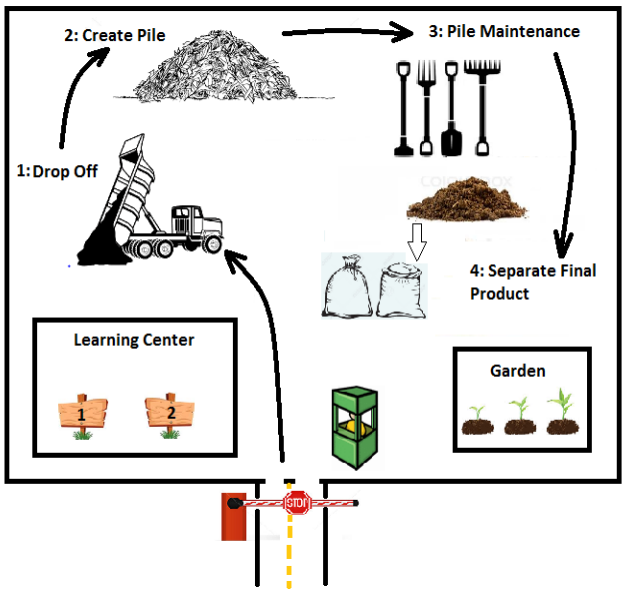

Figure 3: Breakdown of Facility

A key aspect of Figure 3 is the four steps of composting that are necessary to complete the process.

- **Our recommendations for future projects**

We suggest that a future team research more into the capabilities of an industrial scale facility plan for Cantera. They should analyze the maximum size Cantera's potential facility can reach and how much waste could be handled. We also suggest that future investigators look into a private business investor or find government funds to develop an industrial grade composting facility. Lastly, we recommend future investigators work with the San Juan Municipality gain more detail on specific permits. This will be a critical aspect on planning out the industrial grade facility and gaining approval to move forward on the project.

Video Overview

We produced a video to summarize our project, click the image below to access it

Authorship

Executive Summary.....Tyler/Maddy
Chapter 1: Introduction.....All
Chapter 2: Background.....All
2.1. Waste:.....Tyler
2.2. Waste Management in Puerto Rico:.....Tyler
2.3. Waste Management in Cantera:.....Jake
2.4. Composting.....Tyler
2.5. Community Involvement and Education.....Maddy/Jake
2.6. Summary:.....Maddy
Chapter 3: Methedology.....All
3.1. Create Community Involvement Plan.....Maddy
3.2. Investigate Other Composting Efforts.....Tyler
3.3. Develop Operational Protocols.....Maddy
3.4. Summary.....Jake
Chapter 4: Results.....All
4.1. Evaluation of waste management habits.....Tyler
4.2. Assessment of a Composting Facility.....Maddy/Tyler
4.3. Development of Composting Protocols.....Maddy
4.4. Summary.....Jake
Chapter 5: Recommendations.....Tyler/Maddy
5.1. Our Recommendations.....Tyler
5.2. Address Limitations.....Tyler
5.3. Suggestions for future.....Tyler
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Chapter 1: Introduction

Proper waste management, which includes a variety of waste recycling and disposal methods, is an integral part of a functioning society. Without a sustainable waste disposal system, populations are overwhelmed by increasing volumes of uncollected waste that bring health detriments to the community (Troschinetz & Mihelcic 2008). Impoverished communities with inefficient management strategies recycle less than 4% of all generated waste (Hoornweg & Bhada-Tata, 2012). According to a journal on the Contributions to Urban Sustainable Development by Baud, Grafakos, Hordijk, and Post in 2001, the best way to maintain a clean community and provide jobs for impoverished community members is through implementing methods of recycling waste, like composting.

With its minimal waste management infrastructure, Puerto Rico demonstrates the need for proper waste management, as it is becoming an island overflowing with waste. Puerto Rico has a population density of over 1,000 people per square mile. Each individual's average waste production is 5.4 pounds of waste per day; 1.2 times the average waste production of a U.S. mainland resident (Miranda & Hale 2005). Along with the overproduction of waste, the decline of Puerto Rico's manufacturing industry and increasingly high poverty rates have negatively impacted waste removal practices (Puerto Rico in Perspective 2015). Current waste problems are masked by the use of the island's 32 landfills, 28 of which are approaching their maximum capacities (EPA 2015).

The waste management problems in Puerto Rico are magnified in an impoverished, poorly constructed area called the Cantera Peninsula. A large portion of the roads and alleyways are not large enough for waste collection vehicles to pass through. Due to the lack of waste

collection services, open dumping habits are widespread and have created a view of Cantera as a dumping ground. Throughout its history, Cantera has expanded into the neighboring Martin Peña Canal through the build up of trash that has been continuously dumped into the water, almost completely stopping the flow of the canal (Zapata 2015). One natural disaster, hurricane Hugo, had devastating effects on the island's waste infrastructure. The strong category three hurricane struck the island in 1989, leaving a shattered community in its wake. More specifically, Cantera's shack towns were demolished, leaving debris scattered throughout the community (Scatena 1991). Parts of the region are still recovering from the aftermath.

In order to further understand and address this problem; our teams task was to investigate how environmentally friendly recycling methods, like composting, along with community involvement can contribute to the establishment of a proper waste management system. Understanding the process of composting and how it can be used to create a feasible business allowed us to create a plan that will ultimately reduce the amount of trash sent to landfills. The general public must be informed of the consequences of overfilled landfills and the detrimental effects on the public's health, economic system, and surrounding environment. We expect that, once informed, the Cantera community will support the implementation of a composting plan that has been developed for the betterment of their community.

Previous research in the region has established plans for a waste collection facility to benefit the surrounding community. Building off of these plans, a proposal for a viable composting plant has been outlined to cooperate with the waste collection facility. The most suitable site location in Cantera has been identified, and we complemented this by gathering more information on the community's current knowledge of composting, how the process works,

and how to generate a profit from it. We also needed to know the communities willingness to participate in this waste management project and how to convince them of the benefits.

We addressed this problem by researching comparable projects and interviewing both the government and community stakeholders. Similar waste management efforts, such as a case study in Cerfu, Greece, were beneficial background references in supplementing our modeling process. Data was collected through interviewing local San Juan composting businesses, interviewing the Cantera youth, and conducting a sample composting process. These methods helped generate an understanding and a diagnosis of Cantera's current waste issues, both socially and industrially. We then chose a proper composting plan to match the supply of organic materials. More specifically, we determined that the addition of a composting plant to the waste collection process would be beneficial to Cantera's specific waste management issues and to raising awareness of the currently unsustainable practices.

In this proposal we discuss the background behind waste management problems around the world and how this is magnified in Puerto Rico, and more specifically Cantera. From this, a problem with poor waste management infrastructure and practices in the Cantera peninsula has been identified. In order to address this problem, methods aimed at collecting data on the current waste disposal practices and opinions in the surrounding community were examined. The methods were used to evaluate the extent of the problem and allow the generation of recommendations towards a composting facility in Cantera.

Chapter 2: Background

One of the largest problems facing the world today is waste management and sustainability. All nations are generating far more waste than current disposal methods can

handle. We need to take a deeper look at how we manage our waste as we head towards a more industrial world. The wealthier nations with the capital to create appropriate infrastructure to handle the volume of waste are currently implementing new strategies of recycling. For example, one logical method for reducing recyclable waste from entering landfills is composting. The composting processes would be able to reuse and prevent organic waste from being deposited in landfills. Puerto Rico's lack of a recycling plan and infrastructure leads to a reliance on landfills to deal with most of the municipal waste. In this chapter we analyze waste management as a whole and analyze sustainability techniques, such as composting.

2.1. Waste:

2.1.1. Waste Global Problem:

With the growing industrialization in the world today there is an emerging effort to handle the current waste crisis. Current growth rates of population are predicting that the generation rate of municipal solid waste is expected to double in the next 25 years (Hoornweg, D., & Bahda-Tata, P, 2012). Municipal solid waste is more commonly known as garbage, consisting of everyday items; such as newspapers, food scraps, packaging, and batteries. Globally, the most commonly used method for waste disposal are landfills (Schubeler, P., Wehrle, K., & Christen, J,1996). Unfortunately, landfills result in negative and undesirable aspects such as noise pollution, odors, visual eyesores, and transportation costs. Additionally, landfills that are not up to EPA code can allow decomposing trash to seep into the surrounding soil, tainting surrounding water sources (Miranda, M. L., & Hale, B., 2005). The leakages can lead to detrimental effects in the surrounding communities.

2.1.2. Effects of Poor Waste Management

2.1.2.1 Environmental Drawbacks

Continuously using improper waste management can lead to negative consequences on the environment. Impacts can range from simply throwing a wrapper on the ground to the deforestation of large rainforests (Buchholz, 1998). Alfredo Zapata of the CDIPC explained that in Puerto Rico, certain residents lack access to public waste removal services, which then leads them to rely on different approaches. These residents either take all material waste to a landfill or simply dump it in the streets and canals (Miranda, M. L. & Hale, B., 2005). There are many potential impacts of these two practices, for example, overflowing landfills. With only 7% of the landfills in Puerto Rico meeting EPA standards, the remaining 93% can pollute the surrounding ecosystems or taint water sources (EPA 2015). Puerto Rico is a small, densely populated island with limited terrain for landfills; it cannot uphold the current waste being produced which is leading to pollution (Miranda, M. L. & Hale, B., 2005).

Similar to poorly maintained landfills, improperly treated waste results in major damage to the surrounding ecosystem. In order for a community to reuse a space previously filled with waste, they will set fire to it to clear the area. This may take care of the buildup of waste, but these fires release environmentally damaging air pollutants and volatile organic compounds. If these waste removal tactics are not improved, an irreversible impact to the environment could occur on the island (Hoornweg & Bhada-Tata, 2012).

2.1.2.2 Health

The mishandling of solid municipal waste often leads to pollution, which can cause health issues. In impoverished areas the infrastructure to remove waste is poorly designed or nonexistent (Murad & Siwar, 2007). Therefore, in these locations open dumping is very common since there are no other options. If the waste stays stagnant in the street, infestation of insects and rodents will follow. These species tend to carry diseases and can cause illnesses such as diarrhea, minor respiratory issues, cholera, and other water-borne diseases (UN Habitat, 2010). Contrarily, even if solid waste is collected and properly filtered to the correct waste management facilities, mismanaged landfills can still cause adverse health effects. The largest concern is poorly built landfills and the displacement of polluted leachate. Leachate, the process of filtering water through a solid, can carry harmful toxins to potable drinking sources, which can to be harmful to human health (Miranda, M. L. & Hale, B., 2005). Some examples of harmful chemicals present in landfills are vinyl chloride monomers and benzene, which have all been classified as carcinogenic. This classification is upheld by nationally recognized organizations, such as United States Environmental Protection Agency and the International Agency for Research on Cancer (U.S. Department of Health and Human Services, 1997). These negative health effects should be considered when looking at Puerto Rico's waste management system.

2.2. Waste Management in Puerto Rico:

2.2.1. History

Puerto Rico's current waste crisis comes from a multitude of factors that all lie in the history of the island. Through the 1940s, Puerto Rico's economy was primarily driven by the

agricultural industry. Agriculture being the main facet of the economy meant that there were sustainable farms and businesses that operated with little to no waste generation (Abuyuan, Hawken, Newkirk, & Williams, 1999). Through the 1950's Puerto Rico rapidly industrialized and shifted the economy towards a reliance on the manufacturing sector. Political leaders drove this effort because it would increase global market interaction and create job opportunities on the island. Following the decision to industrialize, Puerto Rico saw its most prosperous economic period from 1950 to 1975 (Bosworth and Collins, 2006). This quick improvement to the economy allowed for more and more manufacturing companies to see the benefits of coming to Puerto Rico. The rapid industrialization also increased the affluence of the Puerto Rican community, which led to an impact on their environment as individuals. The impact is from spending more on materialistic products, such as plastic products, which end up creating more waste that needs to be disposed of. During the economic boom, construction of new facilities and buildings led to a creation of industrial grade waste as well (Chan, Kwok Loon, 2006). The most common waste removal process utilized to handle the overflow of waste was landfills. These poor waste management habits have continued and created sanitation issues throughout urbanized parts of Puerto Rico (Presser 1991). For example in Figure 3, below is a storm drain clogged with garbage debris.

Figure 4: Clogged Drain in Cantera

The lack of proper waste removal, extensive use of landfills, and lack of recycling procedures have led to Puerto Rico's current waste crisis.

2.2.2. Current Issues

Puerto Rico currently maintains a waste generation rate per capita that is about 25% higher than that of the United States (Miranda, M. L., & Hale, B., 2005). Puerto Rico relies primarily on landfills as their main waste disposal system, with little to no other alternatives. There are currently 32 major landfills in Puerto Rico and only 7% of the landfills on the island are in full compliance with the requirements held by Environmental laws (EPA 2015). In order to reduce compostable and recyclable waste being sent to landfills, a new waste removal process is needed.

In 1992, a recycling program was implemented by the government that aimed to improve the overall recycling habits of Puerto Rico (Courtney et al., 2004). The program implemented curbside trash removal that would be taken to transfer stations. These transfer stations would help separate waste and outsource non-recyclable waste to landfills. Another possibility was

incineration of the waste build up; nevertheless the harmful consequences of the practice caused the option to be avoided (Chan, Kwok Loon, 2006). Ultimately the program failed to meet its target of 35% waste recycling in 1992 and waste recycling is still very low at 16% (Courtney et al., 2004). The program showed some positive intentions, but lacked support of the community and proper execution of the waste removal process. New implementation of proper recycling and waste management techniques are required. Along with new waste removal techniques, the effect of poverty and economy must be considered in the current waste crisis.

2.2.3. Influence of Poverty, Economy

Puerto Rico is currently suffering from its worst economic summer to date and possesses a debt of 70 billion dollars, according to Jorge Colón's article, *Puerto Rico's future at stake*. The economy is in a downward spiral and the territory recently defaulted on a bond payment for the first time in its history (Colón, 2015). Along with the struggling economy, the unemployment rate is high, at around 15%, and causing Puerto Ricans to flee the island in search of a more stable economy. This loss in population will have a lasting effect on the already crippled economy. In order to stabilize the country, much work has to be done (Colón, 2015). The following Figure 5 shows how the Puerto Rican unemployment rate is almost double that of the US.

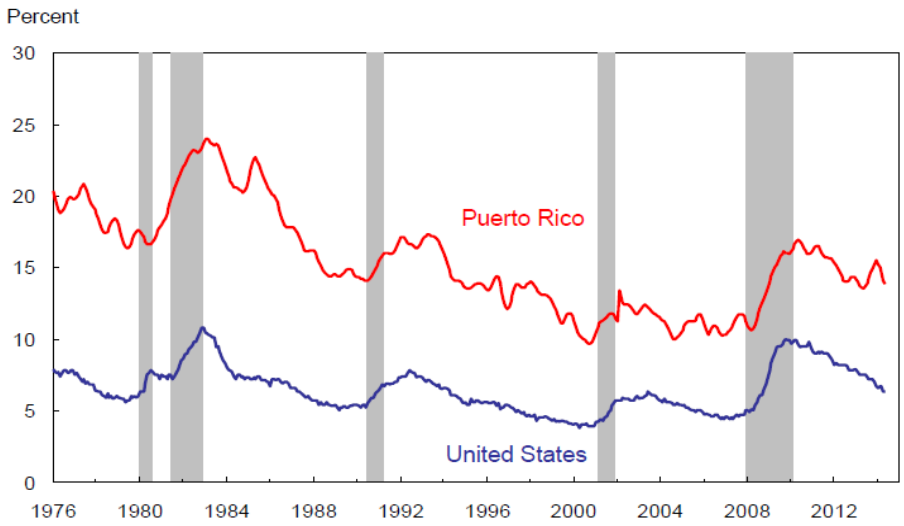


Figure 5: Unemployment Rate

(Lopez, L, 2015)

While the economy is in distress, there are also problems with the policy addressing environmental issues. One reason for this trouble is trying to implement an economically productive waste removal processes to promote cleanliness in Puerto Rico, as well as increase job opportunities. There is also the struggle of certain procedures to ensure the community follows specific regulations of the U.S. Environmental Protection Agency and Puerto Rican Environmental Quality Board. For instance, appropriately designed environmental taxes can become an important element of environmental policy. Nevertheless, this policy could lead to detrimental effects on the surrounding economy as well. Such an instance could result in a deterioration of environmental quality along with increasing economic costs and undesirable social consequences. Also taking into account policy instruments such as bottle deposits or a landfill tax could add incentives to the support of a new waste management system (Turner, 1998). While change will be slow, making Puerto Rico self-sufficient and increasing the infrastructure for sustainability will be beneficial to the territory and its people (Colón, 2015).

This Economic burden doesn't help the already poverty stricken communities, such as Cantera, Puerto Rico.

2.3. Waste Management in Cantera

2.3.1. Lacking Infrastructure

Cantera is an overpopulated, impoverished community located in the Las Casas peninsula region jutting into the San José lagoon in San Juan. The Martin Peña Canal cuts through the peninsula connecting the lagoon to the San Juan bay. The area surrounding the canal consisted of wetlands filled with a variety of plants, for example mangroves. Up through the 1950's mangroves were perceived as problem areas since they festered with mosquitoes that spread disease (Boyer and Polasky, 2004). The local communities began to fill in the wetlands with construction waste to create buildable land in the cramped peninsula and eliminate the mangrove hazard. Over time the destruction of mangroves expanded the size of the peninsula, slowly clogging the local canal. This is shown below in Figure 6, where the population around the Martin Pena Canal has aggressively progressed over 47 years.

