Bakery and Biodigester

Increasing sustainability of the La Escuela Agricola San Fransisco

Rebecca Hamilton • Zachary Ligham • Connor Willgress • Jingyi Wu

May 2, 2017

WPI

fundación paraguaya

Bakery and Biodigester in Paraguay

An interactive Qualifying Project Proposal

Submitted to the faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

Submitted on:

May 2, 2017

Submitted by:

Rebecca Hamilton

Zachary Ligham

Connor Willgress

Jingyi Wu

Submitted to:

Fundación Paraguaya

Project Advisors:

Dr. Robert Traver

Dorothy Wolf

Abstract

La Escuela Agrícola is a self-sustainable school located in Paraguay. It was developed to help the rural youth develop skills to rise out of poverty. The team sought to accomplish two projects working in parallel to benefit the school's self-sustainable mission. The first project was the evaluation and construction of a biodigester system. The biodigester reduces the school's energy costs by producing biogas. The second project was to determine the feasibility of a bakery business. The team determined that a bakery could be feasible, but an in-depth market analysis should be conducted.

Acknowledgements

We would like to express our gratitude to the following for their contributions to our Interactive Qualifying Project:

- Dorothy Wolf for her recommendations and constant help pushing the objectives of the process.
- Dr. Robert Traver for his guidance and feedback throughout the entire project. Also for his help digging the biodigester hole.
- Martin Burt and Fundación Paraguaya for creating the self-sufficient Escuela Agrícola and allowing us to be a part of the community.
- Luis Cateura, the director of La Escuela Agrícola, for allowing us to be a part the school and helping shape the projects.
- Virgilio Borges for working closely with us as an advisor and making recommendations for the biodigester design.
- Rosa Paez for letting us interview her and providing us with the information on the day-to-day kitchen schedule.
- Ricardo Negrete for providing us with the knowledge on how to run a business.
- Fernando Gonzalez for providing us with expert knowledge on biodigesters and allowing us to see a small-scale working model on his farm.
- Jose Luis Solomn for his help towards the end shaping our presentations, editing our Spanish, and helping finish the final stage of our project
- All the students of the San Francisco Agricultural school for welcoming us into their school and helping us on our projects.
- WPI for providing the opportunity to travel to Paraguay and be a part of this project.

Executive Summary

Project Overview

This IQP focused on two projects to promote self-sustainability within La Escuela Agrícola. One project was to reduce energy costs at the school through the implementation of a biodigester. The second project was to determine the feasibility of a bakery.

The team worked with La Escuela Agrícola for seven weeks on the two projects. For the first project, the team designed and installed a new biodigester system. The old biodigester was unsalvageable due to poor design and improper maintenance. Additionally, the team provided the school with a maintenance schedule and plans for future expansion.

For the second project, the team created the first steps of a feasibility plan for a bakery. The bakery projections are profitable if there is sufficient demand. After capital investment, the school will break even in three years. A full feasibility study is required to understand market demand.

Recommendations

The team recommends that the biodigester be maintained according to the maintenance guide. Additionally, the school should expand the system to better meet their energy needs. For the bakery, a full feasibility study should be conducted. This study will be a sturdy base for a bakery business plan.

Methodology

To build the new biodigester system, the team analyzed the problems of the old system. After determining it could not be repaired, the team designed a new system. The material specifications and design advice came from Virgilio Borges, the school's facilities manager, and Fernando González, a biodigester and sustainability expert.

To assess the bakery feasibility, the team interviewed the Cheesemeister of Cerrito, Ricardo Negrete and the Head Chef of Hotel Cerrito, Rosa Paez. These experts provided information on business strategies and production capability. Using this information and the 2016 IQP kitchen audit data, the team evaluated and numerically modeled current production. This data was compared to extrapolated production models for two levels of capital investment, assuming low market demand.

Authorship Page

All members of the team participated in research and discussions related to the biodigester and bakery. In addition, all contributed to the design of the biodigester and cost analysis of the bakery feasibility plan. They also all equally worked on the completion of this report.

Table of Contents

List of Figures

1 Introduction

Paraguay is a landlocked country located in the heart of South America and is home to 6.64 million people. Out of Paraguay's total population, 2.6 million live in the rural countryside. Compared to other sectors of Paraguay, the rural areas have the highest percentage of poverty (World Bank, 2010). Those living in the rural sector must generate a source of income to provide financially for themselves. One way to create revenue is to learn and develop skills that can be used to market goods and services. The Fundación Paraguaya supports this need for rural populace development.

Fundación Paraguaya is a self-sustainable, non-government organization. Created in 1985, it focuses on microfinance to promote entrepreneurship within Paraguay's rural population. The organization's goal is to develop sustainable solutions to alleviate poverty. One of the main solutions is education. A key means to this education is a "learn by doing, selling, and earning" methodology (fudacionparaguaya.org). La Escuela Agrícola San Francisco exemplifies this philosophy through its operation.

La Escuela Agrícola is a self-sustainable school located forty minutes outside Asunción. The students pay tuition by working to produce and sell goods. The mission is to empower the youth of the impoverished, rural community. It teaches skills to become what the Fundación Paraguaya calls "rural entrepreneurs and micro enterprises". Like any business, the school must be profitable to maintain its self-sustaining nature.

During our time in Paraguay our team worked on two projects. The first project was to design and install a biodigester. Previously, the school had implemented a large-scale biodigester. The biodigester had been plagued with problems from the start. These problems prevented effective production of biogas. Therefore, there had been little financial benefit. The goal was to redesign and implement a new, functioning system.

The second project consisted of looking at the feasibility of a commercial bakery. Upon arriving at La Escuela Agrícola the kitchen facility was being renovated. A new building was being set up to house an expanded kitchen with new equipment and more space. The team looked at the possibility of implementing a bakery in the new space. The aim was to set in motion the beginning steps of a commercial bakery.

Our two projects go together with La Escuela Agrícola's self-sustainability mission. The team could see first-hand the challenges and benefits of a large-scale, self-sustainable educational model. The biodigester works on reducing the school's energy costs and the future bakery will increase revenue. Working on these projects while navigating the cross-cultural experience was both challenging and rewarding.

2 Background

2.1 Paraguay's National Economy

Paraguay is a developing country located in South America. The country is landlocked and lacks direct access to sea-trade. The country's inability to trade via the sea strongly influences its economy. Paraguay relies on what it exports to the world via its nearby neighbors in Mercado Común del Sur (MERCOSUR). Paraguay's main exports are soybeans, bovine meat, and leather (OEC). These goods are all from the agricultural sector and produced internally. The agricultural sector contributes the most to the GDP of Paraguay, followed by the commerce sector. These two sectors accounted for over 42 percent of the country's GDP in 2009. They also represented over 25 percent of employment, especially over 70 percent of the employment of the poor (World Bank, 2010).

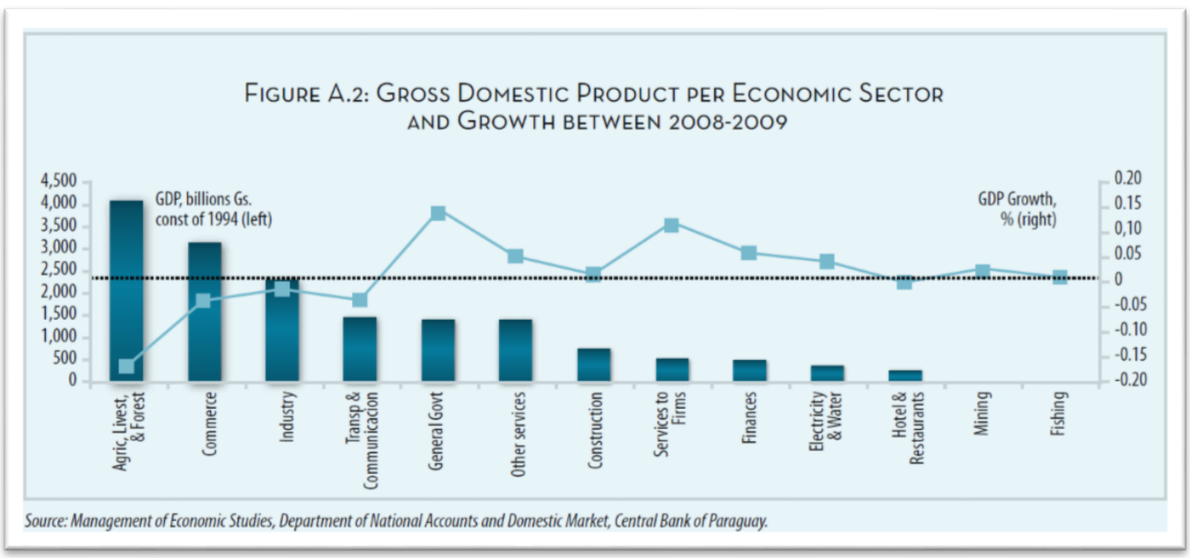


Figure 1: Gross Domestic Product per Economic Sector and Growth between 2008-2009

