

July 6, 2005

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Dear Dr. Musmanni:

Enclosed is our report entitled Preventative Actions to Reduce Agricultural Water Contamination in Costa Rica. It was written at El Centro Nacional de Producción más Limpia during the period May 14 through July 6, 2005. Preliminary research was completed in Worcester, Massachusetts prior to our arrival in San José. Copies of this report are simultaneously being submitted to Professors Gerstenfeld and Vernon-Gerstenfeld for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you have devoted to us.

Sincerely,

Danielle DeOssie
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Report Submitted to:
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PREVENTIVE ACTIONS TO REDUCE AGRICULTURAL WATER
CONTAMINATION IN COSTA RICA

July 6, 2005

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of el Centro Nacional de Producción más Limpia or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be construed as a working document by the reader.

This report was prepared by members of Worcester Polytechnic Institute Costa Rica Project Center. The relationship of the Center to El Centro Nacional de Producción más Limpia and the relevance of the topic to the Center to El Centro Nacional de Producción más Limpia are presented in Appendix A.

ABSTRACT:

The focus of this report, prepared for El Centro Nacional de Producción más Limpia, is on the prevention of water contamination from Agro-Industry in Costa Rica, specifically on hog farms. The paper discusses waste water management as well as the current and potential use of biogas technology on medium-sized hog farms. The data showed that biogas technology could easily be implemented on many farms, producing financial benefits to the farmer as well as significantly preventing water contamination. Based on an analysis of the data, we made recommendations that include educating the farmers about biogas technology and about the advancement of current finance systems.

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EXECUTIVE SUMMARY

Currently in Costa Rica, wastewater from the Agro-Industry sector is polluting the environment. As the population of Costa Rica grows, water pollution is becoming more and more of an important problem. This being said, we have focused our study on how to improve the waste water from hog farms and lessen the negative environmental impact of the waste water.

We worked with El Centro Nacional de Producción más Limpia (CNP+L) to accomplish our goals of reducing the negative environmental impact of waste water from hog farms as well as educate the farming community about biodigesters and the benefits of biogas. In order to accomplish these goals we had three main objectives. The first was to understand how farms currently manage the waste water and where there was room for improvement. The second was to investigate the potential for biogas on the farms to make sure it was a viable solution. The third was to educate the farmers about biogas. In doing this, we created a brochure to be distributed to the farming community.

In order to understand the full scope of this issue we needed to become familiar with current waste treatment methods for hog farms as well as alternate waste treatment technologies. The main alternative waste treatment technology that we studied was the biodigester. A biodigester is an enclosure that waste is put in and through a series of bacteria breakdowns the waste is converted in to methane gas. This methane gas is often called biogas. This biogas then flows out the top of the biodigester and can be used as an energy source. The remaining waste flows out the other end of the biodigester where it is then safe to use as fertilizer.

In Costa Rica, some farms have made an attempt to help solve the water pollution problem by installing biodigesters on their farms. On many farms waste is often left untreated or minimally treated before it is disposed of into the environment. This often leads to contamination of the water sources of Costa Rica which can have a negative effect on other industries that utilize water sources.

To understand the specific problems on medium sized hog farms in Costa Rica we conducted interviews to collect data. To collect this data, we used a modified Quick Scan to interview farmers with a CNP+L engineer. Quick Scan is a tool that utilizes a set of templates that help to organize data about cleaner production. Quick Scan gave us the points of topic that we wanted to analyze on the farm. These topics were general farm information, hog population, energy consumption, water, waste handling, and biogas.

After collecting the data we found that there is a large potential for biodigester use in Costa Rica. This is because all the farms had adequate space for the installation of a biodigester and produced an adequate amount of waste to run a biodigester. Just on the smallest farm we interviewed, there was the potential to produce over nine thousand liters of biogas every day. This is enough biogas to operate a cooking stove for a twenty eight hours period. In addition to the logistics of biogas technology use, the farmers we interviewed were all interested in learning more about the benefits of biogas technology. However, biodigesters are currently not a popular tool on these hog farms.