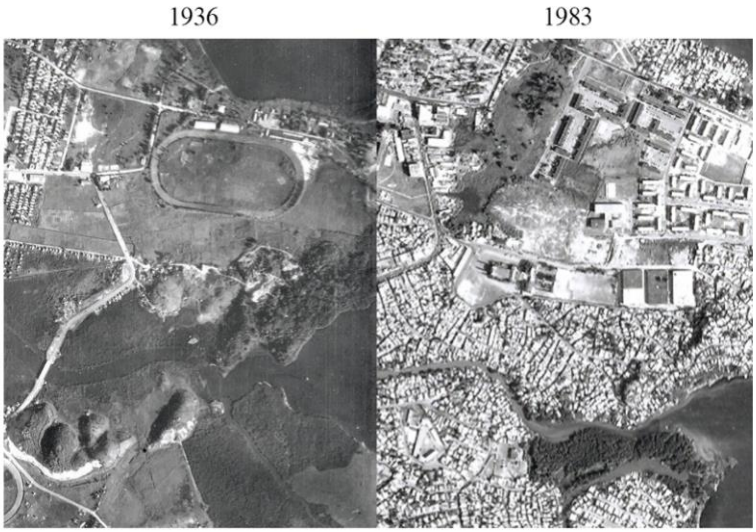


Figure 6: The Drastic Change in the Martin Peña Canal

(CDIPC, 2015)

This careless dumping of trash instilled a mindset in the surrounding communities that Cantera was essentially a region to dispose of unwanted waste (Zapata, 2015).

In a recent effort to move people off of the clogged canal, the government has begun to move people into subsidized housing. From the previous year's IQP conducted in Cantera by Cotter, Hu, Miranda, and Reinertsen, approximately 60% of the community lives in subsidized housing while 40% remains in areas called *barriadas*. Barriadas are settlements built on solid waste buildup along the local canal in Cantera. The community is moving to help these residents into subsidized housing but it is an ongoing effort. These areas are not up to construction code and have very limited access for vehicles, including utility services. These problems present large obstacles to proper waste management in the area (Cotter, Hu, Miranda, & Reinertsen,

2014). There are a number of organizations working to develop waste management infrastructure in the Cantera region (Zapata, 2015).

2.3.2. The CDIPC:

La Compañía para el Desarrollo Integral de la Península de Cantera (CDIPC) was established in 1992 to promote the social, cultural, and economic development of the Cantera Peninsula. This government-owned company is funded both publicly and privately to achieve its budget of almost 33 million dollars a year. A portion of these funds is allocated to address the area's waste management problems (CDIPC, 2011). The company has conducted community projects targeted at waste collection in past years, including a project with a WPI IQP team in 2014.

2.3.3. Previous Cantera Waste Management IQP

In 2014, a WPI IQP team conducted their project on the *Evaluation of the Feasibility of Establishing a Waste Collection Facility to Serve the Community of Cantera* for the CDIPC. The group achieved four main objectives:

- Evaluate the current waste management situation in Cantera
- Determine important stakeholders' opinions on the establishment of a waste collection facility
- Identify and compare locations for the facility
- Prepare different methods to encourage community involvement

2.3.3.1 Evaluate Current Waste Management

To understand the current waste management system in Cantera, the group conducted a trash bag audit to understand the composition of the waste that will be managed by the facility.

The study included 76 participants from the two main types of living conditions in Cantera, barriadas and subsidized housing. The group found that the community of Cantera generates about 22,450 pounds of waste every day. This is an important number for understanding how much waste a facility would need to transport and store. Using a trash separation method, they determined around 34% of the total waste generated was recyclable. This information led the group to recognize the importance of recycling efforts in reducing the amount of solid waste that a facility would need to handle (Cotter, Hu, Miranda, & Reinertsen, 2014).

2.3.3.2 Identify Stakeholders

The team also reached out to organizations in the area and found key insights from these groups, which the WPI team found to have very similar goals to the CDIPC. They interviewed representatives from the Municipal Government of San Juan, the Autoridad de Desperdicios Sólidos, and the Environmental Quality Board. With the expertise of the representatives, necessary components for the success of the potential facility were identified. This included the location of the facility: its accessibility to the public, the level of support from the community, and the facility's adherence to environmental regulations. They also gathered some general information about current waste collection in the area and how a new facility would close the gaps of the current infrastructure.

2.3.3.3 Assessment of Facility Location

From this understanding of the key components of the needed waste collection facility, the WPI group moved to select a location for the facility. By setting up the criteria and a rating system, sites were compared by factors including proximity to residential housing, accessibility,

and flooding patterns. Using a consistent rating system, the seven potential sites were narrowed down to a single location with advantageous conditions.

2.3.3.4 Community Involvement

The WPI team members also looked at ways to get the members of the community involved. This was done through gathering information about the Cantera community and analyzing the best ways to educate them. The goal of the education was to promote change while also connecting the community with new waste removal methods. Some of the most important methods included providing employment opportunities to community members, hosting festivals, providing plant tours, and encouraging education in schools and churches by providing lesson plans. This is a great opportunity to start making change by reaching out to the community and the next generation to adopt new recycling habits.

2.4. Composting

Families generate hundreds of pounds of food and yard waste every year; this number is steadily increasing. To be more specific, an individual Puerto Rican generates approximately 1,971 pounds per year, while the US average is 1,643 pounds per year (US Environmental Protection Agency, 2002). These numbers are going to keep increasing, eventually surpassing the capabilities of landfills. Reducing this waste heading to landfills is imperative, through composting; Puerto Rico can reuse a portion of that trash (Epstein, 1997). Composting is the process of waste material decomposing with the aid of bacteria, fungi, and other microbes. Composting tends to start in a container or pile; once a container or pile is established, organic waste is disposed into them. Usually a good compost pile consists of a 50 to 50 split of nitrogen

based and carbon based materials; typically green materials are nitrogen based and brown materials are carbon based. There are some factors that aid in making the process of decomposing quicker. For example, smaller pieces of material tend to decompose faster, since the bacteria has more surface area to work on. Another alternative is keeping the compost piles moist along with adding air (Composting, 2010). Most community waste can be composted; thus, a single composting facility can handle municipal and industrial organic biosolids, yard wastes, and food wastes. This process can be used on household trash and cause a huge impact on a community's waste management system (Epstein, 1997). Composting could be a viable recycling method to reduce improperly handled organic waste in the Cantera region.

2.4.1. Drawbacks vs. Benefits

There are some drawbacks of composting that are important to consider. A few of these drawbacks are the space needed, odor, dust, vermin, and contamination of soil. Refer to Appendix J to gain more knowledge and understanding of these drawbacks. Nevertheless the benefits from composting outweigh the drawbacks, especially if drawbacks are minimized. Some of these benefits include: providing a viable business opportunity for community members, generating a useful soil conditioner to replace chemical alternatives, a new method of recycling for common kitchen and yard waste, and a path to reducing landfill waste. Refer to Table 1 for a comparison of benefits and drawbacks.

Composting Evaluation	
Benefits	**Drawbacks**
• Provide a viable business opportunity for community members • Generate a useful soil conditioner to replace chemical alternatives • Method of recycle common kitchen and yard waste • Reducing waste sent to landfills	• Space needed • Odor • Dust • Vermin • Contamination of soil

Table 1: Composting Evaluation

2.4.2. Business Feasibility

Composting is a process that creates the opportunity for a feasible business. This has been proven by numerous organizations around the world, in Puerto Rico for example, Vivo Recycling in Caguas and the FOHL Corporation in Arecibo. Profitability is possible because the process of composting results in the production of a soil in which microscopic organisms thrive. These organisms encourage air circulation through the soil and break down the organic components that are essential to the compost process. The final product from composting is a rich soil that will readily provide the necessary nutrients to plants. In Figure 7 below, the final bagged product is display at the Vivo Recycling facility in Caguas.

Figure 7: Tyler Kilkenny and José Alsina Displaying Final Compost Product

This is a valuable product that can be sold to community members and businesses to generate a profit to offset the cost of running a composting operation. This is beneficial to the community because it is creating new business opportunities for locals. The product that is being sold is also beneficial to the community because it is a competitive alternative to unnatural chemical fertilizers that are damaging to local ecosystems. In addition, composting utilizes food and garden waste that has historically been placed in mainstream solid waste disposal methods (Composting, 2014). Studies have found the amount of household compostable waste is over 30% of the total waste of a household (Epstein, 1997). Repurposing this waste to be recycled into a new product reduces the amount of solid waste that ends up being deposited in landfills (Composting, 2014). This process has been shown to make an impact in multiple case studies, such as the Cerfu, Greece waste management example, referred to in Appendix K. The study also shows that community support can play a role in the implementation of such a program in Cantera.

2.5. Community Involvement and Education

Education and the involvement of the community is a huge factor in the success of any community-based project. More specifically, any waste collection facility is entirely based on community members dropping off waste at the facility location (EPA, 2002). For the composting plant to be successful, members of the community need to be involved in the responsibly of disposing their trash properly and supporting the new composting system.

2.5.1. Indian Cities Case Studies

A 1989 effort by a non-governmental organization, EXNORA, aimed to establish sustainable, entirely community based waste collection and disposal groups in Chennai and Hyderabad, two Indian cities. The project demonstrates the importance of community participation and highlights the challenges to gaining community support. Both efforts were focused on developing a zero waste management model where local community members would both fund and organize waste collection. Eventually, both cities' efforts failed after they became unsustainable due to inadequate residential and local political support.

In these two communities, the huge diversity in cultures and overpopulation prevented the spread of knowledge about the importance of the project, which in turn prevented EXNORA from being able to gather enough political support and funding. This huge diversity presented a large challenge because it made communication and education about the importance of their efforts very difficult. These cultural differences without significant efforts to unify led to an individualistic lifestyle, allowing residents to justify avoidance of participation in community projects that they did not have an understanding of. In both Chennai and Hyderabad it was found that the topic of garbage and waste disposal was a topic people did not find important. In the

absence of a drive from a wide community base to gather funds and delegate responsibility and leadership, both Chennai's and Hyderabad's zero waste management model implementation failed.

The major takeaway from these failed waste management projects in Chennai and Hyderabad is that providing widespread education for all aspects of a community is key for the success of a community-based project. The diverse populations in these two cities limited the projects because not everyone was provided with information on and representation in the project development (Colon & Fawcett, 2006). This takeaway needs to be considered in the implementation of any new program in Cantera.

2.5.2. Aspects to Successful Education

In order to gain community support for a project, education is the key to developing a widespread understanding of its importance. There are certain aspects that education should incorporate and address in order to have the greatest impact. First, the education methods and materials must be culturally relevant to the community. This insures that the community will be able to relate to the subject matter and take away lessons from each session. Next, the method of education should vary from formal to informal techniques. This means that classroom lessons can be very useful, but should go along with hands-on opportunities. In the case of a waste collection facility, waste management importance can be taught in a school setting while it could also be communicated in the themes of a local celebrations. The last key component to incorporate into education is the global understanding of issues. While ensuring the local relevance on an issue is imperative, it is also important for the group to understand the topic globally. This should include education about other areas and how the same issues are being

addressed (Education for Sustainable Development, 2015). When providing new ideas in Cantera teaching the relevance of proper waste management on a global scale is necessary for successful learning.

2.6. Summary:

Overproduction and improper disposal of waste are pressing global issues. The existence of a waste management system is pivotal for the environmental, social, and economic health of a community. Puerto Rico is currently facing a solid waste epidemic that is negatively impacting its communities and ecosystem. The barriadas of Cantera are now experiencing the effects of this epidemic and are in need of a new recycling process. Composting is an integral piece to a successful waste management program and implementation should be evaluated for Cantera.

Chapter 3: Methodology

Our goal for this project was to assist the CDIPC to change the Cantera community's waste management habits to be more sustainable. We provided educational material about the composting concepts and provided a plan for the establishment of a composting facility. We achieved this goal by completing three main objectives:

1. Create a plan to connect with the community and gain their support for a composting facility by educating about sustainability and composing.
2. Investigate other composting efforts to gain knowledge about the composting process and how to make a profit from it.
3. Develop protocols for the successful operation of a composting facility and an outline of the equipment needed.

In order to complete these objectives, we will be conducting tours with other composting facilities, informal interviews, and a sample-composting project. Meeting these objectives will allow us to develop a proposal for the local community council to outline the benefits of a composting facility for both the environment and community members. With the approval of the community council, the CDIPC will be able to involve the community in establishing the facility. The result of this project will be the guidelines and protocols for the operation of the composting facility so that members of the community can run the composting facility to earn a profit. Along with the establishment of a facility, our project raised awareness on the importance of community involvement in changing their waste management habits.

3.1. Create Community Involvement Plan

The current waste management habits that are accepted as normal in Cantera need to be changed in order to improve the conditions in the community. We determined that in order to develop a plan, we needed to analyze the current social situation related to waste management. This was done by exploration of the community and the citizens that reside within it. From there we worked with a local school to establish a connection with community members. To expand this knowledge further, we generated informational handouts with composting and sustainability concepts to present at local events.

3.1.1. Current Situation

In order to grasp the general mindset of the Cantera community, we were given a tour throughout the peninsula. Alfredo Perez Zapata of the CDIPC conducted the tour. Alfredo has built a strong relationship with the locals through relocating community members living in flood prone areas. Through this interaction, he gave us the ability to interact directly with locals and hear their viewpoints on issues affecting the Cantera Peninsula. Through this tour, we were able to observe the communities cooperation with the company, what living conditions were like, and understand general cultural ideologies. Along with understanding issues arising in the community of Cantera, Alfredo is a civil engineer for the community and was able to discuss the infrastructure needed for the Peninsula. The main issues were utilities, proper road construction, and community cooperation.

3.1.2. Interaction with Cantera Youth

After seeing the current situation in Cantera, the next step was interacting with a class of students, ages 9 to 13, at the local Cantera School, Escuela Manuel Elzaburu Vizcarrondo. We

worked closely with key community leaders, Katrina Weigand and Amanda Marin. Katrina is an Americorps employee and Amanda is a volunteer who operates the school garden and small compost process. Together Amanda and Katrina lead an after school program to educate about environmental awareness. Katrina emphasized that we added to her program by making the students reflect on what they know about sustainability, recycling, and composting. This was an opportunity to gain insight on the community's sustainability because the children reflect the habits of their role models. We asked questions from Appendix A. This gave us insight on their ideas for the most successful way to reach the community members and see how they would respond to new recycling techniques. The questions also touched upon what kind of base knowledge or attitudes people in the area may have about composting. From the students' thoughts and responses we gauged the willingness of the Cantera residents to put effort into changing community habits.

3.1.3. Community Outreach

After making a connection with the Cantera youth, we wanted to provide information to a broader section of the community. In order to do this, we created pamphlets and other informational sheets that can be used to teach people about composting.

We developed a pamphlet and a few informational sheets to hand out at local events. The pamphlet contains a definition of composting, explains what processes happen, and lays out the steps of composting. It also provides an overview of our project and what we hope can be established in the future. These materials can be referenced in Appendix I. Spreading knowledge about this project is key to the implementation of the facility. People need to see how the composting process works and what the results are in order to make an effort to change their lifestyle and utilize the facility. The handouts were ideal because people could look them over

and quickly generate an understanding of composting. There are also other events that happen throughout the year in Cantera that would be great opportunities to spread these materials. While in Puerto Rico, we had the opportunity to attend one of these events, the December 6th Bike Day.

The bike day was a great chance to share knowledge of clean waste removal with the fun of a community activity. The second annual event is organized by CDIPC and stresses the importance of maintaining community awareness on different environmental issues faced in everyday life. The event consists of a biking portion along with numerous tables run by different organizations. With a group of students from the Metropolitan University and the local Cantera Middle School, we set up a table to display compost information and share the composting plan we created.

At the table we worked with the younger students from the Cantera Middle School, as mentioned in section 3.1.2, and talked to a variety of community members. The students helped explain the concepts to people who stopped by the booth. To demonstrate the ideas of compost, we took samples from the community garden's small composting effort so that it was hands on and more interesting for people who stop by. Educating residents at such events will spread awareness and gain support of composting. If more people support the concept of composting, then the facility plan is more likely to be implemented.

3.2. Investigate Other Composting Efforts

In order to develop the composting plan, we needed to understand the most efficient and successful ways to run a composting operation and how they can be applied in Cantera. The first step was to learn about the processes and what infrastructure is needed to support them. We gathered information by conducting five interviews and tours with other waste collection or

compost related groups. These groups had experience with the composting process and were able to share their knowledge. We gained good input on the type of municipal and organic waste desirable for compost as well as the different ways of handling the varied waste. In addition, we were able to observe the operations and management of the facilities first hand. Also, interviews were conducted with the following groups:

- The CDIPC Employees
- Vivo Recycling (composting group) - José Alsina
- El Huerto, Cantera's middle school garden
- The Municipality – Carmen Rivera
- FOHL Corporation

These groups were selected because they have a wealth of knowledge and experience related to waste management, and more specifically composting. During the interviews we asked open-ended questions to gain the most input from the interviewees as possible. An outline of our interview guide can be seen in Appendix B.