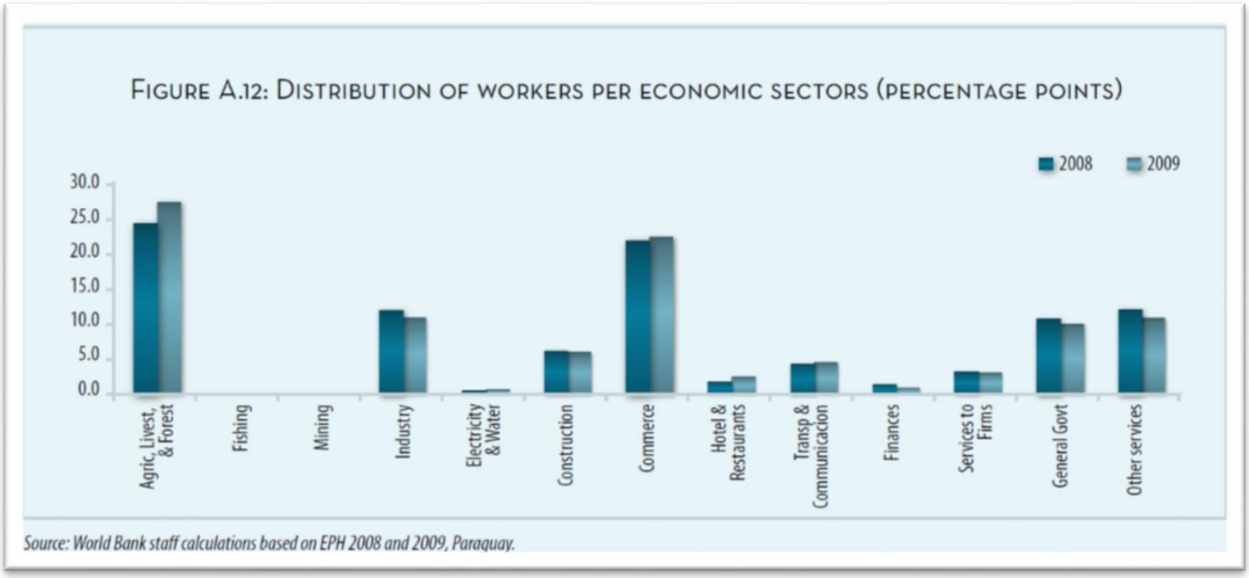


Figure 2: Distribution of Workers per Economic Sectors

In comparison to surrounding countries, Paraguay generally lacks in GDP per capita growth. Since 2003, there has been "six years of consecutive economic growth with an average of 4.6 percent" (World Bank, 2010). Despite trends in growth the GDP per capita gap between the Latin American and Caribbean (LAC) average and Paraguay has increased since 1990 up to 2003 (World Bank, 2010).

2.2 Paraguay's Agricultural Economy

Paraguay has the most agriculturally dependent economy in South America. The economy is highly dependent on agricultural exports (e.g. soybeans, cotton, feed, edible oils) and natural resources. The agricultural sector influences the performance of virtually every other sector. The country also exports a significant amount of electrical energy produced through hydroelectric dams. More than 60 percent of all Paraguayan exports in 2015 consisted of electric energy from the hydroelectric bi-national dams Itaipu and Yacyreta, along with agriculture and livestock production (World Bank, 2016). When an economy is linked to the agricultural sector, it is subject to external price fluctuations and local weather conditions (See figure 3 below). Both have a direct impact on the value of Paraguayan exports. An example is when Paraguay's relative position in Latin America deteriorated in 2009. During this time, Paraguay experienced one of the worst supply contractions in agricultural output in the region. Paraguay’s central bank estimated that the drought early in the year of 2009 shrank the GDP by 3.8 percent (World Bank, 2010). Therefore, it is evident that when the agriculture sector is hit hard, the rural population gets hit harder.

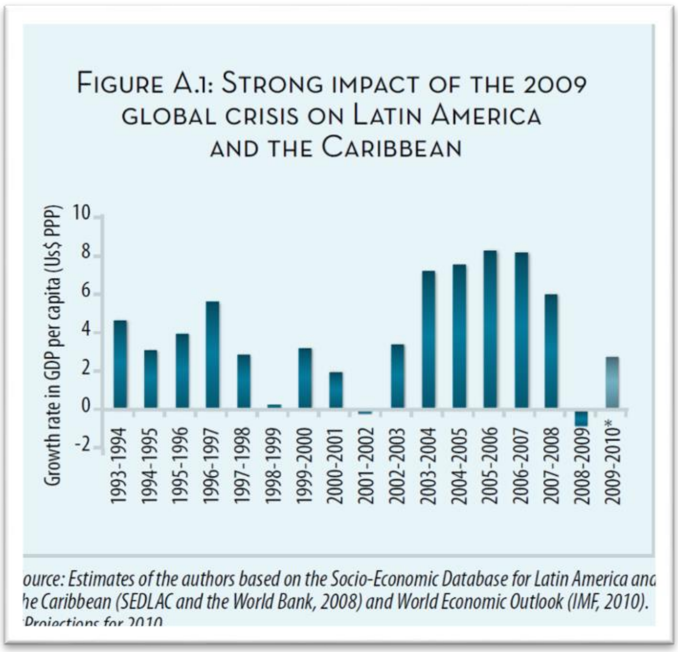


Figure 3: Strong Impact of the 2009 Global Crisis on Latin America and the Caribbean

A study from the World Bank states that the external shock on the agricultural sector underscored the need to enhance this sector’s productivity. This apparent vulnerability also prevented a sound investment climate, or strengthening the human capital of the rural poor. As a result, the poor cannot diversify their sources of income and expand their employment options to be able to face the external shock (World Bank, 2010). In summary, the rural sector needs to develop different skills and business practices to be able to face a fluctuation in the agricultural economy. Fundación Paraguaya is an organization devoted to helping people in rural communities affected by these fluctuations. By teaching skills to help people develop, Fundación Paraguay helps people rise from poverty.

2.3 Fundación Paraguaya

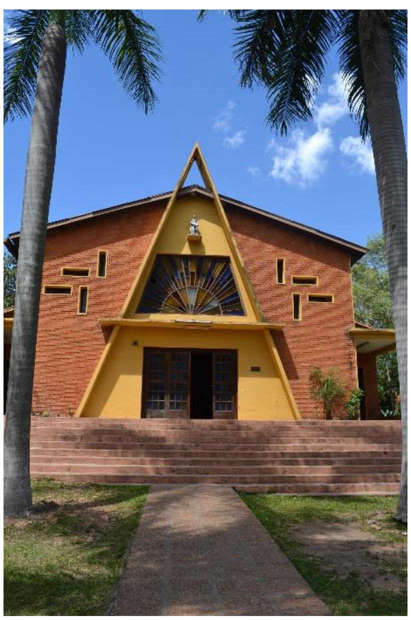
Established in 1985, the Fundación Paraguaya has "spearheaded microfinance entrepreneurship in Paraguay" (fundacionparaguaya.org). The foundation's goal is to develop and implement practical, innovative, and sustainable solutions to eliminate poverty. Fundación Paraguaya completes this objective by using four interrelated strategies:

1. A microcredit program that serves more than 86,000 small and emerging micro-entrepreneurs.
2. A program of entrepreneurial and financial education for children and youth.
3. A program of financially self-sustainable farming high schools that train the sons and daughters of poor farmers to become their own "rural entrepreneurs".
4. Teach-A-Man-To-Fish, a separate NGO established in London that helps spread the foundation's financially self-sufficient school model around the world.

Fundación Paraguaya recognizes that many rural families cannot afford to pay for a good education. Thus, they are unable to learn new skills and knowledge necessary to overcome poverty. Fundación Paraguaya uses an innovative education model paired with self-sustainable business units to train the rural population to become rural entrepreneurs. This model utilizes a "learn by doing, selling, and earning" application. The curriculum is based on theory classes that are complemented by hands-on practice in the field. A specific school, within the third strategy listed above, is La Escuela Agrícola San Francisco (San Francisco Agricultural School) located in Cerrito.

2.4 Escuela Agrícola San Francisco

Built on 153 acres, Escuela Agrícola has over 75,000-ft of facilities. The facilities include classrooms, a library, a computer lab, a dining hall, boy's and girl's dormitories, and other installations. Students learn from different productive units, ranging from agricultural to hospitality based tasks. An example is the cheese factory where students produce cheese, and then sell the products at markets. Students at the school are from all eight departments of Paraguay, as well as Argentina, Bolivia, Haiti, and Ecuador. Most students come from low-income rural backgrounds. Students graduate with two diplomas: a high school diploma as an agriculture/livestock technician, and as a hotel or tourism technician (fundacionparaguaya.org).



Escuela Agrícola has four main goals. The first goal is to provide its students with technical knowledge, practical skills, and business acumen. The second goal is to always use environmentally sustainable practices. The third goal is to promote rural entrepreneurship. The fourth goal is to establish a new model for agriculture, capable of widespread application (fundacionparaguaya.org). With these goals, the school aligns itself with the goals of Fundación Paraguaya to develop and implement practical, innovative, and sustainable solutions to eliminate poverty.

The marketable skills students can study include:

- Poultry and livestock: properly caring for cows, pigs, goats, chickens, and ducks
- Bulk crop: maintaining sweet potatoes, eucalyptus trees, etc.

- Horticulture crops: growing vegetables, herbs, and fruits
- Beekeeping and organic pest control

  (fundacionparaguaya.org)

In addition to technical skills, students learn the value of responsibility, honesty, nature and appreciation for the Guaraní culture.