To understand why farmers in Costa Rica are not utilizing biodigester we examined a model called the Diffusion of New Innovations Theory. Using this model we found that Costa Rica's current biogas technology use is situated between the Early Adopters and the Early Majority. We concluded the reason why the Early Majority has

not adopted biogas technology is because farmers do not fully realize the benefits of biogas and how it can save money. Farmers also do not understand the positive environmental impact a biodigester can have. Furthermore, farmers do not know how to obtain the materials to install a biodigester nor can they always afford the installation and materials cost. Many of these problems stem from a general lack of information about biogas technology because there is no promotion from private sector of Costa Rica's economy.

Based on these conclusions, we made our recommendations to CNP+L. We recommended that CNP+L locate the appropriate organizations that would have the responsibility to do the following: educate the farmers about the benefits of biogas, setup interactive workshops to educate the farmers further, and advance a finance system that can assist the farmers with the initial investment of biogas technology use.

The farmers need to be educated about the basics of biogas so they become motivated to pursue installing a biodigester on their farm. For part of this education, we created a brochure that advocates for their implementation of biodigester on their respective farms. This brochure was distributed with CNP+L, La Cámara de Porcicultura, and any other applicable organizations. The brochure contains information about the basics of biogas, a comparison of biogas energy to current energy uses, environmental information, and resources to gain more information about biogas.

The development of an interactive workshop where farmers can see how biodigester are constructed and purchase biodigester materials is necessary for farmers to gain first hand experience with the installation of a biodigester. In a workshop with a small number of farmers present, it is possible to demonstrate the step-by-step

construction of a biodigester. Along with the demonstration, the materials to build a biodigester should be available for immediate purchase.

The advancement a finance system that is able to assist farmers with the costs of installing a biodigester was our final recommendation. Currently the Ministerio de Agricultura y Ganaderia, El Banco Central, and El Banco Popular have rural development programs. However, a liaison between the farmers and these organizations does not exist. If the farmers are to benefit from these programs an intermediary is necessary facilitate the process.

If these recommendations are implemented there will be great social implications. If biodigester become a common tool on farms in Costa Rica, the goal towards a cleaner environment will be reached faster. In addition to a cleaner environment, the use of non-renewable energy sources on farms in Costa Rica will decrease, allowing the farms to be more self-sufficient. Also, the potential future use of biogas technology in Costa Rica will open doors for skilled workers by adding jobs to the economy.

Globally, the use of biodigester would serve as a step towards reducing the world's reliance on fossil fuels, helping to solve global warming. Although biodigester have certain requirements like temperature and a water supply, with the advancing technology, like the ability to regulate the temperature of the biodigester, biogas technology could be adapted for almost any climate. The use of biodigesters can improve the environment, making the world a cleaner and safer place for future generations.

CHAPTER ONE: INTRODUCTION

Many areas of the world are faced with increasing waste, shortages of clean water, and a high demand for energy. As the global population increases, agricultural productivity must also increase to feed the growing population. With a growing population comes more agricultural waste. There is also an increase in agricultural waste water due to the high volume of water that is used on a farm (Sommer, 2003). The waste water from a livestock farm often seeps into the environment contaminating the ground water and the surrounding areas in which people live and grow (Sill, 1995). In order to clean up the contaminated water and have it available for future use, energy is needed (Hoffman, 2004). Our project focused on finding a way to prevent the contamination before it starts as well as developing a new energy source.

Ideally, a society's agriculture and energy production would be adequate for their population but would not harm the surrounding environment. However, there has been a realization that agriculture and current energy sources are not sustainable for world ecology (Making the Link: Population, Health, Environment, 2002). The waste that is produced from the livestock farms, such as hog farms, is a potential threat to the population and the environment (Sill, 1995). A clean environment and an energy source are essential for the development of a healthy population (Energy, 2000). The demand for a healthy population, therefore, creates a rising demand to minimize agricultural waste and for a more sustainable energy source.

The agricultural industry in Costa Rica is a major contributor to their society, contributing roughly 10.1 percent of its Gross Domestic Product (Bureau of Western Hemisphere Affairs, 2004). This is an increase of three percent from 2002 (Economic

Commission for Latin America and the Caribbean, 2003). Costa Rica, like many nations, is attempting to examine and find a solution to a variety of agricultural problems including the waste from the livestock industry (United Nations Industrial Development Organization, 2005). Organizations in Costa Rica, like the Ministry of the Environment and Energy (MINAE), are taking this a step further by trying to find ways to create new energy sources from the agricultural waste.