Our first tour was conducted with Vivo Recycling, located in the city of Caguas, Puerto Rico. As shown in Figure 8 below.

Figure 8: Discussions of Compost Watering Operation

We selected Vivo to tour because it is a fully operational composting facility that has established a profitable business model, while also making a positive impact on the society around it. Vivo acts as a support to waste removal companies that don't have the infrastructure for recycling organic and yard waste. The founder of the company, José Alsina, had a vision of educating and reducing the impact local Puerto Ricans have on their beloved island, through composting. His technique of sharing the methods he uses to successfully operate the facility is extremely beneficial to the community. He continually offers his support for other similar projects and helps convince people to recycle and independently making a difference. In our tour with Jose Alsina, we gained insights into his view on the issues in Cantera and how he thinks composting will make a difference.

The tour consisted of a breakdown of procedures and techniques he used throughout the composting facility. We looked at each procedure and made sure to understand the components that lead to the success of each process. These components ranged from displaying a plant nursery to prove the effectiveness of the compost to having a gate at the facility entrance to

protect against unwanted waste dumping. Throughout the tour, we addressed the key questions, specifically looking at the costs of maintaining Vivo's facility and the overall distribution of funds in their operation. An in-depth breakdown of our tour at Vivo can be referenced in Appendix L.

The data gathered included: information on planning and implementation of compost collection, storage of compost materials, tools and machines needed, and how the organization is able to make a profit. These factors are critical to any successful composting plant and an already operating example provided guidance on the strengths and weaknesses of various processes in the facility.

3.3. Develop Operational Protocols

An important aspect to measuring the feasibility of a composting facility is to research and develop protocols for the process. The best methods to obtain the information we needed were through research, interviews, and observations.

We first started with researching the fundamentals of composting. Through this research, we created a basic understanding of the steps of composting. The research was conducted by reading scholarly journals and studies previously done on the subject of composting and social implementations. Once an understanding of the process was established, we then conducted a tour and interview at a Puerto Rican composting facility, Vivo Recycling, as mentioned above in section 3.2. Through the tour we were able to understand the model of a functioning facility to replicate in Cantera. We designed a flow chart of the basic compost concepts outlined in Appendix D.

What we found from this opportunity was the protocols needed for a composting facility and any materials needed to support it; for example machinery, storage containers, and garden tools. For the process we gained the following information:

- How to sort incoming municipal waste
- How to break down larger material
- Ways to organize compost during the process
- The daily procedure to maintain the process
- Identification of finished compost
- Duration of entire procedure

From this, we laid out a rough structure of the process we want to implement and identified the necessary materials for each step. Overall, through these methods we were able to set up an efficient and reliable composting plan for the new facility in Cantera.

3.3.1. Municipality Meeting

The first step in planning the compost facility is establishing what legal requirements are necessary to meet. An interview was set up with the Municipality in charge of the local Cantera Peninsula. A municipality is the administrative division that tends to have powers of a self-government or jurisdiction. The municipality has an impact on how the composting plan will be implemented. They have the deciding input on the amount of funds provided and scale of the future Cantera composting facility. The meeting consisted of a discussion of our composting plan in Cantera and how invested the municipality would be in contributing. One important take away was to understand the amount of organic waste they would pass on to the potential facility. This information allowed us to understand the total funds we need, which compost methods to choose, and how to lay out the future building plans.

3.3.2. Evaluation of Composting Organization Methods

During our initial research of composting, we came across different methods of organizing the compost, which caused different variations in the process. We found that there were unique methods that ranged from using earthworms to insects, like the black soldier fly, to help aid in the decomposition process of composting. These were additional catalysts for decomposition of the waste; nevertheless we focused on maintaining a simple process and were more interested in the different storage methods. The top methods we found were holding units, turning units, piles, and trenches. Each process had pros and cons, and we needed an accurate procedure to distinguish between the different methods of storage. Therefore, we developed guidelines that took into consideration the volume of storage, duration of composting, and maintenance. Once the guidelines were established, a table was created for each guideline.

3.3.2.1. Volume storage

Volume storage is an important characteristic to consider because through background research we determined that different organization techniques varied in the amounts of waste they can handle. This was important for choosing the best composting method for the Cantera facility depending on how much organic waste is predicted to be sent to the site and how much space is available at the location. In Table 2, ranges of typical amounts that can be handled are listed in order to allow comparison between numbers of compost storage methods.

Category	Score	Definition
Small storage	1	Holds 1-20 ft^3 of compostable waste
Medium storage	2	Holds 20-60 ft^3 of compostable waste
Large storage	3	Holds 60+ ft^3 of compostable waste

Table 2: Volume Storage Categories

3.3.2.2. Time for Compost

Based on the way compost is arranged and stored, the process of decomposition can occur at different rates. This was an important factor that influences which compost organization method is most suitable for the Cantera facility. Knowing the space that is available at the composting site, helped determine which organization method makes the most sense. If there is a smaller surface area compared to the amount of compost that will be received, then using a faster method will allow the most compost to pass through, even though it may take more effort of turning. If there is a larger surface area, then it is a better option to utilize the space and use a method that may take a longer time to complete. The amount of time it takes to complete composting is generally related to how much maintenance is required.

Category	Score	Definition
Slow	1	Process takes more than a year to create mature mulch
Average	2	Process takes 2 months to a year to create mature mulch
Fast	3	Process takes 2 months or less to create mature mulch

Table 3: Time for Compost Categories

3.3.2.3. Volume storage

The amount of maintenance needed to operate a certain composting method is generally related to how long the process takes. This is because the more aeration the pile gets from rotating it, the faster the decomposition can take place; which is key for making protocols for the selected method. Understandable directions for how to properly operate the facility plan will provide benefits to our project.

Category	Score	Description
High	1	Rotate and maintain once a week
Medium	2	Rotate and maintain every 2 to 3 weeks
Low	3	Rotate and maintain every 4+ weeks
None	4	No maintenance needed

Table 4: Maintenance Categories

3.3.3. Gardening and Composting

After analyzing multiple compost organization methods, we wanted to look at the actual steps the compost goes through during the decomposition process. In order to see the full process of composting, we operated and managed a composting system at a local gardening program. In the garden, there is a small composting area where we saw the steps that come together to create the final product. The final product was fine-grained compost. The effectiveness of this compost was demonstrated in the garden through the success of the healthy plant growth. In the process of gardening, the plants need to be watered and held in the fertile compost. Many nurseries or gardens lack the nutrition in their beds; therefore they use harmful fertilizers to restore nutrition. Instead of using harmful fertilizers or purchasing fertile soil from other companies to keep the

garden nourished; we looked at the benefits of compost. We did this through working with the product and seeing its effectiveness.

3.4. Summary

From the methods of conducting informal interviews, tours of local facilities, and a sample composting project, we were able to complete our objectives and submit a final proposal to include deliverables focused on composting and community habits, opinions, and education. Composting deliverables included a detailed report of infrastructure and protocols for operation that will be needed to create a successful composting facility that meets all legal regulatory requirements. The next deliverable was recommendations for methods of generating an income from the facility including what products are most profitable. Community involvement deliverables included a summary of the informal interview results related to current community waste and compostable material disposal habits, knowledge, and local opinions. In addition to a report of the current situation in Cantera, we provided suggestions and plans for how to improve community involvement in the operation of the composting facility and overall community sustainability efforts.

Chapter 4: Results

Our results are based on information gathered through: research, a guided tour of Cantera, interviews with students and municipality, and a tour of an existing composting facility in Caguas, Puerto Rico. This chapter begins with the assessment of the current waste management habits in Cantera. We then determined the feasibility of the establishment of a composting facility. This chapter concludes with the development of composting protocols for the facility.

4.1. Evaluation of waste management habits

Community members do not have knowledge of eco friendly recycling habits because there is no confidence in local government, opportunity for social interaction, or sense of ownership for build up of waste. We came to this conclusion by:

- Touring the Cantera Peninsula
- Interacting with local students and residents
- Participating in Cantera's local bike day

In order to address the lack of knowledge, we generated educational material to raise awareness of composting.

4.1.1. Community tour

The Cantera community tour gave us perspective on current community circumstances. These circumstances include living conditions, amenities, and waste removal practices. Our tour leader, Alfredo Perez Zapata of the CDIPC, was able to identify goals set by the government and CDIPC. We were able to see their progress in dealing with the current living conditions faced by the community. The infrastructure for many houses is currently being updated through projects led by Alfredo. In addition, the relocation of residents within the flood zone of the Martin Peña Canal's original borders, as discussed in section 2.4.1, is currently under way. Alfredo showed us areas where the canal has been almost completely filled in. This can be seen below in Figure 9.

Figure 9: A Wooden Plan Bridge Across What Used to be the Martin Peña Canal

The wooden planks have been used to make a bridge across solid ground where the canal should be flowing. This shows the drastic effect on the surrounding environment due to residents waste habits.

By discussing the successes and failures of the current relocation process, Alfredo shared an understanding of approaches that are effective in gaining the support of residents. We were able to see their concerns about change and overall reactions to outsiders offering help. Steps have to be taken to gain the trust of the community through education and demonstration of new ideas. The process is slow, but with continued effort for the betterment of the community, trust and support can be established. This observation showed the promise of the acceptance of our composting program for the community.

4.1.2. Working with students

Interaction with the after school gardening program at Cantera's local middle school allowed us to understand the issues of waste removal in the community. The children tend to reflect the habits currently prevalent among residents. Therefore, we interviewed the children to determine the student's current knowledge of recycling and more specifically composting. This interview questions are outlined in Appendix A and discussed in Section 3.1.2. Students in the gardening program have grown to understand the importance of sustainability and recycling. Student responses to the interview questions indicated that their families and some community members had no knowledge of composting and other similar sustainability concepts.

Once understanding their knowledge, we wanted to see what impacts the students could have on others in the community. We prompted them to think about the best ways to share information about composting and asked how to get people invested in the new ideas. They believed a hands-on approach would be best. One student talked about how it would be most beneficial to give presentations and go to community events to show people what compost is and uses for it. A good way to introduce ideas is having an activity of sorting what is compostable and non compostable; or showing them the final product of composting versus the initial inputs. Because most residents have never heard of composting, any information shared should start with the basic definition of composting and involve hands on activities to gain interest.

From these observations we created three educational delivery methods:

1. Informational Pamphlet
2. Compost Diagrams

3. Interactive Activities

The pamphlet and compost diagrams outlined the basic concepts of composting. Raising awareness of our project was a key feature of the informational pamphlet. This pamphlet is shown in Figure 10 below.

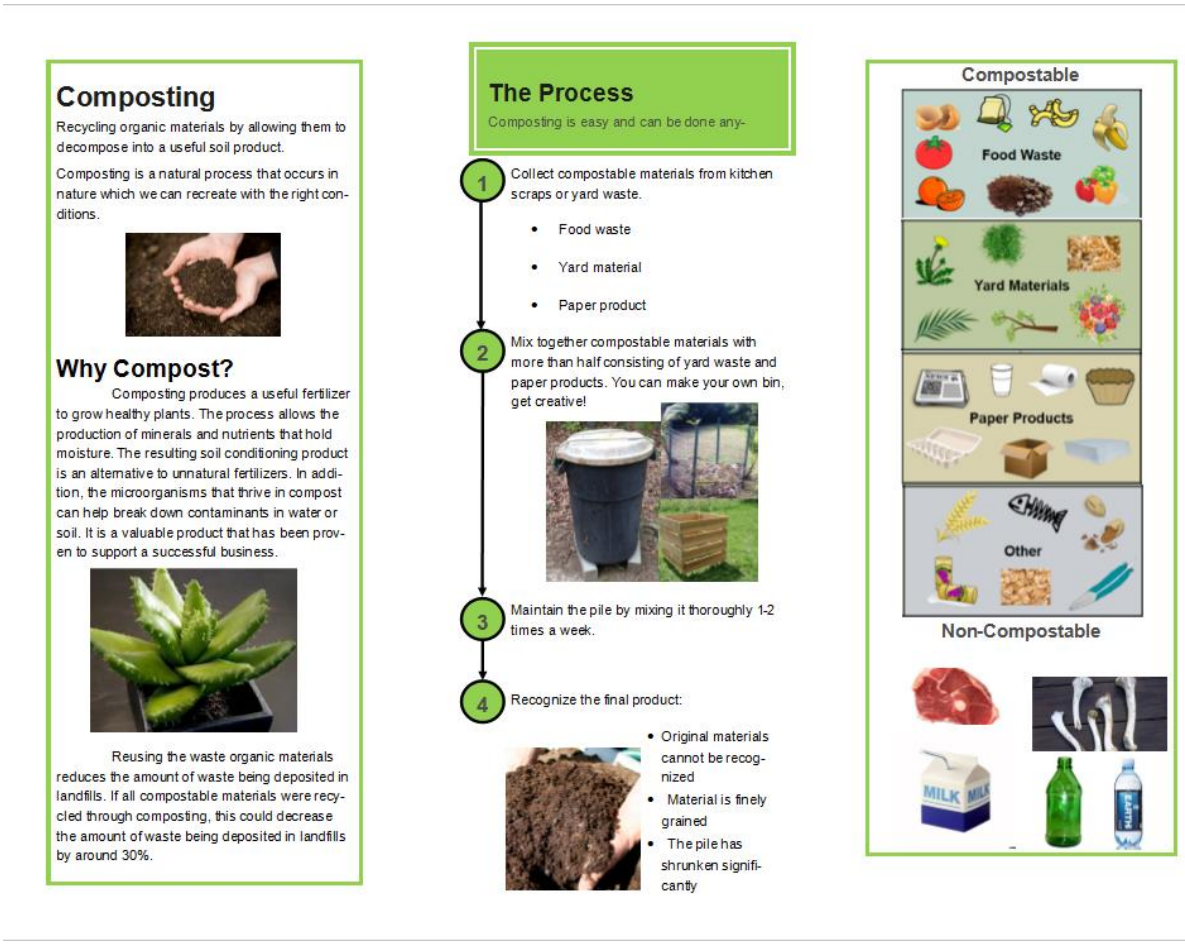


Figure 10: A Picture of the Inside of the Informational Pamphlet

A more detailed description of the pamphlet and diagrams can be referenced in Appendix I. The interactive activities were designed for use at community events, such as Cantera's community bike day. These activities are discussed below in Section 4.1.3.

4.1.3. Bike Day

We participated in the annual Cantera Environmental Bike Day on December 6th, 2015. The day combined the fun activities of biking, dancing, and games while spreading environmental awareness to the community. We hosted a composting table with two students from the Metropolitan University, Josue Jimenez Claro and Melanie Sanchez. Our table display consisted of a sample composting box and two interactive activities:

- Decomposition Process
- Sorting Game

4.1.3.1. Decomposition Process

Our display of the decomposition process showed three stages of composting materials. The initial stage was a collection of compostable materials like fruit and vegetable scraps. The transition stage showed the decomposition process, which displayed the highest temperature of these stages. The final stage consisted of completed compost. To display the temperature change, an infrared thermometer, displayed in Figure 11, was used to read the temperature of the compost at different stages.

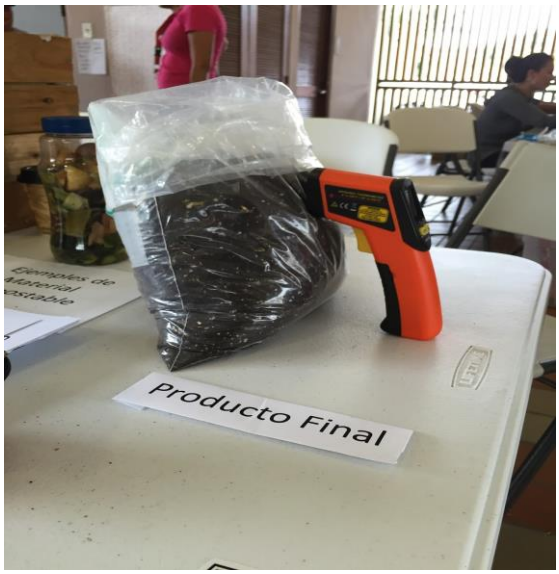


Figure 11: Display of Infrared Thermometer and Compost

We used this to teach residents what is compostable and about the overall process. We found that people were interested in the technology. The use of the infrared thermometer allowed residents to interact with materials and gain an understanding of how decomposition works.

4.1.3.2. Volume storage

In order to see how well the ideas were understood, we created a material sorting game. The set up of the game is shown below in Figure 12.

Figure 12: Display of Composting Sorting Game

The sorting game consisted of a variety items spread across the table to be sorted into two separate piles: one of compostable material and the other of non-compostable material. From the successful sorting that was completed by people who stopped by, we believe the basic idea of composting and what materials can be recycled were clearly comprehended by the participants. We found that people retained information from previous interaction with the decomposition process.

This experience led us to the conclusion that having hands on tools, interactive games, and physical demonstrations of compost are key in explaining concepts and gaining interest in new ideas.

4.2. Assessment of a Composting Facility

Through touring the Vivo composting facility and meeting with the San Juan Municipality; we were able to conclude that a composting plant in Cantera would be feasible.