100 percent of the students that seek jobs are employed (fundacionparaguaya.org). Graduates work in the agriculture-livestock sector, continuing their studies, or have set up their own microenterprise. 2011 marked the fifth consecutive year the school has been 100 percent financially self-sufficient, covering its entire budget (fundacionparaguaya.org). Students pay tuition through selling the products they create at the school and working at the facilities. For example, a student can learn to cook in the kitchen, or learn hospitality by working in a nearby hotel. The students can use these skill sets and work experience to market themselves to future employers.

Environmentally friendly practices are one of the main focuses of the school (fundacionparaguaya.org). The school must develop ways to be sustainable while maintaining a productive environment for school and work. Self-sufficient practices include lowering energy costs, such as the use of a biodigester. Income based practices bring in revenue for the school, such as the implementation of a new bakery microbusiness.

2.5 Biodigester

2.5.1 What is a Biodigester?

The biodigester is a practical and beneficial option for farmers, even those with small-scale production. Over 60 percent of farmers in Paraguay are small-scale farmers living in rural areas

(Finnis, 2012). The advantage of a biodigester is it can be installed virtually anywhere. It is a low-cost option for an efficient energy source. The horizontal-balloon style biodigester is a relatively simple, low-cost device that converts organic waste (raw manure) into fertilizer and biogas via the process of anaerobic fermentation by bacteria (Todd, 2015). A mixture of raw manure and water is placed into the biodigester bag, and the fermentation process releases biogas. The composition of biogas may vary depending on numerous factors. The type of organic waste used and the conditions in the biodigester both affect the final product. Methane, carbon dioxide, and hydrogen are the common components of biogas. Methane is the most valuable component because of its flammability. The higher the methane content in a sample of biogas, the higher its fuel value (Fry, 2013). Maximizing methane production is key to the biodigesters efficiency. After digestion, the effluent of the biodigester is a nitrogen and phosphorous rich slurry. One use of this effluent is fertilizing crops. Another use is enriching compost.

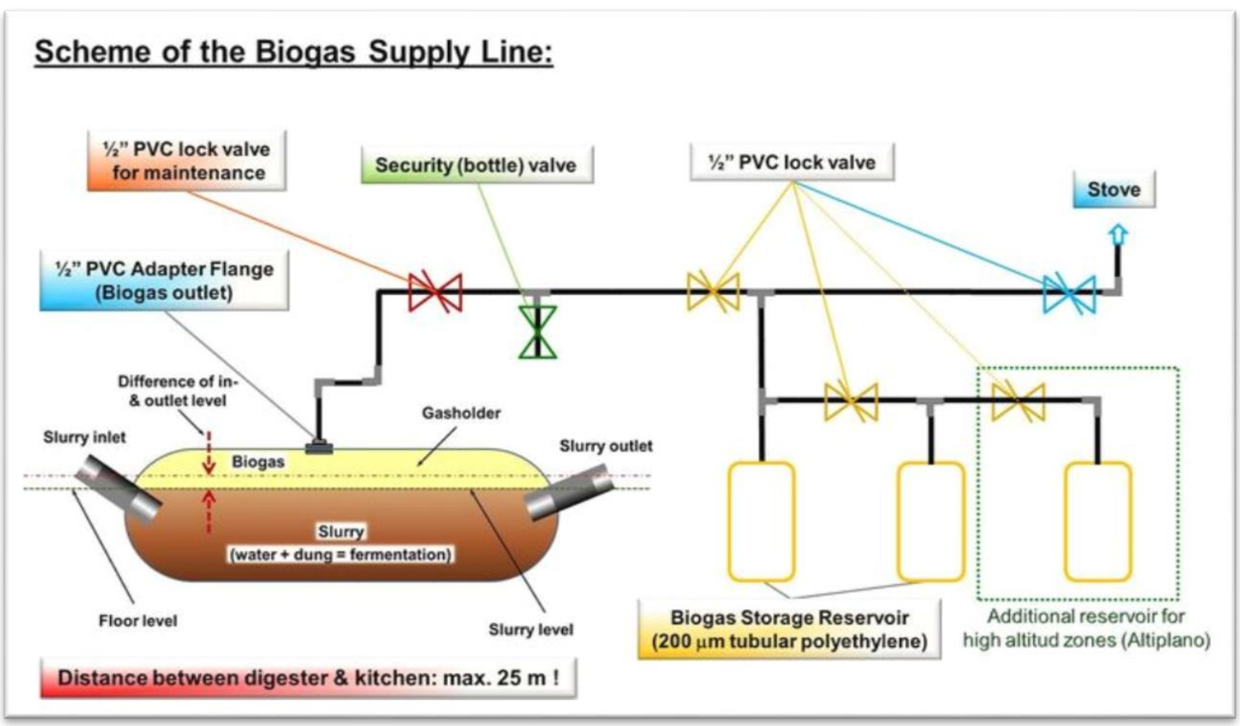


Figure 4: Scheme of the Biogas Supply Line

The basic components of the biodigester are a polyethylene plastic bag, gas valves, and gas tubes. The bag is usually placed in a rigid, typically earthen or concrete, casing for protection. This allows for the bags to inflate above the casing while keeping pressure on the sides. The biodigester must be loaded regularly with fresh raw material to ensure gas production. When biogas is being produced, the bag inflates, and the gas is released via the valves (Aguilar, 2006).

2.5.2 Escuela Agrícola San Francisco Biodigesters

There were two previous biodigesters at La Escuela Agrícola. Neither was inflated nor producing methane gas. One problem was the improper size of the bags. The bags had a diameter too large for the casing. When the bags inflated, they rolled over the sides of the casing and partially compressed one another. Another bag related issue was the lack of proper drainage. Rainwater pooled on top of the bag, making it difficult to inflate. Additionally, the biodigester was not loaded properly. The manure was washed directly into the bags without controlling the manure-water ratio. This incorrect mixture compromised the optimal production of methane.

Figure 5: Old Biodigester System

2.6 The Bakery

2.6.1 The Bakery as a Business

La Escuela Agrícola runs business units that help maintain its self-sufficient status. Starting new branches of business generate more revenue for the school. The school is constructing a new building for the kitchen and dining facilities. Following the self-sustainable business model, the bakery has the potential to evolve into a bigger "microenterprise" and generate more revenue. A feasibility plan determines whether a business will make financial sense.

2.6.2 The Cheese Factory Buisness

The school has a business on campus that has the potential to align with the bakery. It is a cheese factory. The cheesemeister, Señor Ricardo Negrete, oversees all operations including production and sales.

The Señor Ricardo Negrete cheese factory business outline:

1. Executive Summary
2. Product Description and Distinctive Summary
3. Market
4. Business Model and Financial Plan
5. Sales and Marketing Plan
6. Expansion

    (Plan de Negocios Planta Lactea, 2017)

The Executive Summary section describes the cheese factory and its role in the school. Product Description and Distinctive Summary contain further detail about the school and specifics about the cheese. The Market section contains information about the quantity of products and the customers. It also contains an analysis of competitors and a comparison of prices. The Business Model and Financial Plan describes the educational model of the school and the break-even point. The break-even point is key to a profitable business. The financial plan includes previous sales and projected sales. The Sales and Marketing Plan provides future propositions for keeping, expanding, and satisfying the current market. Finally, the Expansion section provides a list of necessary equipment and gives the cost of expansion. A business plan like this clarifies objectives for successful operation.

3 Methodology

The methodology section covers the general approach to solve the problems with the biodigester system and the strategies for analyzing the feasibility of starting a bakery at the school.

3.1 Biodigester

3.1.1 Analysis

The first step to assess an existing problem is observation. The issues of a non-functioning biodigester can be found out via an inflation test and additional observation. To perform an inflation test, the biodigester is filled with water, and exhaust is bubbled into the bag below the water level. The purpose of this test is to determine if the system can hold gas without leakage. If the biodigester fails this test, the underlying causes should be investigated.

3.1.2 Interview and Design

The team met and interviewed Fernando González on April 5th (see Appendix C). Fernando González is one of the few experts on biodigesters in Paraguay. He has been teaching biodigester construction and operation for over ten years. During the meeting, Fernando González showed the team an operational, small-scale biodigester. Additionally, he explained several key considerations for a good biodigester.

To design a biodigester, the first step is site analysis. A good biodigester site is close to its source of manure, within 100 meters of where the gas will be used, in a sunny area free of trees and other sources of falling debris, and away from easily-flooded areas. It is easiest to design a biodigester when the bag size, especially the diameter, is known. The pit depth can be set at 60 percent of the bag diameter. Inlet/outlet pipes of appropriate size can be selected from manufactured products according to the pit depth. A good inlet/outlet pipe has a large enough inside diameter to allow for trouble-free operation, but not too large to let gas escape. The length of the pipes should be determined by the amount of gas needed, as well as the amount of manure produced. This length is limited by the size of the site. Using the information about pit depth, pipe diameter, and length, the inlet and outlet heights and angles can be set. A slight slope from inlet to outlet may be incorporated if the water level is preserved to trap the gas (Fernando González, personal communication, April 5, 2017).

3.1.3 Installation

In general, the first step to construct the biodigester is to dig the pit for the bag. The next step is to line the pit to prevent erosion and protect the bag from sharp roots and rocks. After the pit is prepared, the inlet and outlet pipes should be set in place at the proper heights and angles. Next, the bag is assembled by layering two polyethylene sleeves and installing a gas tap. The bag can be then set into the pit, and secured around the outside of the pipe openings. Inflating the bag with car exhaust smooths out the wrinkles. Then, filling water to the proper height traps the gas. Additional exhaust can be bubbled into the bag below the water level to test the system. This also test the inlet/outlet heights to ensure proper functionality.