Many of the sources of energy, like oil, used now are nonrenewable sources and a renewable source of energy will be needed in the future. The amount of oil products consumed in Costa Rica, for example, rose from approximately 450,000 tons to over 1.8 million tons from 1974 to 2002 (IEA Energy Statistics, 2003). Oil production is not sustainable for long-term energy needs (Forecasts of Future Oil Output, 2004). However, in Costa Rica, unlike much of the rest of the world, ninety eight percent of the electricity comes from a fully renewable source. This shows Costa Rica's commitment to sustainable energy, but there is still much room for improvement as fifty five percent of total energy consumption is from petroleum (Huttunen, 2005).

The Ministry of the Environment and Energy is spearheading an initiative for the hog farms of Costa Rica. With participation of the Cámara de Porcicultura, they want to compile data to increase the understanding of agricultural waste, waste water, and energy use on farms in Costa Rica. As part of this initiative, they are trying to investigate the use of cleaner production methods to reduce waste water runoff from the farms. They also want to investigate a possible energy source from the waste and whether or not it would be economically feasible. The Ministry of Environment and Energy have assigned El Centro Nacional de Producción más Limpia (CNP+L) to this initiative. CNP+L

specializes in analyzing factories, restaurants, businesses, and a wide variety of industrial facilities to help revise their production practices to utilize cleaner production methods and ultimately reduce the facilities environmental impact. This project, therefore, fits right into what CNP+L specializes. CNP+L, in turn, assigned this project to us and assigned their director to be our liaison. We worked with CNP+L to look at hog farms in order to see how they could utilize cleaner production methods to reduce the environmental impact of the waste water runoff from the farms.

Our goal was to reduce the environmental impact of hog waste and waste water by finding a feasible and alternative use for it. We reached our goal through three objectives. Objective one was the development an understanding of the current waste handling practices in Costa Rica. For objective two, we investigated new uses for the waste and its products. Our third objective involved creating a community education program with our results. In order to fully understand the problems associated with agricultural waste of hog farms, we studied the day to day operations of a hog farm. Using this information, we increased our understanding of where the waste is stored and in what quantity it is generated. We then investigated sources of waste contamination and possible ways to minimize it. By focusing on a sample of small to medium hog farms and using the Quick Scan, a methodological tool used to perform a comprehensive analysis of industry, we created an overview of each of the farms we visited which covered the farm's basic information, hog population, water usage, waste handling, energy consumption, and attitude towards biogas. This overview helped us consider ways to treat the wastewater, reduce its environmental impact, and minimize overall waste output. We analyzed the heat and electricity needs for the farms and possible ways

to convert the waste into energy to satisfy these needs. We then used the cost calculation of a gasifier treatment system to determine if the conversion of animal waste into usable fuel and fertilizer was economically possible. At the end of our project, we created a brochure with all of the advantages of biogas that can be distributed to the farming community to show farmers how biogas can help their farms.

CHAPTER TWO: LITERATURE REVIEW

This background chapter will discuss many different aspects of hog farming. These topics will include reproduction methods, housing, breed selection and food for the hogs. Hog waste is a problem on the hog farms that can negatively affect the environment. Some of the methods for waste management are not adequate and allow contamination to occur. There are many proposed methods to solve the hog waste pollution and there are laws and regulations to monitor this. We will also address possible ways to turn hog waste into energy. Finally, we will discuss different theories regarding the adoption of new technologies.

FOOD, HOUSING AND REPRODUCTION

In order to understand how to make hog farms more efficient, one must first understand how hogs are raised. The goal of hog farming is to make the highest profit by converting an economical, low quality feed into a high quality meat which consumers will buy (Bird, 2005). For the best quality meat, certain standards need to be upheld. Some standards include the type and quality of food and the housing. Reproduction also requires additional standards such as special housing units until the piglet reaches maturity. Different breeds also require different living conditions and different types of food. No matter what feed is given to a hog, the feed will inevitably result in waste.

Pigs are commonly housed in cement pens and separated based on the age and development of the pig (Swine Production, 1997, p. 60-63). Sows with babies are housed in special cages which have a small cage attached in which the piglets reside. These special pens allow the piglets to feed from the mother's milk but to avoid getting

inadvertently rolled on, a cause of twenty five percent of piglet deaths (Swine Production, 1997). The profit of a hog farm is directly proportional to the number of hogs that survive to maturity. The above precautions help to ensure that more piglets survive to maturity than if the mother and piglets are housed in the same pen, therefore increasing profit.