4.2.1. Vivo Tour

We toured Vivo Recycling located in Caguas, Puerto Rico, on November 10th, 2015. Vivo is an industrial grade composting business privately owned by José Alsina. Vivo displayed a successful business model based around composting. Viewing his business allowed us to identify key components that are needed for a profitable composting operation. Components included:

- Community need for organic waste disposal
- Partnership with local municipality
- Distribution of revenue
- On site nursery

Cantera has the potential to provide all four of these components for a successful facility. There is currently no outlet for organic waste in the Cantera region. This is causing the use of landfills and open dumping of organic waste. These issues demonstrate a community need for a facility similar to Vivo. Vivo demonstrated a mutually beneficial partnership with the Caguas Municipality. The municipality provides a constant flow of compostable material, and in exchange Vivo cuts their disposal costs. This provides an income for the acceptance of organic waste into the facility.

At Vivo the profits from acceptance of waste account for 80% of income. Other than the municipality, the surrounding community and businesses are included in the drop off profits. Similar to Caguas, Cantera is located in a community, which could provide a variety of income sources. The remaining 20% of income is generated from the sale of compost and nursery products. The three-acre site that has been selected in Cantera is able to implement a nursery as well. For more information on the Vivo tour, refer to Appendix F.

4.2.2. Municipality Meeting

In order to determine the potential for a partnership between the planned facility and the San Juan Municipality, we met with Carmen Rivera on November 30th, 2015. Carmen is a representative for the San Juan Municipality and discussed their interest in a partnership. From our meeting we identified three main takeaways:

- An outlet for their organic waste
- Disposal costs and volumes
- Organic waste is already separated

Carmen discussed the desire for an alternative outlet for organic waste because the municipality is currently depositing all organic waste in landfills. Utilizing landfills to dispose of recyclable materials is expensive and unsustainable. Carmen also provided us with an estimate of the organic waste that could be diverted to a compost facility, roughly 5,000 tons annually. They currently pay a disposal cost of $36.00 per ton of material delivered to landfills. These numbers allowed us to create a more realistic plan for the volume of waste that the potential facility would handle and what infrastructure would be necessary. We learned that organic waste is already separated at waste transfer stations throughout San Juan. Transferring this waste to an alternative facility would cause minimal disruption to the current waste management process. This would allow for a constant flow of compostable materials with a reliable source of profit for the facility in Cantera.

We drew from our meeting with Carmen that a partnership between the San Juan Municipality and a Cantera composting facility would benefit both parties. We concluded that the municipality would be strongly interested in supporting the establishment and operation of a composting facility. To view meeting details, refer to Appendix N.

4.3. Development of Composting Protocols

4.3.1. Composting: Four Steps

From researching compost and decomposition, we identified four steps to successful composting. By grouping the related aspects of the process, four key steps emerged as shown in Figure 13.

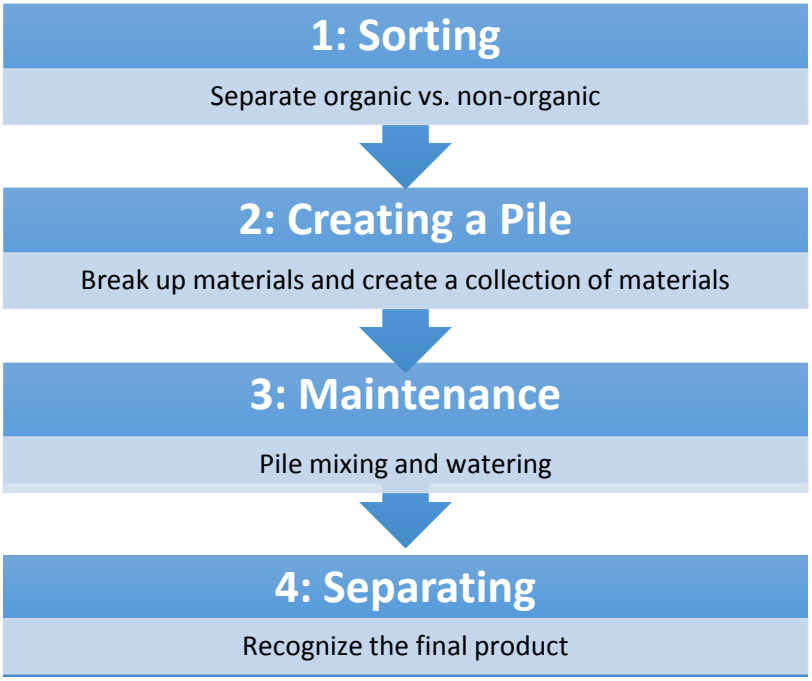


Figure 13: Diagram of Steps of Composting

Sorting is when organic material is separated from the rest of the solid waste stream. This step is important because if not done properly, nonorganic materials like glass and plastic will remain in the final compost product. In addition, chemical materials will cause unhealthy contamination to the compost resulting in leakage into the surrounding environment. Next, creating a pile requires multiple actions to ensure a good mix and texture of materials. An area must be designated for the pile to be established. The material can be placed in a pile, box, or

variety of other compost containment options that will be discussed in Section 4.3.2. Once a pile or collection method is established, the third step is maintenance of the pile. Maintenance is extremely important to ensure a high quality of compost is created efficiently. This will prevent any potential hazards to the surrounding community. After allowing the compost to decompose from four to eight months, the final product can be recognized. In order to ensure a consistent quality, the compost is run through a sifting process that removes any larger components. The finely grained material is sellable, while the larger pieces are returned to the pile for further decomposition. A technical breakdown of the entire process can be accessed in Appendix E.

The understanding of the four identified steps is crucial to the composting plan we have provided. To confirm the applicability of these steps, we observed the process at Vivo Recycling and in the local middle school garden.

4.3.2. Comparing Compost Organization Systems

Through our preliminary research, our group determined that compost can be organized in a variety of arrangements. The four distinct techniques we researched include as shown:

- Holding units
- Turning units
- Piles
- Trenches

Figure 14: Examples of Composting Organization Methods

(Clarity J, 2010) (Crystalclear, 2007) (Derzsi Elekes Andor, 2013) (Red58bill, 2005)

A complete description of each of these systems is included in Appendix M. Initial research into these techniques allowed us to identify four key factors that vary between them. We determined that important characteristics include:

- Volume that can be handled
- Time to complete composting
- Amount of maintenance needed
- Amount of area needed

An in depth description of each of these key factors and how they were rated is shown in Appendix G. Below, in Table 5, there is a summary of the characteristics that each technique has been rated by.

Key Factors:	Holding Units	Turning Units	Piles	Trenches
Volume that can be handled:	Medium 30-50 ft^3	Small Around 15 ft^3	Large About 75 ft^3 per pile	Large
Time to Complete Composting:	6 months to a year	2 months or less	4-8 months	Up to a year
Amount of Management Needed	Large effort to turn every 2 weeks	Easy to turn every 5 days	Turn every 1-2 weeks large effort	None
Area Needed	Small	Small	Medium	Large

Table 5: Summary of Compost Organization Techniques Comparison

From the ratings, we determined that the most applicable organization techniques are holding units and piles. These two techniques allow for most efficient expansion qualities needed for the facility plan. Holding units are more controlled and take up less space. The smaller volumes of each container also make it easier to rotate often and consistently monitor the compost. Because the containers are enclosed, it is easier to prevent any potential odors, dust, and attraction of pests in the area. Holding units are a viable option for the first tier of the facility plan.

As the facility expands, the organization technique of piles will be more advantageous. As shown in Table 5 piles can handle larger volumes of organic material. Once the Cantera facility is processing these higher volumes of organic waste, the pile method will be more space efficient than the holding units. These techniques will be implemented in the planning and establishment of the Cantera composting facility.

4.3.3. Process of Facility Establishment

From talking with Jose Alsina in our tour of Vivo Recycling, we gained an understanding of the expenses involved in his business. The industrial equipment he uses, like mulchers and sifters, can cost from half a million to one million dollars. Establishing a facility like this is not feasible in Cantera because finding funds to purchase big investments is unrealistic. In addition, because of the size of the land, approximately 3 acres, and the proximity to resident's homes, a large-scale plant may have opposition in the community. To generate a reasonable plan for Cantera, we decided to start with a plan for a small facility that is community operated. This means that it will not provide any official employment opportunities and will rely on volunteer work for operation. Once established, the operation of the facility in the community will provide opportunities to expand the business to a larger scale. We found that providing three tiers of operation, which slowly increase in size and volume of organic waste, is an effective strategy for Cantera.

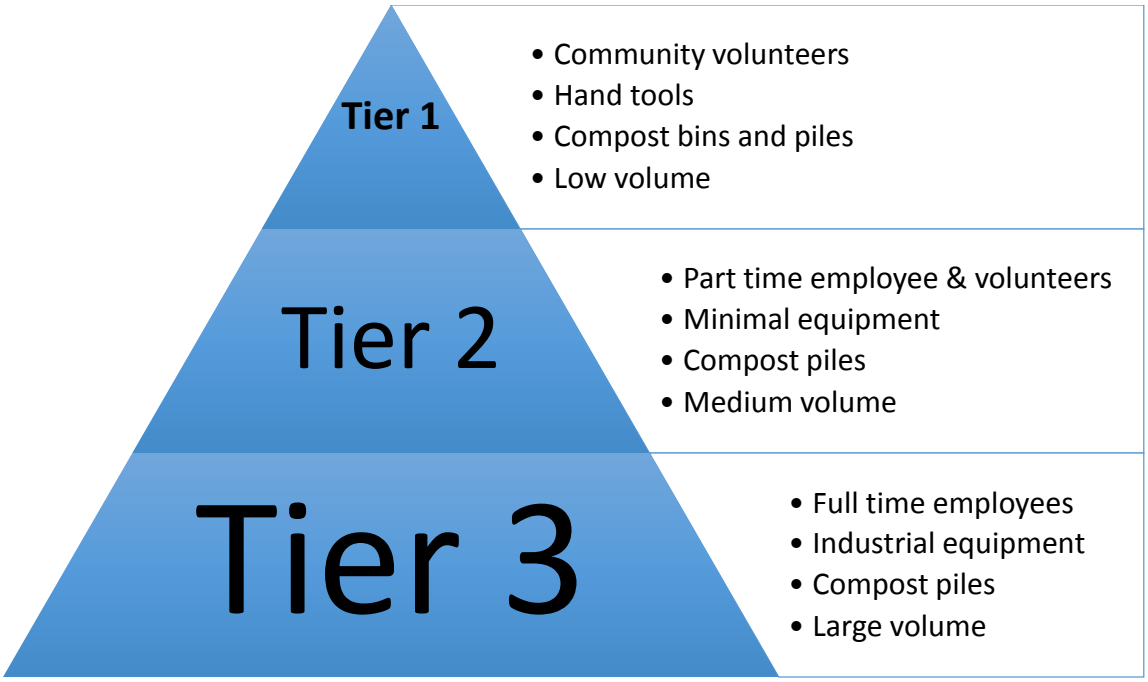


Figure 15: Layout of Three-Tier for Facility Establishment

As shown in Figure 15, the first tier is a community operated compost facility and garden. This develops through a transition phase, seen above in Tier 2, where some equipment is purchased. Lastly, the plant will become an industrial grade composting facility that can provide employment opportunities. A document with an outline of the three tiers we identified and the infrastructure that is needed for each one is available in Appendix F.

4.4. Summary

We concluded that the concept of composting would have a positive impact on the Cantera community. The evaluation of the current waste management habits shows the need for educational material to teach residents about composting. With community awareness of

composting, the facility plan in Cantera would be feasible. For establishment, we have provided the steps necessary for the implementation and operation of a successful composting plant.

Chapter 5: Recommendations

In this chapter we have outlined our recommendations for the CDIPC through results gathered in the previous Results Chapter. The two recommendations are directed towards community education and the implementation of a composting facility. The limitations of our recommendations are then outlined and discussed. Building from the recommendation limits, we provide future suggestions to help further the implementation and growth of the recommended facility. Lastly we concluded and provide a summary of the project.

5.1. Our Recommendations

We identified recommendations to increase the reception of a community composting plan based on the analyses of our results. We focused our recommendations on the education of composting concepts in Cantera to encourage progress towards the implementation of a composting facility.

5.1.1. Basic Knowledge of composting for community

We recommend spreading the basic knowledge of composting concepts to residents in the community of Cantera. A large importance to the implementation of the composting program and facility is the community's understanding the composting process. We created pamphlets and handouts that would be able to create a basic understanding of the process. The informational material should be handed out at schools and community events. The individuals

delivering the information need to be established as a trustworthy source with connections to the CDIPC. After interaction with the material, residents' knowledge will then be assessed through interactive activities. These activities include a compostable sorting game and decomposition temperature gauging. Once residents are engaged in the learning of composting, and then the plan for the implementation of a facility will hopefully gain support. Support can be determined by discussions with community leaders and interaction with residents.

Once support for composting becomes more widespread, the facility can then begin to be established. The planned site is a 3-acre piece of land located near the local public middle school, shown in Figure 16.

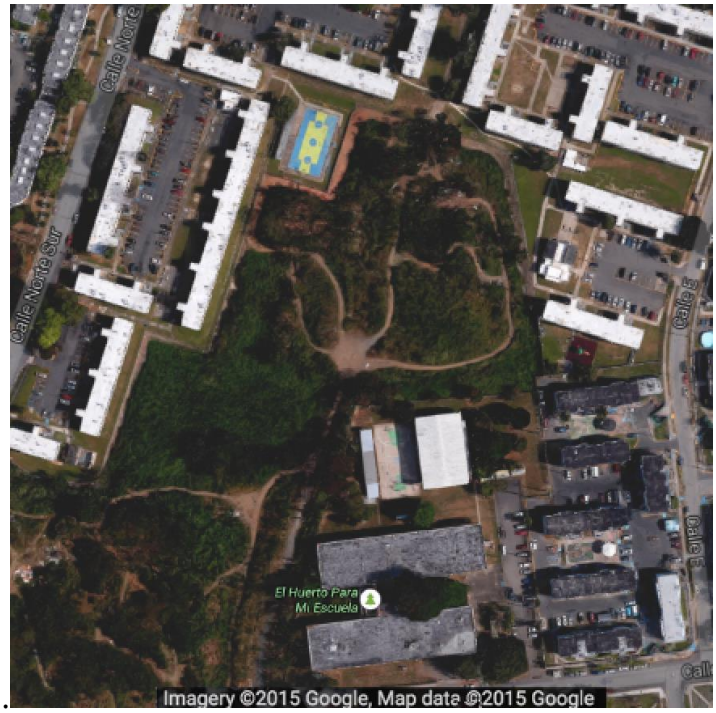


Figure 16: Planned Facility Site

At the site, education will be continued through a learning center. The learning center will help implement hands on composting tactics and strategies that will be used to build the site.

Refer to Appendix H to view one of the diagrams to educate. The CDIPC should hold community events to continue teaching the idea of recycling and composting to increase residents' participation at to the composting facility.

5.1.2. Creation of community composting facility

We recommend the creation of a compost facility. This should be implemented by the CDIPC along with a partnership with local community leaders. Some funding for the facility could be generated through a partnership with the San Juan Municipality. The composting facility location will be where the community can come together and work in a common area. The techniques of composting that we have provided will be utilized at the site. The overall layout of the site will include a learning center, garden, and process of composting. The layout can been seen in Figure 17 displayed below.

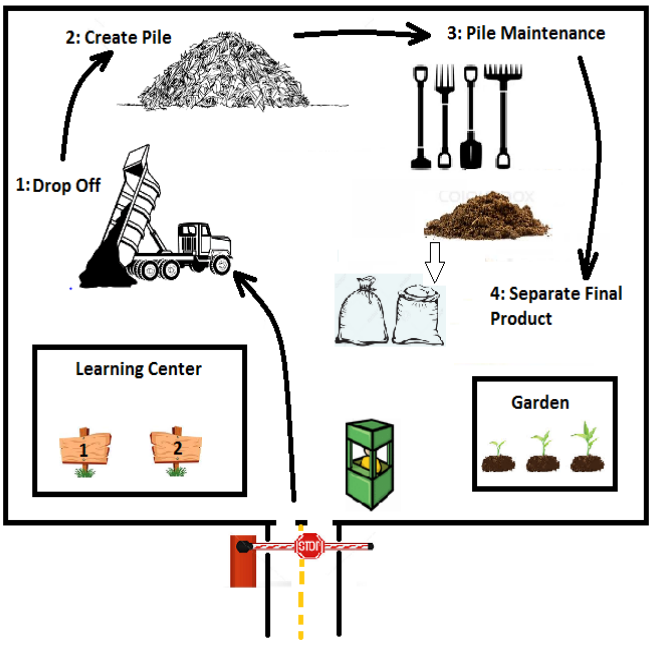


Figure 17: Breakdown of Potential Facility

A portion of the facility will be dedicated to a learning center. The learning center will teach the four main steps of composting through stations. The stations would help residents grasp an understanding with interactive samples. The individual signs display simple directions to breakdown each step of the process are outlined in Appendix O. An example of one of the individual signs is shown below in Figure 18.