3.1.4 Bakery

The team first attempted to create a business plan for the bakery with the assumption that the school wanted one. Such a plan will indicate the best location, the necessary equipment, and products to sell. On March 16th, the team met with Luis Cateura. Luis Cateura changed the direction of project by revealing that the school was still deciding whether or not to undertake a bakery business. Therefore, instead of “how do we do it?” the driving question became “should we do it?” To answer this question, the team undertook a feasibility plan.

3.1.5 Feasibility Plan

A feasibility plan is an analysis to determine if a business is worth pursuing. The plan determines whether a proposed business will be profitable. The new outline came from a book written by Martin Burt, one of Fundación Paraguaya’s founders. The team decided to use this style of feasibility plan because it works well with organizations like the foundation. A feasibility plan usually contains the following six sections:

- Introduction
- Market Information

- Scale Assumptions
- Start-up Costs
- Pro Forma Financials
- Feasibility Discussion (Burt, 2011)

The team realized that there was insufficient time to complete the full study. Market research is important to understand market demand. The research requires an analysis of customer behavior and market trends. The team fulfilled the feasibility plan as best as they could to tell the school whether to go ahead with a full study.

3.1.6 Interviews

There is a successful cheese factory on campus. Ricardo Negrete, a professional artisan cheese maker, oversees this factory. The team set up an interview with Negrete on April 24th. He provided advice on how to find the market, the type of products, pricing, and general recommendations. He recommended targeting high-end markets in Asunción. Ricardo Negrete explained small productive units could not compete with bigger business in making cheap bread. The bakery would focus on making artisanal, high-quality bread to sell at a higher price.

The next interview was on April 25th with the head of the kitchen, Rosa Paez (see Appendix D). She provided information about the day to day routine inside the kitchen. Twenty-one loaves of bread are made in each morning and evening. She also estimated the daily consumption of ingredients. In addition, the team asked her opinion of the feasibility of implementing a commercial bakery.

3.1.7 Calculations

To see if a bakery would be profitable, three different production levels were calculated. To make an estimate, the fixed cost, marginal cost, and capital investment needed to be calculated. To calculate fixed cost, it was necessary to find the amount of money required to operate all the equipment. This information came from taking the time it takes to bake and the energy costs associated with baking. Next, to calculate marginal costs, it was essential to learn the price and quantity of each ingredient. Last year's IQP group audited the kitchen (Gonzalez *et al*., 2016). The prices of each ingredient were taken from the audit. Lastly, capital investment was calculated. To calculate capital investment, the prices of the equipment needed for a commercial bakery were summed together. The budget list that contains the prices for all the equipment came from the director of the school. To get three distinct levels of production, the team incremented the different levels by creating three different production scenarios.

4 Results and Discussion

This section gives a detailed description of the conclusive results of the biodigester and bakery project. The product of the biodigester project is a new design and a new, fully installed biodigester. The product of the bakery project is a preliminary feasibility study.

4.1 Biodigester

This subsection reviews the design and final setup of the biodigester. The old biodigester failed due to excessive size of the bag and holes in the bag surface. The team observed other problems such as lack of drainage and poor operation. On March 15th, the team discussed these problems with the school's director Luis Cateura and the school's facility manager Virgilio Borges. The participants determined that the old system was unsalvageable, and a new system was needed. The rationale for the new design is included in the discussion section

4.1.1 Design

The design of the new biodigester system incorporated online information, suggestions from experts, and solutions for the problems that appeared in the old biodigester. The team decided on a cell-style design with multiple biodigesters. Each unit is independent from the others. With respect to available space, three large units and two small units can be installed (see below).

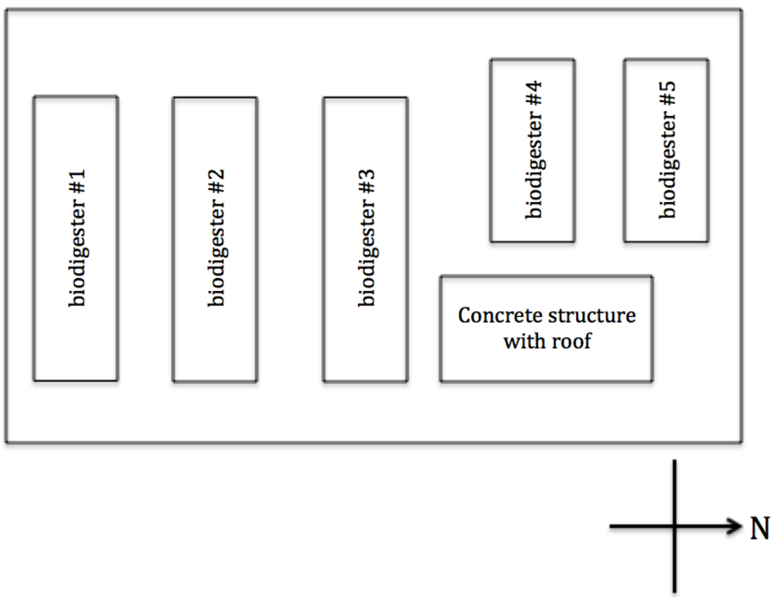


Figure 6: Map of New Area for Biodigester System

The basic setup of the new biodigester is a long, cylindrical plastic bag placed in a pit of the same length, with both ends secured to the inlet and outlet pipes. For the design details, the bottom of the pit should have a slight decline from the inlet to the outlet to aid the flow of slurry. The sidewalls are rounded to form a trough shape that cradles and thus stabilizes the bag. The base should be lined with protective material to prevent rocks from damaging the bag. The inlet and outlet pipe diameter is about 2.5 ft. According to Virgilio Borges, the optimum slurry height (water level) should be 60 percent of the bag's diameter. The design also includes a protective netting above the biodigesters to keep direct sunlight, fallen leaves, and debris off the bag. The fence around the site needed to be fixed to keep animals out.

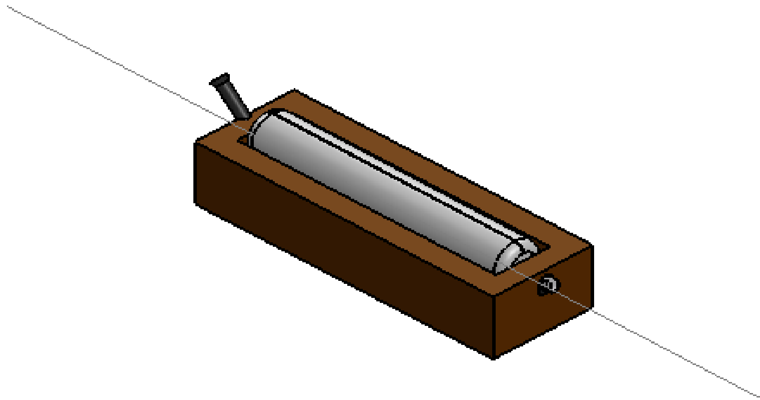


Figure 7: Three-Dimensional Model of Biodigester

4.1.2 Construction Process and the New Biodigester

The new biodigester follows the design described above, with a few slight changes. The general procedures were excavation, setting the sunshade, and installing the main components of the biodigester. First, the team removed the vegetation at the site, and dug a pit of about forty feet in length, six feet in width, and three feet in depth. Before installing any components of the biodigester, the sunshade was set up. The sunshade is the same netting used in the vegetable fields to reduce direct sunlight on the crops. Then, the bottom of the pit was lined with the plastic from the old biodigester bags. To allow better drainage, openings were cut out in the lining. Finally, the inlet and outlet were placed at each end of the pit, and the bag was installed. The inlet and outlet are made of cement, and were set at an angle (see Appendix E). The bag was double-sleeved, and was secured to the inlet/outlet with wire. An image of the final installed biodigester is shown below:

Figure 8: Horizontal View of New Biodigester

Figure 9: Lengthwise View of New Biodigester

The team has a plan for building more biodigester units at the site. One other full-length pit was dug, but nothing has been installed. The plans for completing this biodigester system can be found in the Recommendation.

4.1.3 Discussion

In order to ensure the functionality of the new biodigesters, the new design has to address all the problems associated with the former biodigesters. Also, the team had to consider the available resources for a functional product. The goal was to build a biodigester that is easy to maintain at minimal cost.

Switching to the "cell-style" adds a level of redundancy. If one of the biodigesters fails, the other units are not affected. The old system had a shared source of slurry that flowed freely into the inlets. However, the slurry fed unevenly into the two bags due to the slope at the two inlets (see below). For the new design, each bag is loaded individually. This form of loading avoids the uneven distribution of waste material.