The operation of a hog farm depends a great deal on the number of hogs that are present there. A hog farm with sixty hogs will be run significantly different from a farm with six thousand hogs. Small hog farms can use a large straw-bedded pen where all weaned hogs will live communally. On this small scale the hog waste mixes with the straw bedding and this mixture ecologically decompose together. This method of housing hogs results in very minimal environmental impact (Frantzen, 1998). More commonly on small scale hog farms, hogs are housed on cement pads and separated by metal cages. These cement pads are hosed off several times daily, resulting in a large amount of water waste. These pens are used on most small farms in Costa Rica. However, not all hog farms are small; therefore, different farming techniques are utilized. On larger farms this system of utilizing small pens would not be practical due to the large number of separate pens required. In the United States, factory farming is becoming the mainstream style for hog farming. From 1978 to 1992, the number of hogs in the United States grew one 134 percent while the number of hog farming facilities in the United States decreased by 50 percent (Griffith, 2001).

Although the hogs may be housed separately, they are all fed the same basic diet. In the United States the basic content of a hog diet is displayed in Table 1 (Swine Production, 1997). However, different parts of the world supplement the hog's diet with

their regional crops. The content of hog waste is determined by what the hog is fed (Intec, 2002).

Table 1: Typical Diet of Growing Hogs
Source: Swine Production, 1997

Typical Diet of Growing Hogs	
Ingredient	Amount Percent
Yellow Corn	76.5
Soybean oil meal	21.0
Dicalcium phosphate	1.25
Ground limestone	0.75
Trace mineralized salt	0.35
Vitamin supplement	0.10
Antibiotic Supplement	0.10

HOG WASTE: DISPOSAL AND ITS EFFECTS

Hog waste is commonly referred to as slurry because it is formed from the mixture of the urine and feces in a hog's excrement. This mixture is roughly ninety five percent liquid (Intec, 2002). The average size hog, weighing 188 kilograms, can produce roughly 8 kilograms of slurry a day. Of what a hog is fed, about fifty percent is turned in to waste. The major components of hog waste that are pollutants are nitrogen, potassium and phosphorus. On average, hog waste contains about 5 percent nitrogen, 2.9 percent potassium and 4.5 percent phosphorus. Hog waste contains a higher amount of nitrogen than most farm animal waste, increasing the potential for both environmental damage and use as a fertilizer (Intec, 2002). Nitrogen, potassium, and phosphorus, and the environmental pollution they cause, are discussed later.

Most Costa Rican hog farms are small compared to those in the United States and use different waste management techniques. In most large hog farming facilities within the United States, slatted flooring is used to allow the slurry to flow away and not build up on the ground of the hog corral. In most farms the slurry is then transported to a lagoon which is usually located on the farm property. A lagoon is an in-ground pit that is made to store the hog waste. Theoretically, when the waste is in the lagoon, the solid components of the waste sink to the bottom to act as a lining and prevent contamination of the surrounding ground and water (Warrick, 1995).

However, this is not an environmentally friendly way to dispose of the waste properly. According to studies conducted by Rodney Huffman, an assistant Professor of Biological and Agriculture Engineering at North Carolina State University, slurry leaks into the environment from the lagoon causing local pollution because the solids do not create a lining, as was expected (Warrick, 1995). The pollution is caused by the unnaturally large amounts of nitrogen, phosphorus and potassium. The environment surrounding a lagoon uses these chemicals on an everyday basis as part of the natural nutrient cycle, but it cannot handle the overwhelming influx of nutrients that leaks out of a lagoon into the ground (Fletcher, 2005). There are very few farms in Costa Rica that use this method of waste disposal. Even if a farm does use this method, there is a high chance that it has a high negative impact on the environment and on ground water.

Nitrogen appears to be the most harmful of the nutrients leaking out of the lagoons. Excess levels of nitrate-nitrogen, a form of nitrogen, can cause methemoglobinemia or “blue baby syndrome” which is fatal to a human infant. There is also a significant amount of ammonia from the decomposing slurry. Ammonia is harmful

to the environment because it is released into the air as a gas and returns to the earth with the rain. This excess ammonia causes algae blooms in the natural waterways which, in turn, suffocate the fish and destroy the ecosystem (Warrick, 1995). The phosphorous in the slurry can lead to eutrophication (See Glossary) of the local water shed when it infects the soil surrounding a lagoon (Lee, 2005).