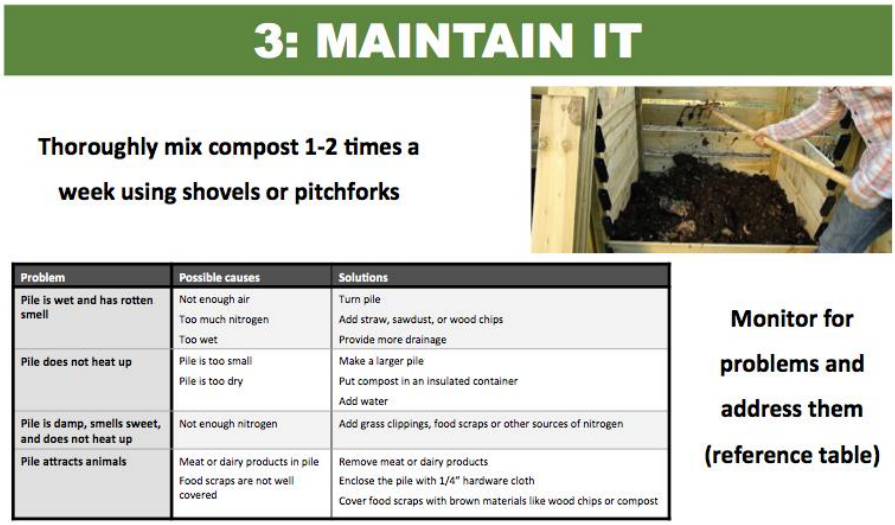


Figure 18: One of the Signs for the Learning Center

Along with the four steps, a final sign will explain the use of the final product of compost and the benefits it has. The learning center will provide a crash course on composting and help interact with the surrounding community to become more involved. Members who already work in the facility can proactively help with any questions new volunteers or residents may have about the facility or process.

The main portion of the facility will be the composting section of the site. It will involve the same steps shown in the learning center, but done to a larger scale. The section will involve material drop-off and continue on to complete the composting process. This portion will be managed by the more experienced volunteers and have constant work being performed.

Another portion of the facility will be dedicated to a garden. The garden will demonstrate the positive effects of compost on planting. Also the garden will provide a place to use the final compost and generate sellable products. These products would include plant seedlings or consumable goods, like vegetables. This would provide a profit to cover operation costs.

5.2. Address Limitations

The proposal of composting is beneficial, but does have limitations. Some of these restrictions include facilities capabilities and amount of jobs provided.

5.2.1. Facility Capabilities

Volunteer workers using hands on methods of composting will operate the initial facility. This means that compared to larger industrialized facilities with heavy machinery; the Cantera community compost site will only be able to handle small volumes of organic waste. Initially, it may not be able to handle the San Juan Municipalities need of disposing 5,000 tons of organic waste to the facility. Refer to Appendix O for a breakdown of the steps that must be taken to eventually handle larger volumes of waste.

In addition, composting is a fundamentally strong method of dealing with recyclable organic matter. While a large portion of the waste stream consists of organic material, a community can't solely depend on composting. In order to create an even greater impact, other recycling and waste removal methods should be implemented as well. Some of these habits include glass recycling, plastic recycling, and esc.

5.2.2. Limited amount of jobs

A large issue in Cantera is unemployment. The initial facility will mostly be volunteer driven and will rely on community participation. As the composting operation begins to grow, we hope that job opportunities begin to develop as the business is established. The final composting facility will be able to supply a number of jobs to the community. This is a limitation because it is not guaranteed that employment opportunities will be available when the facility is established.

5.3. Suggestions for future

The following section gives suggestions on what critical information future researchers should obtain next in order to start the implementation process. Some important topics to research are the capabilities of the facility, funds to build facility, and permits for construction and operation.

5.3.1. Facility capabilities

We suggest that a future team research more into the capabilities of an industrial scale facility plan for Cantera. They should analyze the maximum size Cantera's potential facility can reach and how much waste could be handled. Once the community-operated facility is established, research can be conducted based off of how it handles waste. Specifically, the acquisition of heavy machinery should be evaluated during this process. In the Table 6 below, the potential waste inflow and total space for the site in Cantera can be seen.

Vivo Facility vs. Cantera Site	
Vivo	**Cantera**
• Organic Inflow = 15,000 Tons Per Year • Size of Lot = 8 Acres	• Estimated Organic Inflow = 4,933 Tons Per Year • Size of Lot = 3 Acres

Table 6: Comparison of Vivo and Cantera

The comparison on these two numbers show it's possible to handle all the waste received; nevertheless Vivo has heavy machinery that allows for quicker composting.

5.3.2. Funds

We suggest that future investigators look into a private business investor or find government funds to develop an industrial grade composting facility. An important aspect to the success of surpassing the community based composting facility stage is to support the gradual industrialization of the site. The San Juan Municipality is one identified potential investor because it would benefit greatly from the facility's establishment. Once these investors are identified, the next step will be to gain approval on building the facility.

5.3.3. Permits for larger facility

We suggest that future investigators work with the San Juan Municipality to research and gain more detail on permits. From our municipality meeting, we learned that permitting for such an operation takes six permits; that can take from six months to a year to obtain. This will be a

critical aspect on planning out the industrial grade facility and gaining approval to move forward on the project.

5.4. Conclusion

In this chapter, we provided a summary of our key findings and recommendations for the implementation of a composting program. Through our fieldwork we gained an understanding of the Cantera's social and waste management issues. We analyzed these issues in the findings and have provided recommendations for improvement. We believe that our recommendations will help spread community awareness, create support for a community composting program, and eventually develop that program into a business venture. We believe that the composting program and facility in Cantera will help set the base for addressing waste management issues. We hope that the program is implemented by the CDIPC and will continue to improve the Cantera community, both socially and economically. This program can be used as an example for the rest of Puerto Rico to follow and hopefully change the Puerto Rican practice of sending organic waste to landfills. As a small island, the method cannot be continued and hopefully more recycling, like composting, will be implemented in Puerto Rico's overall waste management system.

Works Cited

Abuyuan, A., Hawken, I., Newkirk, M., & Williams, R. (1999). Waste Equals Food: Developing a Sustainable Agriculture Support Cluster for a Proposed Resource Recovery Park in Puerto Rico 1999.

Alexander, R. (1996). *Field Guide to Compost Use*. Alexandria, Virginia: [Composting Council]. <http://compostingcouncil.org/admin/wp-content/plugins/wp-pdfupload/pdf/1330/Field_Guide_to_Compost_Use.pdf>

Baud, I., Grafakos, S., Hordijk, M., & Post, J. (2001). Quality of Life and Alliances in Solid Waste Management: Contributions to Urban Sustainable Development. *ResearchGate*, 18(1), 3-12. Retrieved December 5, 2015, from <http://www.researchgate.net/profile/Isa_Baud/publication/222533814_Quality_of_Life_and_Alliances_in_Solid_Waste_Management_Contributions_to_Urban_Sustainable_Development/links/09e41510bef39c3045000000.pdf>

Berechet M, Fischer K. Ecological Evaluation of an Optimized Waste collect System - Case Study in a German Community. Environmental Engineering & Management Journal (EEMJ), 1361-1369.

Bioscrubbers. Retrieved November 10, 2015 from http://www.sciencedirect.com/science?_ob=MiamiCaptionURL&_method=retrieve&_eid=1-s2.0-S0956053X05001881&_image=1-s2.0-S0956053X05001881-gr1.jpg&_cid=271837&_explode=defaultEXP_LIST&_idxType=defaultREF_WORK_INDEX_TYPE&_alpha=defaultALPHA&_ba=&_rdoc=1&_fmt=FULL&_issn=0956053X&_pii=S0956053X05001881&md5=eb8dc2bf8ddda6fb5631dc8009b0bc52)

Bosworth, G., Collins, S. (2006) Economic growth. Pp. 5-18 in Restoring Growth in Puerto Rico: Overview and Policy Options, Collins, S. Collins, G. Bosworth, M. Soto-Class, ed. Washington DC: Brookings Institution Press.

Boyer, T. and Polasky, S. (2004). Valuing Urban Wetlands: A Review of Non-Market Valuation Studies. Wetlands, 24, 744-755. http://dx.doi.org/10.1672/0277-5212(2004)024[0744:VUWARO]2.0.CO;2

Buchholz, R. (1998). *Principles of environmental management*. Upper Saddle River, N.J.: Prentice Hall.

Chan, Kwok Loon. (2006). A characterization of the recycling sector in puerto rico. *Yale school of Forestry and Environmental studies* Colon, M., & Fawcett, B. (2006).

Colón, J. (2015). Puerto Rico's future at stake. Science, 349(6253), 1145-1145.

Community-based household waste management: Lessons learnt from EXNORA's 'zero waste management'scheme in two South Indian cities. *Habitat International*, *30*(4), 916-931.

Compañía para el Desarrollo Integral de la Península de Cantera. (2011, December 9). Retrieved September 8, 2015. <http://www2.pr.gov/Directorios/Pages/InfoAgencia.aspx?PRIFA=167>

Composting. (2010, November 17). Science Weekly, 27(6), 1+. Retrieved from http://go.galegroup.com/ps/i.do?id=GALE%7CA244158789&v=2.1&u=mlin_c_worpoly&it=r&p=GRGM&sw=w&asid=e4af1eb016db07b517a6c51d2a6e4f11

Composting-a guide to making compost at home, using compost tumblers, bins & other composters. (2014). Retrieved November 5, 2015, from http://eartheasy.com/grow_compost.html

Cotter, J., Hu, V., Miranda, A., & Reinertsen, H. (2014). *Evaluation of the Feasibility of Establishing a Waste Collection Facility to Serve the Community of Cantera* (Undergraduate Interactive Qualifying Project No. E-project-121814-103003). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: <http://www.wpi.edu/Pubs/E-project/Available/E-project-121814-103003/unrestricted/Cantera_Final_Report_Dec18.pdf>

Courtney, J. Dasso, R. Holland, J. Mier, D. (2004). Evaluation of Puerto Rico's Current Recycling Program. Puerto Rico: Project Center D04.

Daskalopoulos, E., Badr, O., & Probert, S. (1998). An integrated approach to municipal solid waste management. *Resources, Conservation and Recycling, 24*(1), 33-50. <http://www.sciencedirect.com/science/article/pii/S0921344998000317>

Davis, Jenn. (2013). Growing Local Fertility: A Guide to Community Composting. *The Institute for Local Self Reliance.*http://highfieldscomposting.org/sites/default/files/files/resources/growing-local-fertility.pdf. Accessed on 11/30/2015.

Domingo, José L., Nadal Marti (2009). Domestic waste composting facilities: A review of human health risks. *Environment International*. Volume 35, Issue 2, Pages 382–389

Education for Sustainable Development | Education | United Nations Educational, Scientific and Cultural Organization. (2015). Retrieved September 30, 2015, from <http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/education-for-sustainable-development/ >

EPA. (2002). *Waste Transfer Stations: A Manual for Decision Making.* Retrieved from <http://www.epa.gov/osw/nonhaz/municipal/pubs/r02002.pdf>

Epstein, E. (1997). *The Science of Composting*. Lancaster, Pa.: Technomic Pub. <https://books.google.com/books?hl=en&lr=&id=dXNX4cOMqDUC&oi=fnd&pg=PR13&dq=composting+and+waste+management+puerto+rico&ots=LscGSV7N_U&sig=xt5pdkh_ZwC_Ut3v1IQJZfIMzRg#v=onepage&q&f=false>

Goto, M. (2013, October 30). Global Waste on Pace to Triple by 2100. Retrieved December 9, 2015, from http://www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple

Hoornweg, D., Thomas, L., & Otten, L. (1999). Composting and Its Applicability in Developing Countries. *Urban Waste Management,8*. <http://www.worldbank.org/urban/solid_wm/erm/CWG%20folder/uwp8.pdf>

Hoornweg, D., & Bahda-Tata, P. (2012). *What a Waste* (Vol. 15). Washington, DC: World Bank. <http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf>

I. Körner, J. Braukmeier, J. Heerenklage, K. Leikam, M. Ritzkowski, M. Schlegelmilch, R. Stegmann. Investigation and optimization of composting processes – test systems and practical examplesWaste Management, 23 (2003), pp. 17–26

Kleinke, Bidlingmaier (Eds.), Biological Waste Treatment, Know-how Transfer from Research to Practice, International Workshop for Eastern European Countries, Initiativen zum Umweltschutz, 3-503-07026-5, vol. 49, Erich Schmidt Verlag (2002), pp. 141–150

Laboy-Nieves, E. (n.d.). Energy Recovery from Scrap Tires: A Sustainable Option for Small Islands like Puerto Rico. Sustainability, 3105-3121.

J. Lavoie, C.J. Dunkerley, T. Kosatsky, A. DufresneExposure to aerosolized bacteria and fungi among collectors of commercial, mixed residential, recyclable and compostable waste. Sci Total Environ., 370 (2006), pp. 23–28

Lopez, L. (2015, August 7). Puerto Rico's 'death spiral' can be traced back to one mistake. *Finance*. http://www.businessinsider.com/how-puerto-rico-got-in-over-its-head-2015-8

Murad, W., & Siwar, C. (2007). Waste management and recycling practices of the urban poor: A case study in kuala lumpur city, malaysia. Waste Management & Research, 25(1), 3-13.

Miranda, M. L., & Hale, B. (2005). *Paradise recovered: energy production and waste management in island environments*. Energy Policy, 33(13), 1691-1702. <http://www.researchgate.net/publication/222668225_Paradise_recovered_Energy_production_and_waste_management_in_island_environments>

Obara, A., Suzuki, H., Takemoto, R., Tomanik, A., Corredato-Periotto, T., & Silva-Dias, M. (n.d.). Environmental education in the Upper Paraná River floodplain, municipality of Porto Rico (Paraná State), Brazil. Braz. J. Biol. Brazilian Journal of Biology, 627-635.

Peele, E. R., Singleton, F. L., Deming, J. W., Cavari, B., & Colwell, R. R. (1981). Effects of pharmaceutical wastes on microbial populations in surface waters at the Puerto Rico dump site in the Atlantic Ocean. *Applied and environmental microbiology*, *41*(4), 873-879.

Presser, B. Harriet & Kishor, Sunita. (1991).Economic Development and Occupational Sex Segregation in Puerto Rico: 1950-80. *Population and Development Review*. <http://www.jstor.org/stable/1972352>.

Puerto Rico in Perspective. (2015, August 10). Lecture. <http://www.nationalpfg.com/pdf/Presentations/PRinPerspective.pdf>

Renkow, M., & Rubin, A. (1998). Does municipal solid waste composting make economic sense? *Journal of Environmental Management, 53*(4), 339-347. <http://www.sciencedirect.com/science/article/pii/S0301479798902146> (M)

Rivera, M. (2014). Economy. Economic Development Administration.

Sallis, J., Mckenzie, T., Alcaraz, J., Kolody, B., Faucette, N., & Hovell, M. (1997). *The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students.* Sports, Play and Active Recreation for Kids.Am J Public Health American Journal of Public Health, 1328-1334.

Scatena, F. N. & Larsen, M. C., (1991). Physical Aspects of Hurricane Hugo in Puerto Rico. *Biotropica Vol. 23, No. 4, Part A. Special Issue: Ecosystem, Plant, and Animal Responses to Hurricanes in the Caribbean*. <http://www.jstor.org/stable/2388247>.

Schubeler, P., Wehrle, K., & Christen, J. (1996). Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries. *Urban Management and Infrastructure.* <http://www.worldbank.org/urban/solid_wm/erm/CWG%20folder/conceptualframework.pdf>

Skordilis, A. (2004, June 1). Modelling of integrated solid waste management systems in an island.

Stegmann, Doedens, Hensel (Eds.), Abluft 2001, Biologische Abfallbehandlung – Emissionen und deren Behandlung, Dokumentation der Fachtagung vom 05.-06.11.2001 in Hamburg, Hamburger Berichte, 3-9806505-9-6, vol. 17, Verlag Abfall aktuell, Stuttgart (2001), pp. 183–191

Gabrey, Steven W., Belant,Jerrold L., Dolbeer, Richard A., and Bernhardt, Glen E. (1994). In My Experience: Bird and Rodent Abundance at Yard-Waste Compost Facilities in Northern Ohio. *Wildlife Society Bulletin* (1973-2006). Vol. 22, No. 2 , pp. 288-295.

Tchobanoglous, G., & Theisen, H. (1993). Integrated solid waste management: Engineering principles and management issues. New York: McGraw-Hill.

Teixeira, C., Russo, M., Matos, C., & Bentes, I. (2014). Evaluation of operational, economic, and environmental performance of mixed and selective collection of municipal solid waste: Porto case study. Waste Management & Research, 1210-1218.

Troschinetz, A., & Mihelcic, J. (2008). Sustainable recycling of municipal solid waste in developing countries. *Waste Management*, 915-923.

Turner, R., Salmons, R., Powell, J., & Craighill, A. (1998). Green taxes, waste management and political economy. *Journal of Environmental Management,* 121-136.

US Environmental Protection Agency, 2002. Municipal solid waste in the United States: 2000 facts and figures. Office of Solid Waste and Emergency Response.

UN-HABITAT. (2008; 2010). State of the world's cities 2010/11: Cities for all: Bridging the urban divide. GB: Earthscan.

U.S. Department of Health and Human Services (1997). Toxicological profile for vinyl chloride.

VDI 3477, 2004. Biological Waste Air Purification – Biofilter. VDI/DIN-Handbuch Reinhaltung der Luft, vol. 6. Beuth Verlag, Berlin (DE).

VDI 3478, 1996. Biological Waste Air Purification – Bioscrubbers. VDI Guideline 3478. VDI-Handbuch, Reinhaltung der Luft, vol. 6. Beuth Verlag, Berlin (DE).