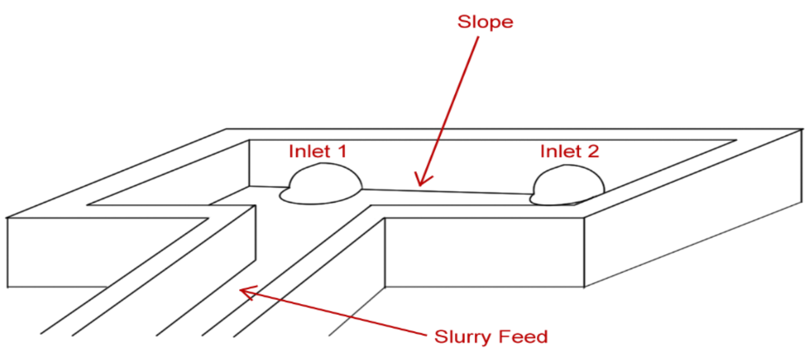


Figure 10: Diagram of Old Biodigester Inlets

The old biodigester bags were too large in diameter for the pit. When the bags inflated, the top of the bags rose about 1.5 m above the edge of the pit. The extra height above the pit caused the bags to tilt and overlap. Purchasing slightly smaller bags (six feet in diameter) and designing the pit according to the size of the bag solved the problem of overlapping and collapsing. In addition, wider inlet and outlet pipes (about 70 cm in diameter) were suggested by Virgilio Borges for easier loading and maintenance.

After speaking with the biodigester expert Fernando González, the team decided that the bag did not have to be shielded from rainwater once the bag is fully inflated. Therefore, the netting was used for the roof material instead of solid plastic sheets. This was the cheapest and most available option for protecting the biodigesters from fallen debris.

The initial design for the arrangement of biodigesters at the site features six small units (see below). When marking the biodigester boundaries and visualizing the orientation for Biodigester 1, there was insufficient room for Biodigester 2. The team decided on a 14-ft. increase in length instead of building Biodigester 2. The redesign has a 40-ft. bag, and leaves about 10 ft. space at each end, including occupied area of inlet/outlet pipes. The extra space ensures easy passage for maintenance personnel.

4.2 Bakery

The team determined two levels of capital improvement to compare to the current situation. The team used PYG (Paraguayan Guarani) for the calculations. Level 1 purchased a new hot plate, mixer, a bread oven, and 10 flat trays for PYG 29,058,720. Level 2 purchased a new hot plate, wrapping machine, yeast riser, bread rack, table, and 10 flat trays for PYG 21,493,700 in addition to Level 1 for a total investment of PYG 50,552,420 (slightly over $9000). The team assumed that the bread for school consumption was sold at cost. Using the production information from Rosa Paez and the previous kitchen audit, the sale price of a single loaf was determined to be PYG 5,400. Energy and labor costs were extrapolated from data sent from the school director, Luis Cateura. The current daily operation cost was PYG 83,000 for an 8-hour day. Level 1 daily operation cost was determined to be PYG 91,190 and level 2 was PYG 130,740, both for an 8-hour day.

4.2.1 Analysis

The first analysis compared the various levels of capital investment to find the time if investment recovery. This analysis assumed no external bread sales and only production of bread for the school's consumption. Level 1 broke even in slightly more than three years. Level 2 broke even in four and a quarter years (See figure below). Also see appendix F for the full calculations.

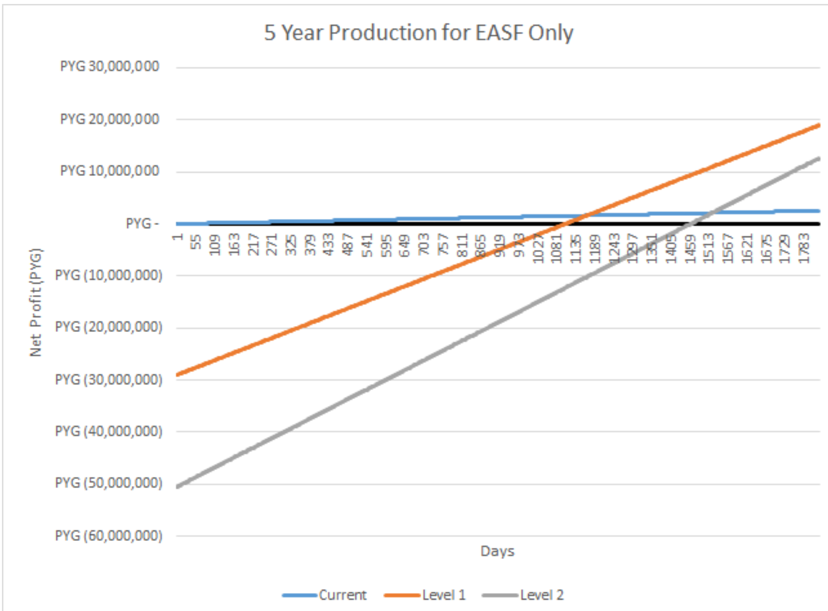


Figure 11: Five Year Production for EASF Only

Although levels 1 and 2 initially started with a large capital investment, they caught up relatively quickly due to the much lower time required to produce 42 loaves of bread. The large capital investment is paid off by energy and labor savings. An additional benefit is the investment will give the school the capability to produce additional bread to sell.

4.2.2 Market

The most feasible way to determine the interest of high-end clientele is to bring free bread samples to restaurants with the cheesemeister's deliveries. The cheesemeister can leave a business card with contact information so the restaurants can order bread if they like it and agree with the price. For this to succeed, the bread must be of the highest quality, the bread must be packaged and presented in an aesthetically pleasing manner, and the bread must be marketed so the consumer associates its name with quality. If there is sufficient market demand, the bakery will be a profitable production unit. The chart below shows the net profitability of attainable potential production scenarios over the first year. See appendix F for the full calculations.

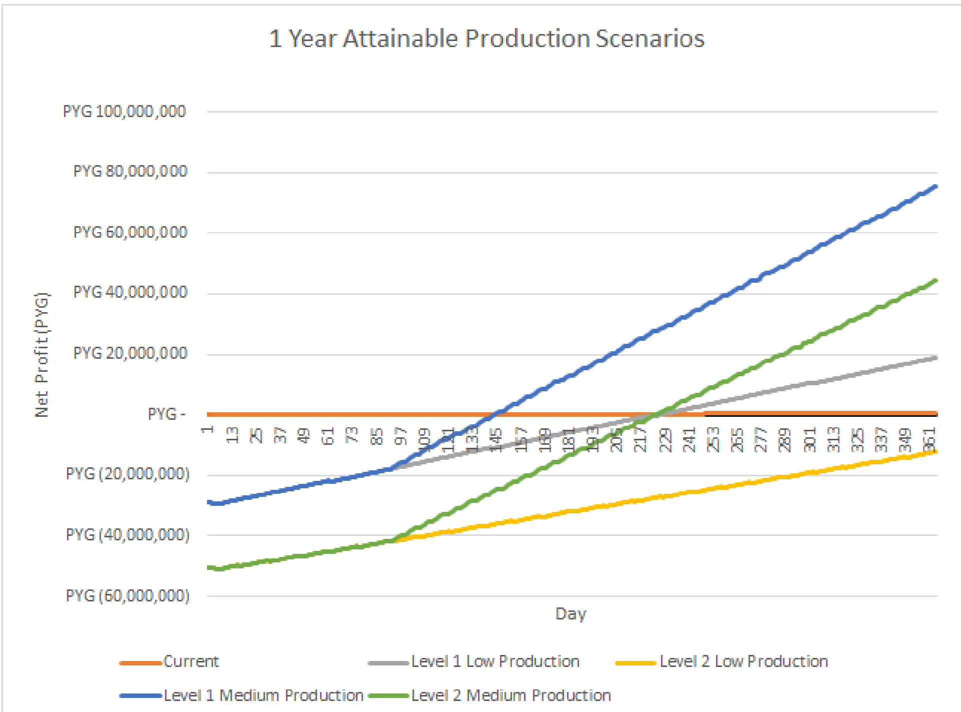


Figure 12: One Year Attainable Production Scenarios

It is important to note that transportation costs are not included. This model assumes artisanal bread is delivered with cheese twice a week. If there is an elevated level of demand (as opposed to the low level shown), transportation and other logistical costs (labor, packaging, etc.) must be considered. With these scenarios in mind, it is of the highest importance to understand the market demand. A full feasibility study is required.

4.2.3 Discussion

Due to time constraints and working on two projects, the team did have the time to complete an in-depth market analysis. Interviews with the Señor Ricardo Negrete provided us with the information on how to go about the market research. The team created the first steps of a feasibility plan and believes that a bakery business can be profitable.

5 Conclusions and Recommendations

For the best long-term effect of the projects, the team has come up with several suggestions. This section contains the proper maintenance details (see Appendix A) and plans on expansion (see Appendix B) for the biodigester. It also contains guidelines for future market research for the bakery.

5.1 Biodigester

In conclusion, a new biodigester has been installed. The new biodigester system requires proper maintenance. To get the system up and running, the team recommends following the maintenance guide (Appendix A). The next step is to add the slurry mix at the correct ratio for the fermentation process to begin. The ratio of organic waste to water should be 1:4 by volume. The bags should be loaded every other day. The content inside the biodigester should be agitated daily to keep the fermentation process constant.

5.1.1 Expansion

Currently, only one biodigester has been installed. In the future, there is room for expansion. The team recommends adding more biodigester units in the same field. In addition, a slurry-feed system located at the outlet still needs to be designed. The effluent can be used as fertilizer on the farms.

Considering the conditions of site for the biodigesters, the northwest corner of the field can have two potential future uses: more biodigester units, or a compost area (see Appendix B). The space is big enough for two shorter biodigesters of around 25 feet in length. Alternatively, compost with a water-heating system can be built.

5.2 Bakery

Based on preliminary research and calculation, the bakery is a promising business venture. The team highly recommends completing a full feasibility study with a heavy emphasis on market demand and potential clientele. A thorough feasibility study can be incorporated into a business plan.