Zapata, Alfredo Perez. In person interview. 20 Nov. 2015.

Appendix A: Materials for Student Informal Interviews

Share information about our project and how we are trying to develop a composting facility right next to their school where community members can come and drop off their organic waste.

Questions:

1. How familiar are you with composting?
2. How familiar are other community members with composting?
3. When did you first learn about composting?
4. Do you tell other people about the things you learn in the garden at school?
5. Do you think that other community members would be interested in learning about compost?
6. What do you think is the best way to spread knowledge about composting?

¡Gracias por su participación!

Thank you for your participation!

Appendix B: Potential Interview Questions for Waste Collection/Composting Groups

Interview Guide for Waste Collection/Composting Facilities:

1. **¿Cuáles son los procesos claves involucrados en el compostaje?**

   What are the key processes involved in composting?

   a. **¿Cómo son los materiales entregados a usted?**

      How are materials delivered to you?

   b. **¿Proceso de selección?**

      Sorting process?

   c. **¿Pasos para el compostaje?**

      Steps to composting?

2. **¿Alguna idea de cómo generar un beneficio a partir de los residuos que se recogen ?**

   Any ideas for how to generate a profit from the waste that will be collected?

3. **¿Tiene su planta un aspecto de investigación y desarrollo ?**

   Does your facility have a research and development aspect?

4. **¿Su planta tiene conexiones establecidas directos con otras organizaciones de recogida de residuos ?**

   Does your facility have direct established connections with other waste collection organizations?

   a. **¿Cómo es esto una ventaja ?**

      How is this advantageous?

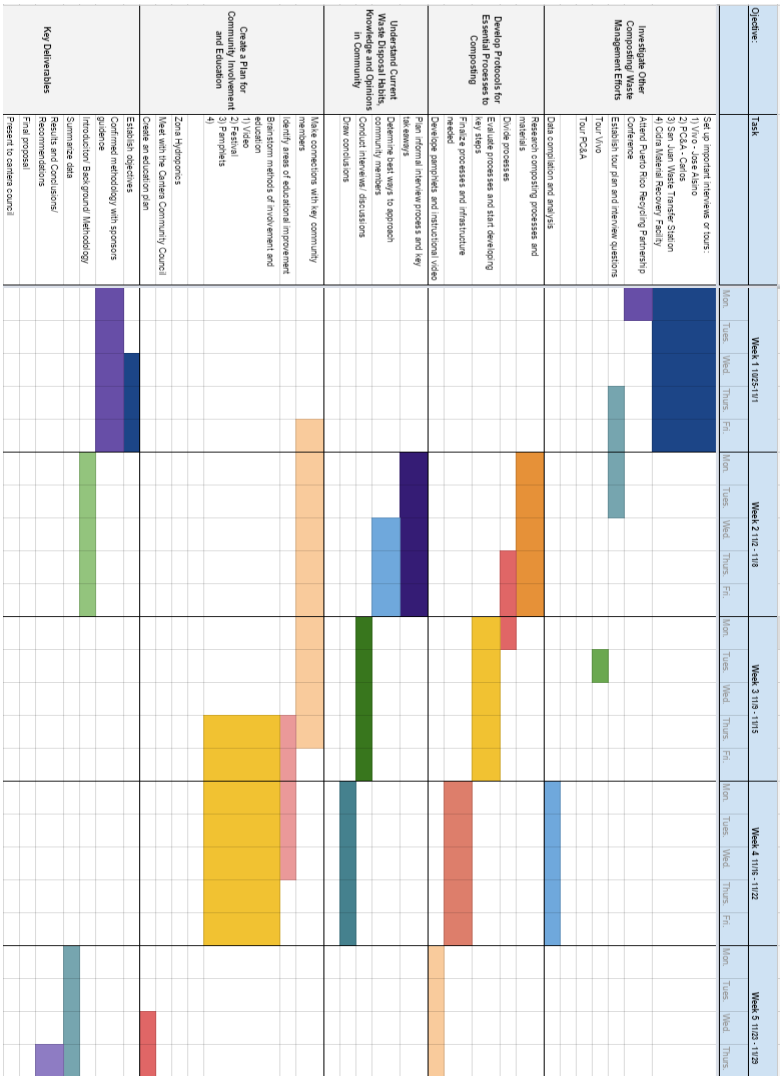
5. **¿Mayores desafíos y mayores mejoras ?**

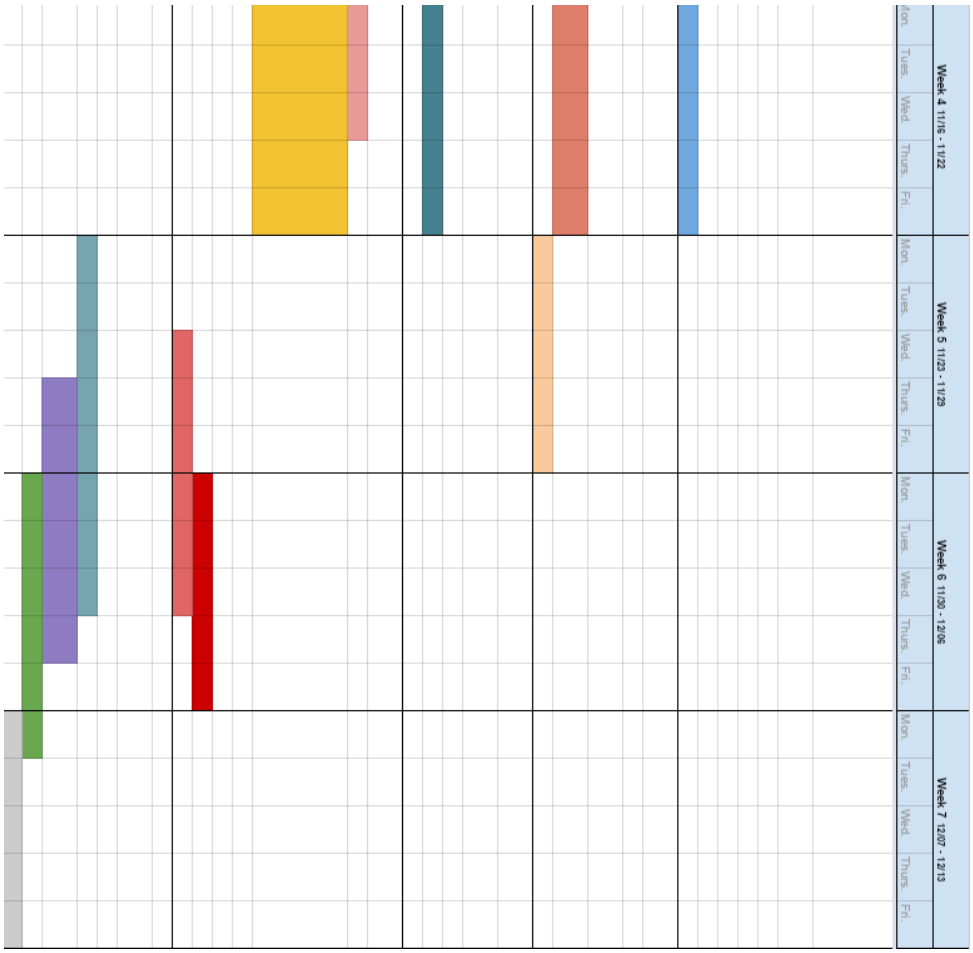
   Biggest challenges and biggest improvements?

Facilities to Contact:

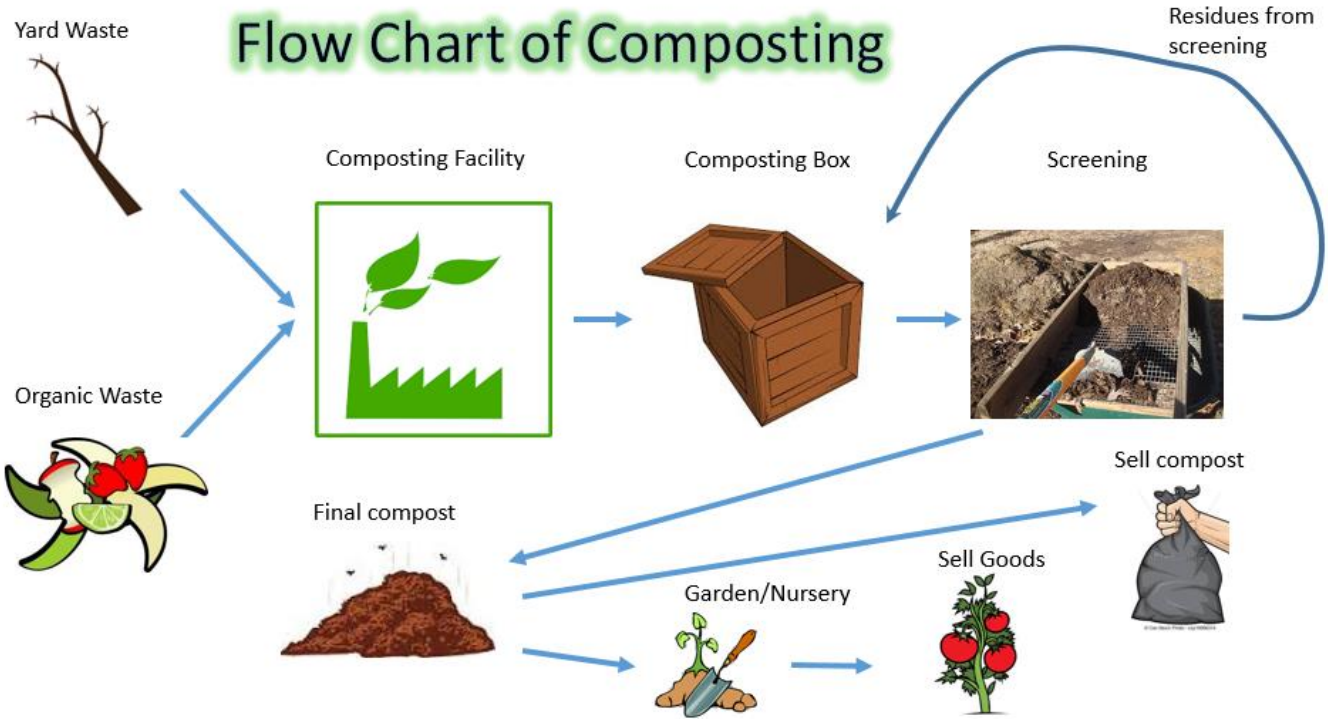
- The Consejo Vecinal (The community council)
- The CDIPC Employees
- San Juan Waste Transfer Station
- Cidra Material Recovery Facility
- The Reciclaje del Norte
- Vivo - Jose Ansino

Appendix C: Project Timeline Gantt Chart




Week 4 11/16 - 11/22
Week 5 11/23 - 11/29
Week 6 11/30 - 12/06
Week 7 12/07 - 12/13
Mon
Tues
Wed
Thurs
Fri

Appendix D: Composting Flow Chart



Appendix E: Technical breakdown of composting

Why Compost?

- Useful product:
    - A great fertilizer (Lots of minerals and nutrients and retains moisture)
    - Useful for house plants or gardens
    - Can be used as a mulch around the base of a plant
- Reduces waste being deposited in landfills
    - Nearly 25% of landfill waste could have been composted to create a useful resource

Uses:

- Planting or replanting house plants
- Use it on outdoor plants
- Donate to a neighbor, a local garden, or a local organization
- The microorganisms in compost can break down contaminants in water or soil

The Process:

STEP 1: Collect Compostable Materials

- Collect kitchen scraps: any extra food materials (including egg shells), spoiled food, napkins, and other paper materials.
    - Place a collection bin in a convenient location.
    - Do not compost: Dairy or meat products.
- Collect yard waste: leaves, brush, sticks, grass clippings, weeds and others.
    - Allow materials to dry out until they turn brown.
- Cut or break large materials into smaller pieces. Larger pieces will take longer to decompose.

Composting Materials:		
COMPOSTABLE		**NOT COMPOSTABLE**
• Fruits and Vegetables • Eggshells • Coffee grounds and filters • Tea bags • Nut shells • Shredded paper and newspaper • Cardboard • Yard trimmings • Grass Clippings • Houseplants	• Hay and straw • Leaves • Sawdust • Woodchips • Cotton, wool and silk fabric • Hair and fur • Ashes (fireplace)	• Coal or charcoal • Dairy products/ egg inner contents • Diseased or insect filled plants • Fats, grease, lard, or oils • Meat, fish, bones, scraps • Pet wastes (Feces or litter) • Yard trimmings with chemicals or pesticides • Black walnut tree material

STEP 2: Creating Composting Pile

- Make your own compost bin.
- Place collected materials into the compost container.
  - Mix the yard waste and kitchen materials so that the composition is no more than half food waste.
- Mix materials.

STEP 3: Maintaining Compost Pile

- Thoroughly mix compost 1-2 times a week. The more you mix it, the faster the process works!
- If larger pieces are not degrading, remove them and cut into smaller pieces.

Symptom	Problem	Solution
Pile is wet and smells like a mixture of rancid butter, vinegar and rotten eggs	Not enougth air Or too much nitrogen Or too wet	Turn pile Mix in straw, sawdust or wood chips Turn pile and add straw, sawdust, or wood ship; provide drainage
Pile does not heat up	Pile is too small Or pile is too dry	Make pile larger or provide insulation Add water while turning
Pile is damp and sweet smelling but will not heat up	Not enough nitrogen	Mix in grass clippings, food scraps or other sources of nitrogen
Pile is attracting animals	Meat or dairy products have been added Or food scraps are not well covered	Keep meat and dairy products out of the pile; enclose pile in 1/4" hardware cloth Cover food with brown materials such as, wood chips or finished compost

STEP 4: Final Product

Recognizing final product

- The pile has shrunk significantly (around ½ of its original size)
- No longer recognize original material in pile
- Finely grained product
    - Some parts of the pile may be finished composting before the rest of it. The completed compost can be filtered out using a sifter

Appendix F: Appendix F Three Tier Facility Breakdown

The first two tiers rely on the facility to be operated by community volunteers. Each tier we will be looking to have a garden component in order to aid in the general composting education as well as a learning center. The amount of organic waste handled by this facility won't be known till after a few months or years of operation. Once this is calculated and the operations begin to form a steady process then consideration of expansion can begin. After the composting facility begins to receive enough material to make expansion necessary and funds are located, then Tier 2 can be enacted. Tier 2 will be very similar to tier 1, but with a few enlargements in certain procedure or tools used.

Tier 3 is the end goal. This Facility will run similar to the Vivo facility in Caguas. Funds should be present to incorporate heavy machinery, full-scale three-acre facility, full-time job opportunity and handle San Juan Municipalities 5,000 Tons per year of organic waste.

Since open dumping is a serious issue in Cantera it is important that the facility is not accessible for open dumping that there are gates to prevent cars from unloading unwanted waste in the area.

Water supply

Water is important for all tiers since the compost and garden need to stay moist. The site has availability to a stream running through it, which provides the option of collecting water from it, The utilization of a water pump could be beneficial for a water supply. We would fill water holding tanks with water from the steam using a water pump. Water is a huge factor in composting and having a stream so close to the site is very beneficial. A pump estimate is shown below, along with a holding container as well. Other techniques that are relatively cheap

are creating collecting units for rainfall as well. Nevertheless this isn't as reliable as a flowing stream.

Pump estimate cost- $100-$200 (through various quotes online)
http://www.homedepot.com/p/Wayne-3-4-HP-Submersible-Sump-Pump-CDU980E/203448474

100 Gallon water holding tank- $100 - $200

Tier 1 - Stepping Stone

We have determined that Constructed Bin systems or turning piles will be most productive for this facility.

Garden: outdoor community driven small garden
Learning Center: incorporate community learning of composting and gardening
Composting Method: Constructed Bin System or Turning Piles
Turning Method: Volunteers
Estimated Volume: Based on number of volunteers and amount of organic waste delivered to site
Space required: Have up to 3 acres to use
Employees: Community members

Equipment needed:
Wood for construction of bins (Optional) ---- Estimated $0 - $500 (piles are free alternative)
The woodbins can be optional if there are lacking funds, a cost free alternative can be piles
Thermometer for compost ---- Estimated 30$, typically 18"
Hand Tools ---- Estimated $10- $50 (Rakes, Forks, and Shovels)

Tier 2- Transition

Composting Method: Piles
Turning Method: Volunteers
Estimated Volume: To be determined off Tier 1
Space required: 3 Acre
Employees: Volunteers

Equipment needed:
Residential Wood Chipper - 1k-2k

Air Pump ---- $50 - $300
Perforated PVC pipe ---- $20 - $200
Tarps ---- $200

Tier 3 - Industrial

Composting Method: Piles
Turning Method: Large Machinery
Estimated Volume: 5,000 Tons
Space Required: 3 Acres
Employees: Full-time and Part-time

Equipment needed:
Commercial Wood Chipper ---- 10k - 50k
Commercial Screener ---- 15k - 100k
Front Loader Tractor ---- 10k - 100k
Operating costs ---- Estimated $30 per hour per machine (Davis, Jenn, 2013)
Tarps ---- 12 ft. x 16 ft. Heavy-Duty Tarp $30-$35/each (estimate from looking at prices online)

Appendix G: Compost Organization Rating System

Key Factors:	Holding Units	Turning Units	Heaps/Piles	Pit/Trench (N/A)
Volume that can be handled:	Medium 30-50 ft^3	Small Around 15 ft^3	Large About 75 ft^3	Large
Time to Complete Composting:	6 months to a year	2 months or less	4-8 months	Up to a year
Amount of Management Needed	Large effort to turn every 2 weeks	Easy to turn every 5 days	Turn every 4-5 weeks large effort	none
Area Needed	small	small	Medium	large

Holding Units

Volume storage

Category	Score	Definition
Small storage	1	Holds 1-20 ft^3 of compostable waste
Medium storage	2	Holds 20-60 ft^3 of compostable waste
Large storage	3	Holds 60+ ft^3 of compostable waste

Time for compost

Category	Score	Definition
Slow	1	Process takes more than a year to create mature mulch
Average	2	Process takes 2 months to a year to create mature mulch
Fast	3	Process takes 2 months or less to create mature mulch

Maintenance

Category	Score	Description
High	1	Rotate and maintain once a week

Medium	2	Rotate and maintain every 2 to 3 weeks
Low	3	Rotate and maintain every 4+ weeks
None	4	No maintenance needed

Holding units are a very effective method since they are very versatile. It performs at a pretty average level compared to the other storage options.

Turning units

Volume storage

Category	Score	Definition
Small storage	1	Holds 1-20 ft^3 of compostable waste
Medium storage	2	Holds 20-60 ft^3 of compostable waste
Large storage	3	Holds 60+ ft^3 of compostable waste

Time for compost

Category	Score	Definition
Slow	1	Process takes more than a year to create mature mulch
Average	2	Process takes 2 months to a year to create mature mulch
Fast	3	Process takes 2 months or less to create mature mulch

Maintenance

Category	Score	Description
High	1	Rotate and maintain once a week
Medium	2	Rotate and maintain every 2 to 3 weeks

Low	3	Rotate and maintain every 4+ weeks
None	4	No maintenance needed

The rotational storage machine has low maintenance and average composting speeds. nevertheless has low storage capability. Overall an effective method in home or small scale use.

Piles

Volume storage

Category	Score	Definition
Small storage	1	Holds 1-20 ft^3 of compostable waste
Medium storage	2	Holds 20-60 ft^3 of compostable waste
Large storage	3	Holds 60+ ft^3 of compostable waste

Time for compost

Category	Score	Definition
Slow	1	Process takes more than a year to create mature mulch
Average	2	Process takes 2 months to a year to create mature mulch
Fast	3	Process takes 2 months or less to create mature mulch

Maintenance

Category	Score	Description
High	1	Rotate and maintain once a week
Medium	2	Rotate and maintain every 2 to 3 weeks
Low	3	Rotate and maintain every 4+ weeks
None	4	No maintenance needed

Trenches

Volume storage

Category	Score	Definition
Small storage	1	Holds 1-20 ft^3 of compostable waste
Medium storage	2	Holds 20-60 ft^3 of compostable waste
Large storage	3	Holds 60+ ft^3 of compostable waste

Time for compost

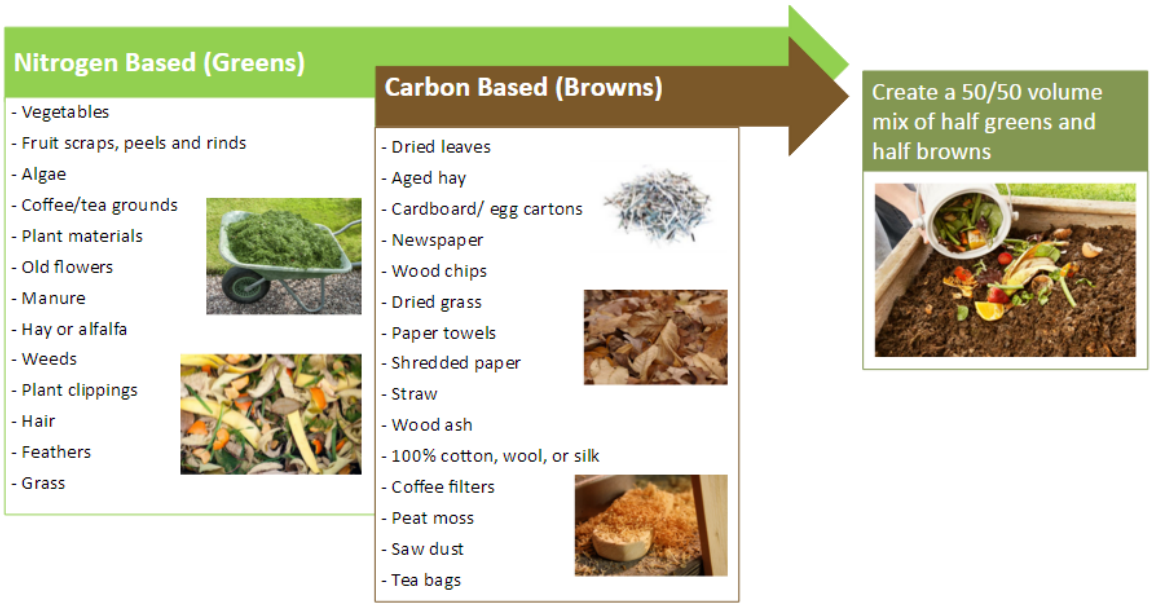
Category	Score	Definition
Slow	1	Process takes more than a year to create mature mulch
Average	2	Process takes 2 months to a year to create mature mulch
Fast	3	Process takes 2 months or less to create mature mulch

Maintenance

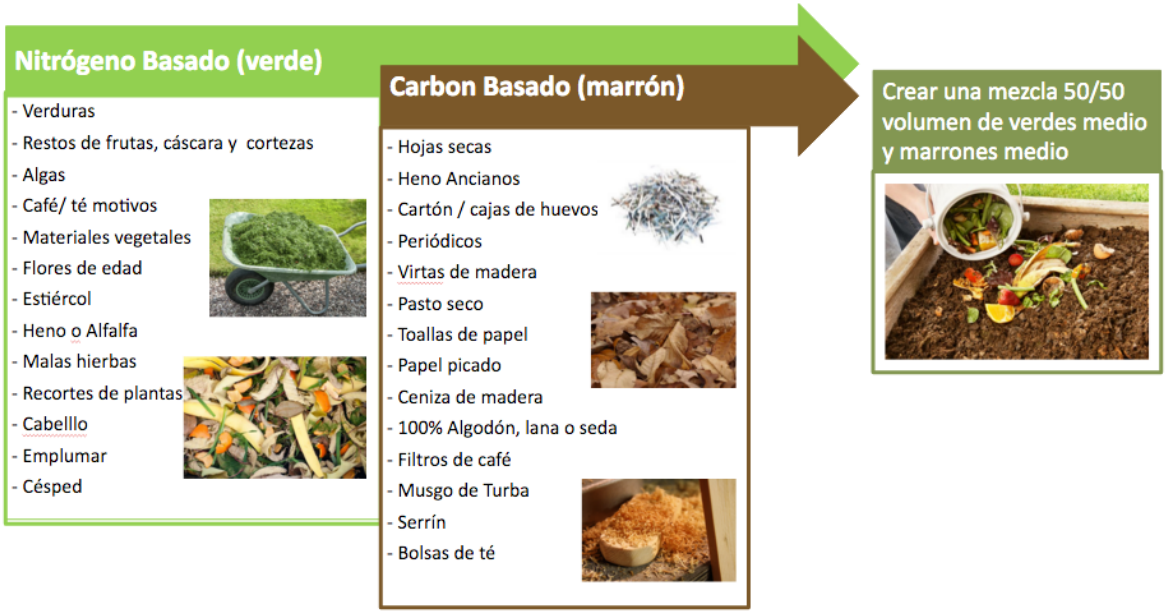
Category	Score	Description
High	1	Rotate and maintain once a week
Medium	2	Rotate and maintain every 2 to 3 weeks
Low	3	Rotate and maintain every 4+ weeks
None	4	No maintenance needed

- If looking for very low maintenance and slow composting, but has high storage capability
- Good for open backyards or areas not needing maintenance

Appendix H: Visual for separating composting



This has been translated into Spanish below.



Appendix I: Compost Pamphlet

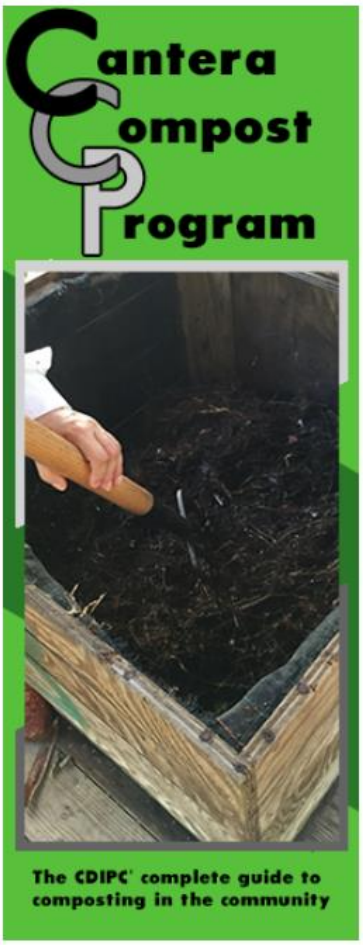
The Cantera Composting Project

To create a plan for a local composting facility that could potentially provide job opportunities and other resources to community members.

Spread knowledge about composting and sustainability.

Goals

- Get community involved
- Create understanding of recycling
- Show the positive aspects to composting



Composting

Recycling organic materials by allowing them to decompose into a useful soil product.

Composting is a natural process that occurs in nature which we can recreate with the right conditions.

Why Compost?

Composting produces a useful fertilizer to grow healthy plants. The process allows the production of minerals and nutrients that hold moisture. The resulting soil conditioning product is an alternative to unnatural fertilizers. In addition, the microorganisms that thrive in compost can help break down contaminants in water or soil. It is a valuable product that has been proven to support a successful business.

Reusing the waste organic materials reduces the amount of waste being deposited in landfills. If all compostable materials were recycled through composting, this could decrease the amount of waste being deposited in landfills by around 30%.

The Process

Composting is easy and can be done any-

1. Collect compostable materials from kitchen scraps or yard waste.
   - Food waste
   - Yard material
   - Paper product
2. Mix together compostable materials with more than half consisting of yard waste and paper products. You can make your own bin, get creative!

3. Maintain the pile by mixing it thoroughly 1-2 times a week.
4. Recognize the final product:

- Original materials cannot be recognized
- Material is finely grained
- The pile has shrunken significantly

The pamphlet has been translated into Spanish below.

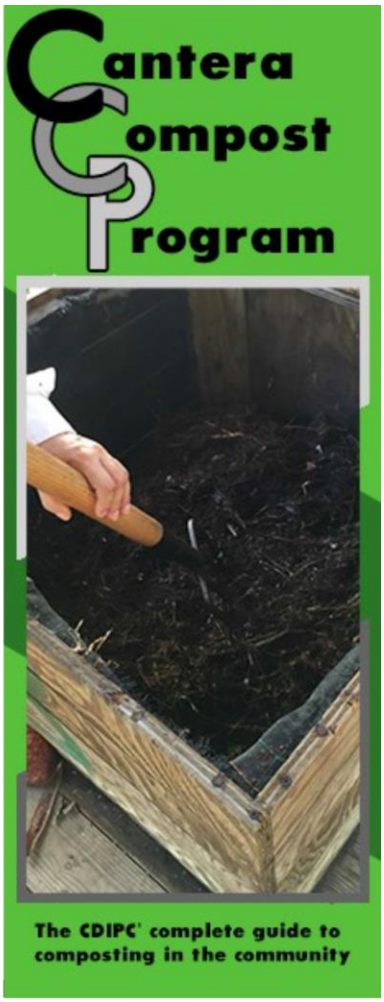
La Cantera Proyecto de compostaje

Para crear un plan para una planta de compostaje local que potencialmente podría ofrecer oportunidades de trabajo y otros recursos para miembros de la comunidad.

Difundir el conocimiento sobre el compostaje y la sostenibilidad.

Objectivos

- Obtener la comunidad involucrada
- Crear comprensión de reciclaje
- Mostrar los aspectos postitive a compostaje



Compostaje

El reciclaje de materiales orgánicos por lo que les permite descomponen en un producto útil del suelo.

El compostaje es un proceso natural que ocurre en la naturaleza que podemos recrear con las condiciones adecuadas.

Por eso el composta?

El compostaje produce un fertilizante útil para cultivar plantas saludables. El proceso permite la producción de minerales y nutrientes que mantienen la humedad. El producto acondicionamiento del suelo resultante es una alternativa a los fertilizantes no naturales . Además , los microorganismos que prosperan en el compost pueden ayudar a descomponer contaminantes en el agua o el suelo. Es un producto valioso que se ha demostrado para apoyar un negocio exitoso.

La reutilización de los materiales orgánicos de desecho reduce la cantidad de residuos depositados en los vertederos. Si se reciclaron todos los materiales compostables a través del compostaje , esto podría disminuir la cantidad de residuos que se depositan en los vertederos en un 30 % .

El Proceso

1. Reunir materiales compostables de desechos de la cocina o desechos de jardín
   - Residuos de alimentos
   - Materiales de jardín
   - Productos de papel
2. Mezclar materiales compostables junto con más de media que consiste en residuos de jardín y productos papel. Usted puede hacer su propio bin, ser creativo!

3. Matener la pila mezclando a fondo 1-2 veces a la semana
4. Reconocer el product final :

- Materiales oringinales no pueden ser reconocidos
- El material es de grano fino
- La pila se ha encogido considerablemente

Appendix J: Composting Drawback Details

First off, in order to construct a compost facility, a large plot of land is needed. The facility would be taking in a constant flow of waste every day, but it takes time for the waste to decompose. Therefore a large space for multiple piles of compost is needed to handle the daily waste intake (Domingo and Nadal, 2009). Also if the construction of the plant is on a larger piece of property, it will be easier to design and manage the environmental impacts (Epstein,E, 1997). Another large issue with composting is controlling the odor produced during the process. If the compost process is out of control, odors tend to be emitted; and could lead to harmful quantities of greenhouse gases and inhalants to be released. Nevertheless, this can be controlled through multiple preventive measures. First off, a large portion of odorous and hazardous gas emissions can be avoided by optimizing the composting conditions (Körner et al., 2003). For example, composting underneath a semi-permeable cover reduces odor emission (Kühner, 2002). Furthermore, odor and bioaerosols can be managed by better facility designs and conditions. Frequent cleanings of all the devices in the facility, along with any interior walls would keep the facility from emitting odor and gases, (Boisch, 2001). Other methods to implement throughout the emissions of odors and aerosols could be bioscrubbers or biofilters. "Bioscrubbing is a process of biological waste gas treatment in which exhaust air is 'washed' in an absorber with a scrubbing liquid. The scrubbers are used to humidify the air passing to the filter in order to avoid drying of the filter material" (VDI 3478, 1996). While biofilters are fixed beds with biological treatment material that filter out the concentration of impurities in the air. These two processes can be combined to have an optimal effect on cleaning contaminated air (VDI 3477, 2004). Also, biofilters and bioscrubbers are most beneficial in an enclosed environment, indoor facilities.

After the composting process is complete, the final product can release harmful dust particles if mishandled. In order to prevent this harmful impact on the worker's, the use of personal protective equipment is advised. Such equipment would include goggles, gloves, disposable masks, and meticulous personal hygiene (Lavoie et al., 2006). Along with wearing equipment, some other precautionary steps can be taken in, as shown in the table below.

Domestic waste composting facilities: A summary of recommendations to prevent human health risks

Volatile organic compounds (**VOCs**): are organic chemicals that have a high vapor pressure at ordinary room temperature. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air.