From the results, the team recommends the level 1 capital investment of a new hot plate, mixer, bread oven, and 10 flat trays. This recommendation is supported by the net profit calculations. These calculations show that this investment will save enough time and energy to pay for itself in three years.

6 Bibliography

- Aguilar, F. X. (2006). How to install A polyethylene biogas plant. Retrieved from http://colabradio.mit.edu/wp-content/uploads/2012/03/BiodigesterManual1.pdf
- Burt, M. (2011). Defining the Social Impact Model - Part 2. *Business Plants for Social Entrepreneurial Organizations*.
- Feasibility Study. (2015). Retrieved from http://www.investopedia.com/terms/f/feasability-study.asp
- Finnis, E., Benítez, C., Estela Fatima Candia Romero, & Maria José Aparicio Meza. (2012). Changes to agricultural decision making and food procurement strategies in rural paraguay. *Latin American Research Review, 47*(2), 180-190. Retrieved from http://wpi.summon.serialssolutions.com/#!/search?bookMark=ePnHCXMw42LgTQStzc4rAe_hSmECnVdqYqQLutKBBbzcwhiYAy0NOeDrMCyMzTgZIp09HP3cXYMVQvwVHN2DPJ1DfUJCgxx9FFxcnT1BxYqCryOwP-uu4OjnouDm7--iEBDk7xwaBD7yXgF0v3CIqzuwAaXg6acQBNYY4Bjk6B7qGMnNoOzmGuLsoQsrauOhsVQcD7rzAdhBMDIB3ZpOjCoAd708Cw
- Fry, L. J. (2013). *Methane digesters for fuel gas and fertilizer*. Retrieved from http://journeytoforever.org/biofuel_library/MethaneDigesters/MD3.html
- Fundación Paraguaya. (n.d.). *About Us.* Retrieved from http://www.fundacionparaguaya.org.py/?page_id=77
- Gonzalez, Christian, Thiago Tose, Tiana Vasquez, and Sonia Zarate. (2016). 2016 Kitchen Inventory of Escuela Agrícola San Francisco.
- San Francisco Agricultural School Technics Team. (2017). *Plan de Negocios Plantea Lactea*.
- Todd, J., & The Borgen Project. (2015). *Biodigesters: Sustainable fuel from manure* ACI Information Group. Retrieved from http://wpi.aci.info/view/1498226ef7614770388/14cd71c00110001null
- World Bank. (2016). *Paraguay Overview*. Retrieved from http://www.worldbank.org/en/country/paraguay/overview
- World Bank, & Open Knowledge Repository. (2010). *Paraguay poverty assessment: Determinants and challenges for poverty reduction.* Washington, DC. Retrieved from http://documents.worldbank.org/curated/en/292191468057267811/Paraguay-Poverty-assessment-determinants-and-challenges-for-poverty-reduction

Appendix A – Biodigester User Manual

This manual is for the school's use to operate and troubleshoot problems with their new biodigester.

Cronograma de operación:

Este cronograma es un ciclo de dos días. El trabajo de cada día incluye cargar el biodigestor, preparar un nuevo lote de estiércol líquido, agitar el biodigestor, y sacar el efluente. El cronograma de nueva operación y el cronograma de operación en marcha están debajo.

Operación nueva (los primeros dos días antes de la operación en marcha):

Día -1: Llene el barril n°1 con estiércol líquido. La proporción es de 1 parte de estiércol a 4 partes de agua por volumen.

Día 0: Llene el barril n°2 con estiércol líquido. La proporción es de 1 parte de estiércol a 4 partes de agua por volumen. Desenrosque el tubo largo de la válvula de liberación de presión. Coloque el estropajo en la sección t y reemplace la tubería. Ajuste la altura del agua de la botella a 10 cm desde la parte inferior de la tubería.

Operación en Marcha

Día 1: Coloque un barril más grande para recoger el efluente. Cargue el biodigestor con los contentos de barril n°1. Vierta el estiércol líquido en la entrada del biodigestor. Llene el barril n°1 con estiércol líquido. La proporción es de 1 parte de estiércol a 4 partes de agua por volumen. Agite el biodigestor n°1 de ambos extremos con el agitador. Saque el efluente.

Día 2: Coloque un barril más grande para recoger el efluente. Cargue el biodigestor con los contentos de barril n°2. Vierta el estiércol líquido en la entrada del biodigestor. Llene el barril n°2 con estiércol líquido. La proporción es de 1 parte de estiércol a 4 partes de agua por volumen. Agite el biodigestores de ambos extremos con el agitador. Saque el efluente.

Repite la operación de días 1 y 2 por al menos cinco días una semana (Aunque siete días a la semana sería ideal). Es necesario para mantener el nivel de agua de la botella (10 cm desde la parte inferior de la tubería) una vez de semana o después de mucha lluvia o calor. Es importante para limpiar la bolsa para remover partículas que pueden dañarla. También es importante limpiar polvo de la entrada y salida para prevenir daño interno. Adicionalmente, es necesario cambiar el estropajo cada tres meses.

Problemas posibles y las soluciones

La bolsa está desinflada

1. ¿Hay suficiente líquido en la bolsa de modo que el nivel de líquido esté por encima de la entrada y la salida?
    a. Si la respuesta es "no", añada agua al mencionado nivel e infle con escape de camión.
2. ¿Hay una fuga en la bolsa o los tubos?
    a. Si la fuga es en los tubos, reemplace la conexión o el componente afectado. Si la fuga es pequeño o cerca de la salida de gas, la fuga podría ser posible repararlo con plástico y adhesivo de goma.
3. ¿Usa todo el biogás?
    a. Tenga paciencia; la reacción de biodigestor va a producir más biogás pero este proceso requiere tiempo.
1. ¿Hay agua en la botella de alivio de presión?
    a. Si no hay un nivel suficiente de agua, la presión no se mantendrá y es necesario añadir agua.

El gas no es inflamable

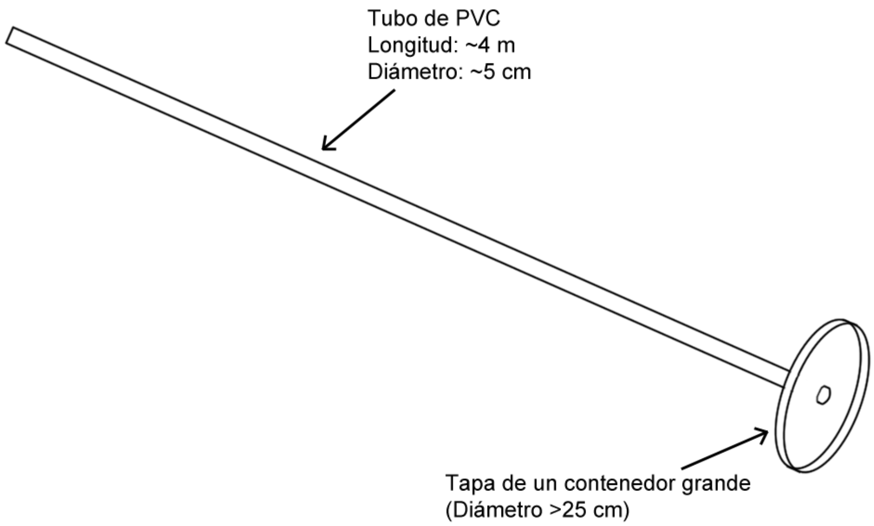
¿Cuánto tiempo pasó desde el inicio de día 1 o la inflación más reciente con escape?

Si hace menos que un mes, no se preocupe, el contento de metano no está suficiente para quemar. Si hace más que un mes, sacar mucha del gas y resuma operación. Pruebe el gas cuando la bolsa está inflada.

El Agitador

Materiales:

- 4m de 2" diametro tubo de PVC
- (1) Tapa de cubo grande
- (2) 2" Tapas de PVC
- (1) 2" Unión de PVC sin rosca
- Cemento de PVC