Potentially affected population	Health risks	Recommendations
Individuals working at composting facilities	Biological risks: bacteria (mainly Gram-negative), fungi (mainly A. fumigatus), endotoxins, parasitic protozoa Chemical risks: volatile organic compounds (VOCs) (mainly benzene)	– Exhaustive control of biological risks– Measurement of microorganisms in the compost and in the air (indoor) – Measurement of indoor concentrations of VOCs – Biological monitoring of VOCs in workers – Protective measures to prevent exposure to VOCs and bioagents – Environmental (outdoor) monitoring of microorganisms and VOCs in the surrounding of the facilities
Individuals non-occupationally exposed	– Metals (mainly As, Cd, Cr, Hg, Ni, Pb), pesticides, PAHs, persistent organic pollutants (PCDD/Fs, PCBs, etc.) – VOCs – Microorganisms	– Periodic analytical quality of compost in order to reject any compost containing concentrations of biological or chemical agents with potential health risks

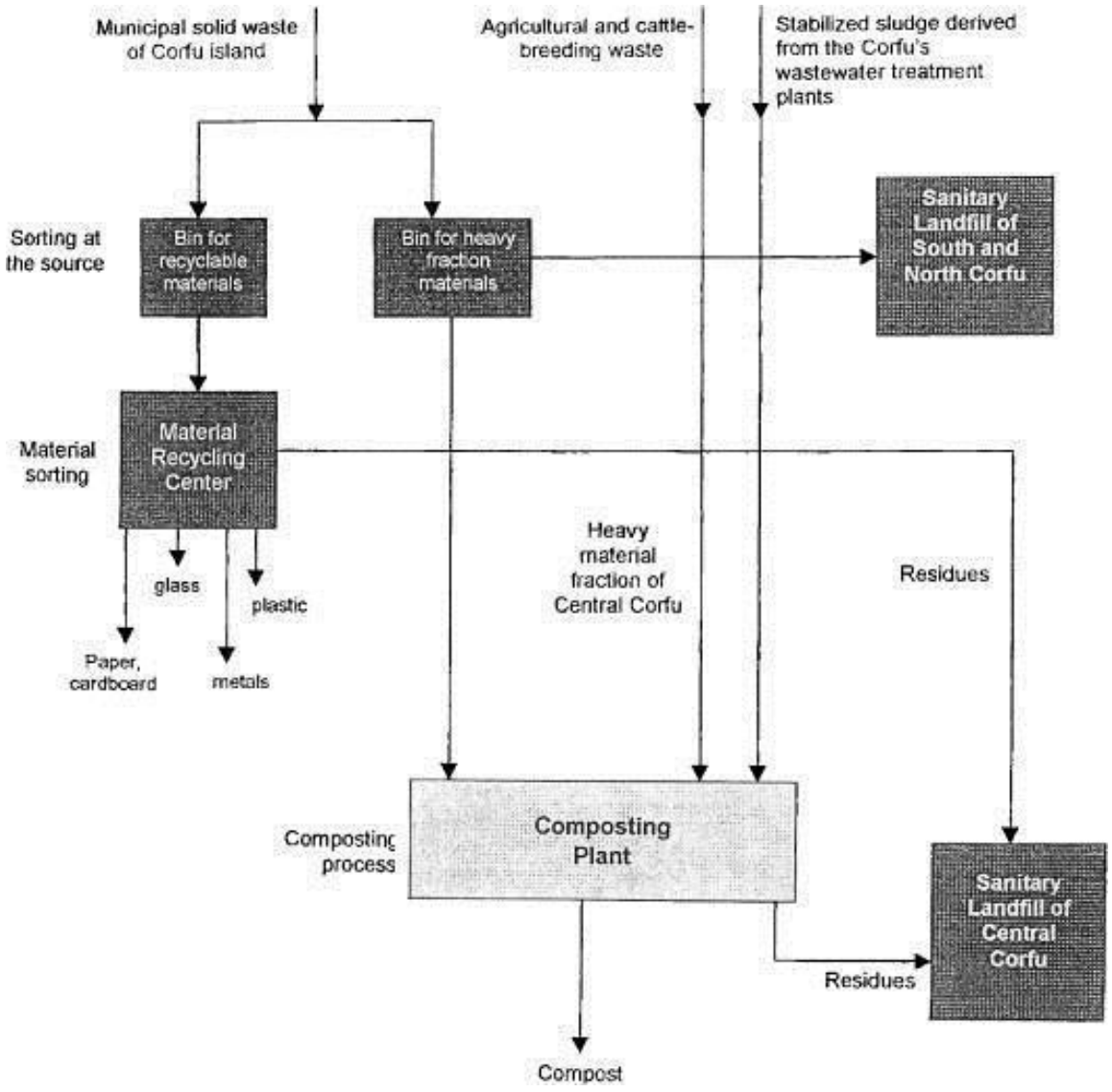
(Domingo and Nadal, 2009)

These Health effects tend to be minimum and commonly do not occur often. Nonetheless, these precautionary steps should always be considered when dealing with human health risk (Domingo and Nadal, 2009). Another factor to account for is the attraction of vermin and rodents. The compost piles create a natural home and food source for animals, which creates the attraction of vermin to the facility. The best way to prevent this attraction is to create an insulated indoor facility, therefore creating a physical barrier to keep them out. Another alternative to such a large scale project is controlling the odor and creating containers to prevent vermin from being enticed to enter the composting plant (Gabrey, Belant, Dolbeer, and Bernhardt, 1994). Lastly, soil contamination should be taken into consideration. What can lead to soil contamination is the improper sorting of material being placed into the composting pile. If any of the contents have been exposed or contaminated with toxic materials, the soil will then become contaminated. Once the soil is used to fertilize plants, then it enters the food chain. The contaminated compost will affect any animals that consume the plant; and conversely humans will ingest both the plants and animals. In order to prevent such actions, the importance of sorting materials in the compost pile should be monitored carefully. (Domingo and Nadal, 2009)

Appendix K: Cerfu, Greece Waste Removal Study

Many small tourist islands, like Puerto Rico, tend to face the same issue of building up waste and improperly disposing it. The issues resulting from not having a legal and efficient waste removal system can cause harm to the environment and local communities. A case study performed on Corfu, a small Greek island in the Ionian Sea, dealt with the issue of finding a suitable waste management system for its small infrastructure (Skordilis, A, 2004). Their current collection of municipal solid waste takes place four to five times per week. Then the waste is disposed directly into 19 different landfills. Currently on Corfu, only 1 of the 19 landfills is within the legal sanitary specifications. With no current alternatives to landfills, the community is dependent upon this method. Problems resulting from unregulated landfills are expected to increase tremendously in the coming years, due to an increase in waste generation. According to the study, the composition of waste is mainly made up of organics, papers, and plastics. The researchers created a sorting method of different wastes and implemented the process to see the impact it had on unnecessary waste sent to local landfills. The largest portion, approximately 45%, of Corfu's waste was organic and can be recycled into compost instead of sending it to landfills (Skordilis, A, 2004). This is where the researchers used the life cycle analysis (LCA) to evaluate the impact of composting. The LCA assesses the potential negative environmental impacts associated with a product or service throughout its life span, "cradle-to-grave." Another key takeaway from an LCA is that it allows the analysis of costs versus benefits of the process. Once the process is accessed, a final decision can be made on the effectiveness of composting. The installation of new recycling habits cut back spending on waste management. Therefore the Corfu community gained environmental benefits of the new system through reduction in waste buildup, reduction in municipal waste sent to landfills, and follow environmental

regulations. They also found benefit in byproducts from the composting which could help cut back other costs in the government or sell to local companies. The image below shows the simple process they used which incorporated new recycling tactics.



The breakdown how shows the procedure in which composting is incorporated into the waste management process, along with recycling glass, paper, plastic, and metals. Once those

specific recyclables are taken out of the solid waste, then the remaining waste is separated into compostable material or sent directly to a sanitary landfill. Most of the remaining waste at that step is organic, so only a small portion is actually being sent to the landfills. The researchers and implementers observed the following conclusion: "The results have demonstrated that the combination of material recovery at the source with the utilization of the organic fraction is the optimum solution for small local communities (Skordilis, A, 2004). The overall results show a benefit to society and support a composting and recycling aspect to Cantera's waste collection issues.

Appendix L: Vivo Tour Detail Information

Composting Company Tour

At Vivo Recycling, a local composting business, we saw a successful large scale facility in operation. The owner, Jose Alsina shared with us the important steps and key elements to the success of his facility and also insights into how to start up a new composting business. Because he has so much experience with the process of composting he has simplified the steps to be the efficient and effective. In order to accommodate all the organic waste he receives, the system has become more industrial.

Vivo receives organic waste by the truckload. It is deposited into large piles as can be seen in front of the excavator. Large machines like the excavator and the industrial conveyor belt shown below are used to sift through material and move it around the site.

After allowing the organic materials to dry out, they are put through a mulching machine that breaks the solid materials up into smaller pieces. All materials must be completely dried out to be placed in the mulcher. The next step, at Vivo, is placing the materials into large heaps. They are continuously watered and flipped over so that they are aerated and maintain the proper temperatures and moisture level. Once the final product can be recognized, the mulch is run through a screener as shown below. This is a large screening machine that separates material that has completely composted from larger pieces that need to be further broken down.

From the tour we learned that if 1000 cubic yards of compostable materials are received, that will break down and degrade to produce less than 100 cubic yards of compost. While walking through the process, Jose identified some problems that he has had to address. One

major problem is that poorly sorted waste can lead to non organic solid waste in a compost pile. Materials like glass and plastic will end up breaking up into smaller pieces that are nearly impossible to remove and decrease the value of the final product. This demonstrates that preventative measures must be taken to insure the production of a quality output. He also warned us that compost pile fires can be a major problem. If not properly monitored during the compost process, a dry pile can heat up due to the decomposition and cause a fire to start in the center of the pile. To combat this, it is important to maintain moist compost piles and maintain a reliable source of water in the case that a fire does start. Foresights like these are extremely helpful to allow us to plan ahead and address potential hazards in the process that are detrimental to worker's or community member's safety and to the compost.

After seeing the whole process from start to finish, Jose Alsina also gave us insights to his business model and how he is able to run a profitable business. He shared that 80% of Vivo's income is from charging $10.00 for the drop off a truck load of organic waste, while the other 20% is generated from selling the compost and related products. Vivo sells compost at $6.00 for a square yard or $25.00 for a pickup truck full. Customers can drive in and collect compost as shown below.

In addition, they sell products like seedlings and soil as supplementary products. Their on site nursery is also a way to demonstrate to customers that their compost product is successful in growing healthy plants. He also discussed the progression of Vivo from a smaller scale operation to the industrial size it is today. Because the machines that allow for processing of large amounts of waste can cost upwards of one million dollars, he had to start with smaller hand held tools and more labor hours in order to gain enough revenue and stability to afford them.

Vivo is a much larger production operation than the conditions in Cantera allow for. Also, the facility will need to start on a smaller scale because industrial equipment is not affordable. Because it is a smaller size, other organization methods then a simple pile may be more applicable.

Appendix M: Detailed Description of Each Composting Organization Method

1. Holding Units

The first method, holding units, is the most common, completely enclosed option. Holding units are constructed from a variety of materials like trashcans, wooden planks and wire mesh. They are simple and inexpensive to construct because a holding unit can be made from a variety of common materials. Based on the available materials or the choice to purchase a unit, the price can range from $30.00 to $300.00. The options pictured above are all static and contain the compost materials inside. This means they require less space but also take more effort to turn the pile and provide aeration. Because the compost is contained inside a solid container, it calls for less frequent maintenance. Depending upon the properties of individual containers, for complete composting to occur it can take six months to a year.

1. Turning Units

Turning units, similar to holding units, are also completely enclosed. The difference is that turning units are made for easy turning capabilities. They are often mounted on a rotating stand or are circular so they can be rolled around to provide oxygen throughout and mix the enclosed composting materials. These units are typically more expensive to either construct or purchase. Turning units are possible in a variety of sizes ranging most commonly from 40 to 80 gallons. Larger units can present maintenance challenges because they are likely to be heavy.

The benefit of this option is that the turning capability provides plenty of air and allows composting to occur at a faster rate that can complete in as little as two months.

1. Piles

The next option is placing the compost in large, uncontained piles which require greater amounts of space. Piles can are generally larger than five cubic feet and can handle more volume of organic waste than other options like a holding or turning unit. Turning the heaps is optional, but is recommended to speed up the decomposition process and maintain a safe process. The time needed to generate a final compost product varies depending on the size of the pile and the frequency of turning but is generally around four to eight months.

1. Trenches

Trench composting is the last composting technique. It consists of digging trenches into soil and placing the mulched compostable materials into the ground. the compost is covered over with soil and left to decompose. It is commonly used in gardens that can be rotated to allow time for composting. This method requires a lot of space and a larger span of time because aeration is not provided. Trench composting was eliminated as an option for the Cantera composting facility because it does not generate a final compost product that can be easily separated for sale.

Appendix N: Municipality Meeting Minutes 11/30/2015

Feasibility of a Composting Plant in Cantera

11/30/2015

Attendees:

- Luis Cintron
- Carmen Rivera
- Alfredo Perez Zapata
- Madelyn Werth
- Tyler Kilkenny
- Jake Nieto

Information to look into:

1. The volume of organic waste that is processed by the municipality
2. The costs for landfills
3. Permitting
4. Timing

Current situation:

All waste, including organic waste, is being disposed of in landfills.

- 3700 tons of Organic Materials generated Jan 2015 - Sept 2015 (roughly 5,000 Tons a year)

Municipality is not currently working with any composting organization to reuse waste.

A lot of organic material is being generated: including branches and plant clippings.

Waste received at the transfer station is separated: Organic waste is separate from other solid waste.

Using a landfill is expensive and the Municipality would be very interested in an opportunity.

Space in Cantera:

Land available is approximately 3 acres

Need a capacity assessment of the land available in Cantera to understand how large a composting operation could be.

Looking into Buffer Zones (Odor / Noise)

Required Permits:

- Endorsement of certain agencies
- Utilities agencies
- Environmental Permits → from the Municipality
- Operational Permits
- Construction Permits

All permitting could take 6 months to a year to complete
Contact Erna Rodriguez (Arecibo) 767-7575

Other contacts:

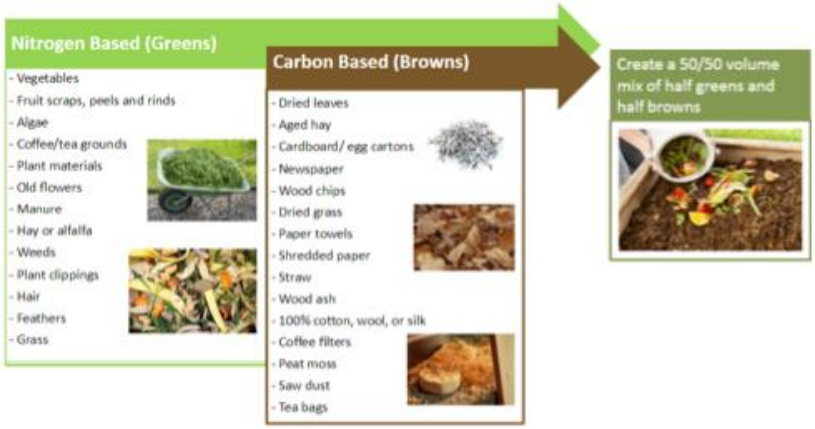
FOHL → Vermicomposting 787-717-4354

Appendix O: Signs for use at the learning facility

1: COLLECT COMPOST MATERIALS

2: CREATE PILE

- **Break or cut up larger materials**
- **Place in a pile or compost bin keeping a proportioned mix** (shown to the right)
- **Mix materials**



3: MAINTAIN IT

Thoroughly mix compost 1-2 times a week using shovels or pitchforks

Problem	Possible causes	Solutions
Pile is wet and has rotten smell	Not enough air Too much nitrogen Too wet	Turn pile Add straw, sawdust, or wood chips Provide more drainage
Pile does not heat up	Pile is too small Pile is too dry	Make a larger pile Put compost in an insulated container Add water
Pile is damp, smells sweet, and does not heat up	Not enough nitrogen	Add grass clippings, food scraps or other sources of nitrogen
Pile attracts animals	Meat or dairy products in pile Food scraps are not well covered	Remove meat or dairy products Enclose the pile with 1/4" hardware cloth Cover food scraps with brown materials like wood chips or compost

Monitor for problems and address them (reference table)

4: RECOGNIZE COMPOST

The signs:

- Pile significantly decreased in size
- No recognizable original materials
- Finely grained product

Separate the compost:

Use a sifter to filter out finished product from larger pieces

Larger pieces can be returned to the compost pile

GARDENING WITH COMPOST

Benefits of Compost

Adds nutrients to the garden

Cuts down use of harmful fertilizers

Promotes growth of healthy plants that can be sold or consumed

- Pile significantly decreased in size
- No recognizable original materials
- Finely grained product

All of the signs have been translated to Spanish below

1: Recoger los materialels de composta

2: Crear Pila

- **Romper o cortar materialels más grandes**
- **Colocar en una bandeja de la pila de compost o mantener una mezcla de proporciones (que se muestra a la derecha)**
- **Mezclar materiales**

3: Mantener Ti

Mezclar bien la composta 1-2 veces a la semana utilzando palas o rastrillos

Problemas	Las causas posibles	Soluciones
Pila es húmedo y tiene olor a podrido	No hay suficiente aire Demasiado nitrógeno Demasiado húmeda	Gire la pila Añadir paja, virutas de aserrín o madera Proporcionar más de drenaje
Pila no se calienta	Pila es Demasiado pequeño Pila es Demasiado seco	Hacer una pila más grande Ponga composta en un contenedor aislado Agregue el agua
Pila es Húmeda , huele dulce, y no se calienta	No es suficiente nitrógeno	Añadir recortes de césped, restos de comida u ortas fuentes de nitrógeno
Pila atrae a los animales	Carne o productos lácteos Los restos de alimentos no están bien cubiertos	Retire la carne o los productos lácteos Incluya la pila con ¼" tela metálica Cubrea las sobras de comida con materials marrones como virutas de madera o de compost

Monitorear los problemas y hacer frente a ellos (tabla de referencia)

4: Reconocer Composta

Las señales:

- Pila disminuyó significativamente en tamaño
- No hay materiales originales reconocibles
- Producto de grano fino

Separar la composta:

Utilice un tamiz para filtar producto acabado de las piezas más grandes

Piezas más grandes pueden ser devueltos a la pila de composta

Jardinería con Composta

Beneficios de composta

Añade nutrientes para el jardín

Reduce el uso de fertilizantes dañinos

Promueve el crecimiento de plantas sanas que pueden ser vendidos o consumidos

- Pila disminuyó significativamente en tamaño
- No hay materiales originales reconocibles
- Producto de grano fino