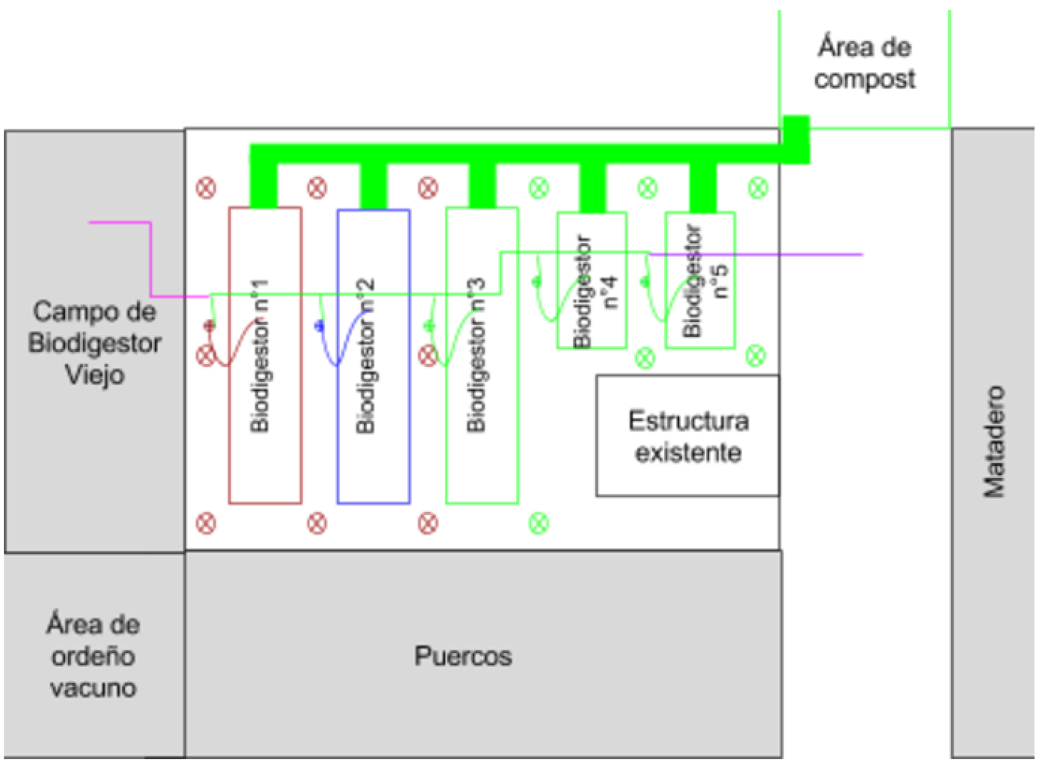
Es necesario solder todas conecciones con el cemento de PVC para prevenir que el agua entre en el agitador. La 2” unión y una 2” tapa aseguran la tapa a la extrema del 2” tubo. Es necesario que el agitador no tenga áreas agudas o rugosas.

Appendix B – Expansion Plan

These expansion plans are for the school's use. These plans outline the recommended layout and describe the function and installation of the components.

Ahora, el sistema del biodigestor tiene solamente una bolsa y el techo de media sombra. El plan debajo tiene nuestra recomendación del uso futuro del campo.

- Negro: estructuras existentes.
- Marrón: estructuras instaladas.
- Azul: estructuras incompleta.
- Verde: expansión en el futuro.
- Círculos con un "X": Los postes para el techo.
- Círculos con un "+": Los válvulas de presión.
- Línea morada: para usar el biogás crudo en la matadero.
- Línea rosada: para transbordar el biogás para ser filtrado y guardado con presión.
- Canal verde: para llevar la efluente a la área de compost.



Descripción de los componentes

Biodigestor:	Una bolsa para convertir estericol a biogás. El efluente se puede usado para fertilizar plantas.
Red de fontanería:	El propósito de esta red es para transbordar el biogás de todo sistema a lugares de combustión o un lugar de compresión y filtración. La red necesita válvulas de un dirección a cada válvula de presión de biodigestor para mantener la funcionamiento del sistema si se falla una bolsa.
Canales del efluente:	Canales empezando a la salida de cada biodigestor para llevar la efluente al área de compost. Es necesario que la efluente no escape de la canal.
Área de compost:	Una pila de residuos vegetales para descomposición. La efluente aumenta este proceso. Es posible que use la energía de esta reacción exotérmica para calentar agua. Una bobina de tubería flexible sin aislar puede funcionar como una intercambiador de calor. Es necesario que aísle la tubería que transborda el agua caliente.
Compresión y filtración:	Es necesario que condense y filtre el biogás si el lugar de uso es más que 100 m de la sistema. La compresión le permite el gas viajar distancias más largas y el filtracion aumenta el porcentaje de metano, el gas inflamable. Se usa el estropajo para filtrar el sulfur del biogás. Agua y cal se usan para filtrar el carbónico del biogás.

Construir e instalar los componentes

<u>Biodigestor</u>

Para construir el biodigestor, es necesario que sepa el tamaño de la bolsa. El pozo debe ser tan ancho como el diámetro de la bolsa, y tan profundo como el medio del diámetro de la bolsa. El longitud del pozo puede ser elegido del área del lugar de biodigestor. Después de excavar el pozo, es necesario que lo forre con plástico. Agujeros pequeños en el plástico permiten drenaje. Próximo, peude instalar los tubos de entrada y salida. El parte más bajo del extremo afuera de la salida debe estar encima de todos extremos de entrada y salida dentro para preservar la agua. El extremo de la entrada debe estar encima de la salida. Es necesario que use un nivel para determinar estas relaciones. Después de instalación de la entrada y la salida, se puede crear la bolsa del biodigestor. Para crear la bolsa, un manguito de polietileno se coloca dentro del otro. Se necesita crear un agujero pequeño para instalar el tubo de gas. Es importante que selle la conexión bien. Es imprescindible enderezar la bolsa antes de llevarla a través de los tubos de entrada y salida. Después, la bolsa está asegurada alrededor del exterior de los tubos con alambre de acero. Se necesita instalar la valvula de presion. Esta válvula es un “t” conexión de tubo con una válvula de bola en un lado y una tubería en el parte central. Otro lado es donde la manguera conecta la bolsa y la valvula de presion. La tubería está debajo de un nivel de agua en una botella. Este nivel debe ser 10 centímetros arriba del base de la tubería. Para inflar el sistema, es necesario cubrir la entrada y la salida y cerrar la válvula. Después, se usa un camión para inflar la bolsa con escape. Este proceso llena la bolsa y la cabe en el pozo. Cuando la bolsa está llena, es necesario que ponga el agua en la bolsa con una manguera. El agua va a salir de la salida cuando la bolsa está llena. Es necesario testar el sistema, especialmente, la bolsa y la válvula, con escape. Esta vez, burbujee el escape en la bolsa debajo del nivel del agua. Escape puede salir de la válvula de presión, pero no de la entrada, la salida, u otro lugar.

Red de fontaneria

Para instalar la red de fontanería, las válvulas de los sistemas son conectados a un tubo/una manguera principal. Es necesario que use válvulas de una misma dirección para asegurar que el biogás viaja solamente fuera de las bolsas.

Canales del efluente

Para hacer canales de efluente, es necesario cavar una zanja desde la salida del biodigestor hasta la área de compost. Esta zanja debe bajar suavemente de los biodigestores a la área de compost. Es posible que use plástico para alinear la zanja pero cemento es mas mejor. Los canales no les permite derramar efluentes.

Áreas de compost

Una área de compost es una pila de residuos vegetales. Para calentar agua con una área de compost, es necesario enrollar la tubería flexible a lo largo de la pila para que esté cubierta completamente. Un fuente de agua conecta a un extremo de la tubería y a un tubo aislado para llevar el agua caliente al otro extremo.

Compresión y filtración

Para condensar el biogás, no se puede usar una bomba por el riesgo de fuego. Es necesario usar agua para aumentar la presión. Es necesario tener un fuerte contenedor rígido y una pieza de acero en forma de campana. El biogás se introduce bajo el acero en forma de campana. Agua sella la campana y añade peso y presión. La campana de acero tiene una salida en parte superior para liberar el gas presurizado. Para filtrar el gas, es necesario instalar un estropajo en la valvula de presion para remover sulfur. Adicionalmente, después de la campana de acero, una solución de cal y agua puede tratar el gas con presión. El gas se burbujea a través de esta solución para filtrar el carbónico. El resultado es gas con presión y contento alto de metano (más que 95%).

Appendix C - Interview of Rosa Paez

Rosa Paez is the head chef at EASF. The interview was conducted on April 21, 2017

Finding the right market & customers:

- Go to high-end restaurants/hotels and hand out samples
- The first customers would recommend the product to more people
- Better market in Asunción than in the rural areas

Market research:

- Start with a smaller production scale
- Increase production as demand grows

Choice of products:

- Popular, cheap, easy-to-produce variety in large scale, large companies do this and a small productive unit cannot compete
- A small amount of high-quality specialty products for a higher price
- Branding/naming of products: e.g. Queso Ibérico, the name is not trademarked (no legal issues), but is associated with high quality.

Pricing:

- Cost of production with consideration in production scale (annual production)
- Base the price on the breakeven point of minimal production
- Increase production instead of price

Other recommendations:

- Product quality is the most important (need the quality to attract the first customers)
- Word-of-mouth advertising is crucial especially in the beginning
- Backup plan (for example, if cheese does not sell, it is aged and becomes more expensive, if it still does not sell, it can be shredded and sold)

Appendix D – Interview of Ricardo Negrete

Ricardo Negrete is the cheesemeister of EASF. The interview was conducted on April 19, 2017

Current products from the kitchen:

- Meat sauce (salsa de carne molida)
- Regular bread for school consumption
- Pan con queso (with queso Paraguay), cheese bread

Current production scale:

- Breakfast: 40 L cocido + 21 loaves of bread (~1-1.5 foot long each, 1 loaf = 6 servings)
- Lunch/dinner: 150 pieces of tortilla/torta
- Dinner: 21 loaves of bread
- Lunch and dinner menu varies for each day

Daily consumption of raw materials for baking:

- 30 kg wheat flour
- 150 g salt
- 600 mL cooking oil
- 30 g/pack * 15 packs of yeast

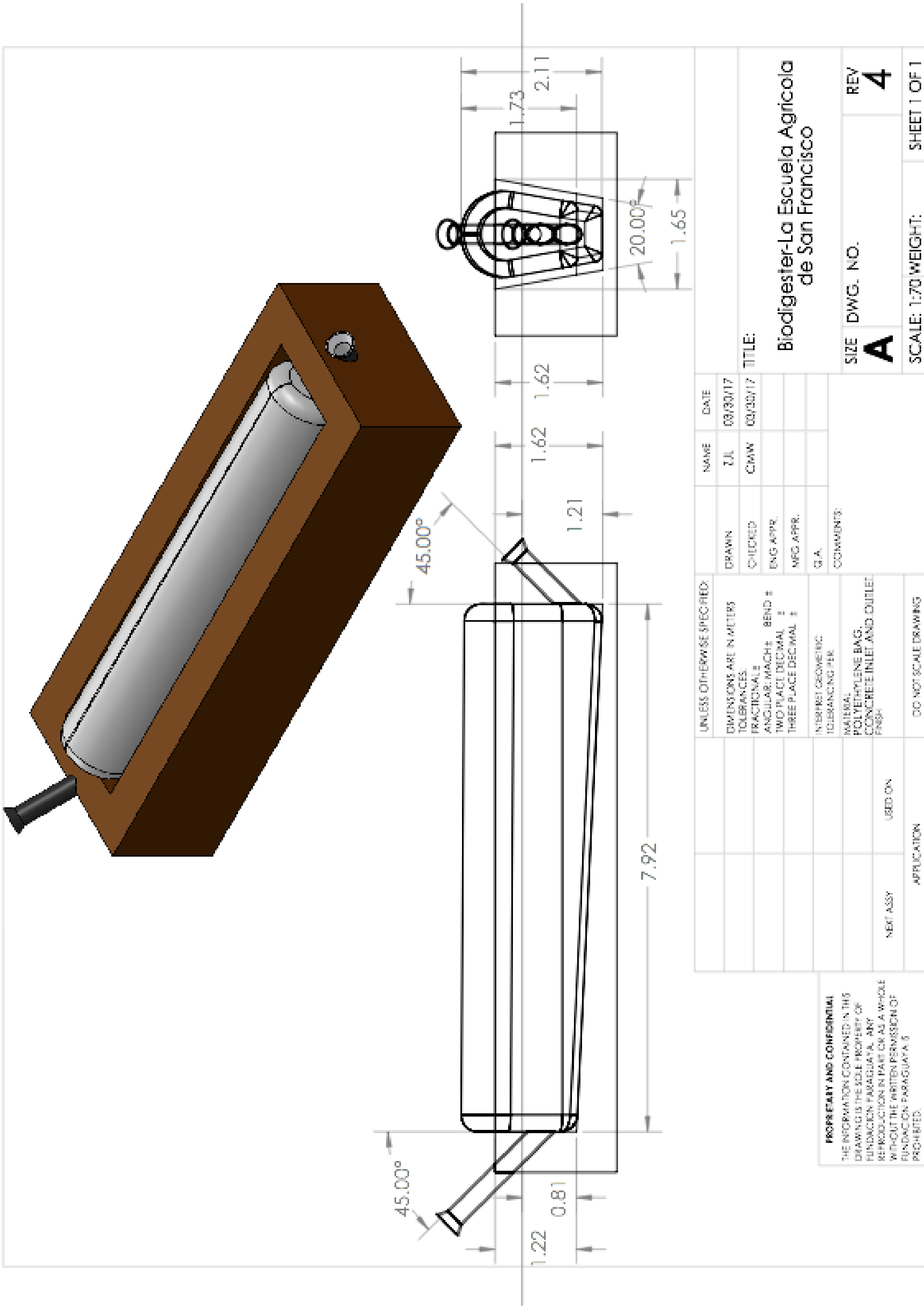
Other notes on specialty products:

- Rosa is willing to make various kinds of artisanal bread
- Pan con queso currently sells well at the hotel

Most important equipment to purchase:

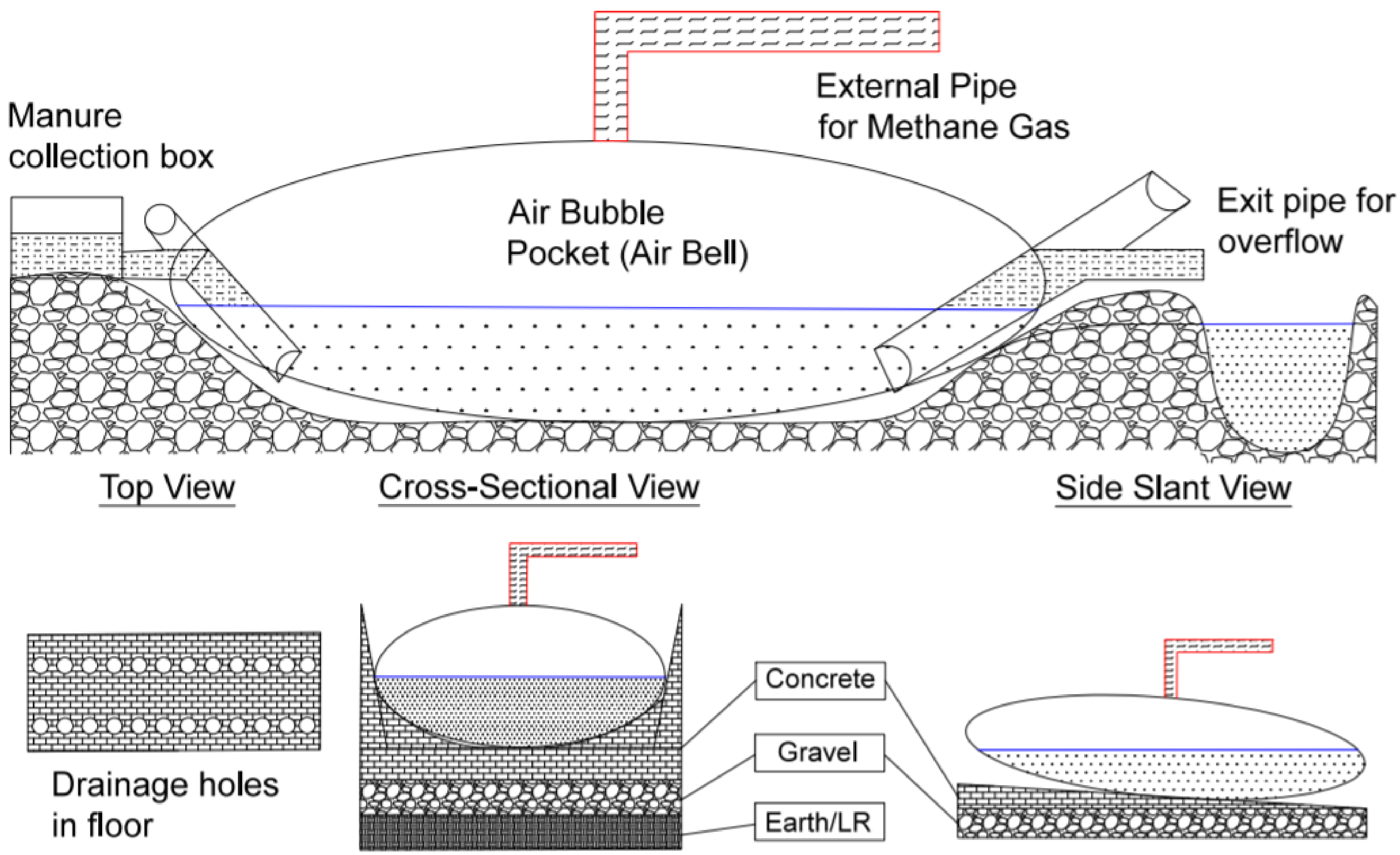
- Larger oven
- Kneading machine
- Fridge
- Stove

Appendix E – Engineering Drawings



Biodigester Bag Design

Inspired by Sistema Biobolsa



Appendix F – Bakery Profit Projection Information

This is the information used for the bakery profit projection charts.

Costs					
Fixed (per day)					
Current Energy	Energia Ahora	PYG	7,800		
Current Labor	Mano de Obra Ahora	PYG	75,200	**PYG**	**83,000**
Level 1 Energy	Energia de Nivel 1	PYG	15,990		
Level 1 Labor	Mano de Obra de Nivel 1	PYG	75,200	**PYG**	**91,190**
Level 2 Energy	Energia de Nivel 2	PYG	17,940		
Level 2 Labor	Mano de Obra de Nivel 2	PYG	112,800	**PYG**	**130,740**
Marginal (cost per loaf)					
School (Cheap) Bread	Pan por la Escuela	**PYG**	**3,374**		
Cheese Bread	Pan con Queso	**PYG**	**9,803**		

Capital Investment			
Level 1	TOTAL	**PYG**	**29,058,720**
Bread oven	Horno Turbo Convector	PYG	12,100,000
Mixer	Amasadora Espiral Industrial	PYG	14,978,520
10 Flat Trays	10 Bandeja Lisa	PYG	1,150,200
Hot Plate	Estufa Electrica	PYG	830,000
Level 2	TOTAL	**PYG**	**21,493,700**
Wrapping Machine	Cilindro Lamidador de Pie	PYG	13,567,500
Yeast Riser	Fermentadora	PYG	4,048,000
10 Flat Trays	10 Bandeja Lisa	PYG	1,150,200
Bread Rack	Carrito Panadero	PYG	768,000
Table	Mesa de Trabajo	PYG	1,130,000
Hot Plate	Estufa Electrica	PYG	830,000

Good Prices			
School (Cheap) Bread	Pan por la Escuela	PYG	5,400
Cheese Bread	Pan con Queso	PYG	30,000