QUICK SCAN

In order to assess the farms and choose which ones to work with, we will be using Quick Scan, a method for evaluation. Quick Scan is a methodological tool that provides the basis for qualitative analysis of the farms based on a set group of criteria. Quick Scan records the production methods, storage and transportation used on the farm. It also looks at the owners and their willingness to comply with cleaner production methods. The whole process is described in great detail in Appendix B.

REDUCTION OF ENVIRONMENTAL IMPACT

There are several approaches to deal with the problems of the excess nutrients leaking out of the lagoon. We are exploring three approaches that cover the main ways that waste can be reduced. The first approach is to reduce the amount of waste nutrients that are put into the lagoon (Pons, 2005). The second approach is to find natural ways to absorb them after they leak into the environment and prevent them from causing harm (Griffith, 2001). The third approach is to use technological applications to treat the waste while it is in the lagoon (Morris, 2003).

Some researchers, sponsored by the United States Department of Agriculture, are using technology to recycle the waste by converting it into fertilizer and then depositing

the wastewater from this process into a lagoon (Pons, 2005). The system significantly reduces the excessive concentration of nutrients that run into the lagoon through three steps. The first step separates the solid components from the liquid. The second step uses nitrifying bacteria to remove the ammonia from the liquid phase. The third step transforms the phosphorous from a liquid into a solid. The result is waste water that has lowered amounts of ammonia and phosphorous that can then be deposited into a lagoon to decompose naturally. On experimental sites, the lagoons color has changed from brown to blue, indicating a marked improvement in the water quality (Pons, 2005). This system works best for large scale farms and can be very expensive and therefore would not be ideal for Costa Rica.

An example of the natural approach that has been devised for the United States is to plant poplar trees near the nitrogen rich lagoons. Researchers at the South Dakota Association of Conservation Districts found that hybrid poplars act as a nutrient sink for waste water. This study has suggested that poplar trees retain as much as sixty eight to ninety nine percent of nitrates and seventy five percent of sediment when compared with an open plot of land (Griffith, 2001). Unfortunately, poplar trees are not suitable for the climate of Costa Rica. In Costa Rica most farms are on steep hills leading to a problem where the water flows past the plants that are planted to absorb the excess nutrients faster than the plants can absorb the nutrients from the waste water. However, this example shows that there are natural ways to clean up hog waste that should be kept in mind for long term supplemental waste water reduction in Costa Rica.

A use of technology, The Vibratory Shear Enhanced Process, was studied by Ridgetown College and the University of Guelph in 2003 to treat the waste (Morris,

2003). The researchers for that project explored the process of separating the slurry from the clean water that could be recycled back into drinking water for the hogs. The process involved an experiment with fifty four pigs in which three water treatments were utilized. The researchers compared the quality of the recovered water with tap water and spring water. They monitored the growth of the pigs and the health of the pigs that were given the recovered water (Morris, 2003). The researchers were using the Vibratory Shear Enhanced Process (VSEP) unit to recover the water. The machine utilizes reverse osmosis and uses high pressures and a vibrating filter pack to separate water from the manure. The VSEP unit is in use in Korea for treating digested livestock manure and shows great promise for treating liquid manure (Morris, 2003). This method could be implemented in Costa Rica, where water shortages can be a problem (Kim, 2005). However, because the initial cost is in the thousands of dollars, this will be too expensive for small and medium farms.

GASIFICATION

An inexpensive way to break down animal waste and to turn it into a useful fuel is through gasification. Biogas is produced through the anaerobic decomposition of hog and other animal's byproducts. Methane is separated from the hog waste through the gasification process, which creates a fuel very similar to natural gas. From start to finish this process takes around a month for the animal waste to completely decompose. Waste is added daily to biogas facilities so it is a continual process that produces a steady stream of biogas and fertilizer. Every time waste is added it displaces a near equal amount of fertilizer which leaves the digester. As is shown in Figure 1, biogas can be used as a heat source for water, a lighting source, or even to power an electric generator. The high

nutrient fertilizer is safe to use on fields and on gardens as the majority of pathogens have been killed by the gasification process (Kossmann et al).

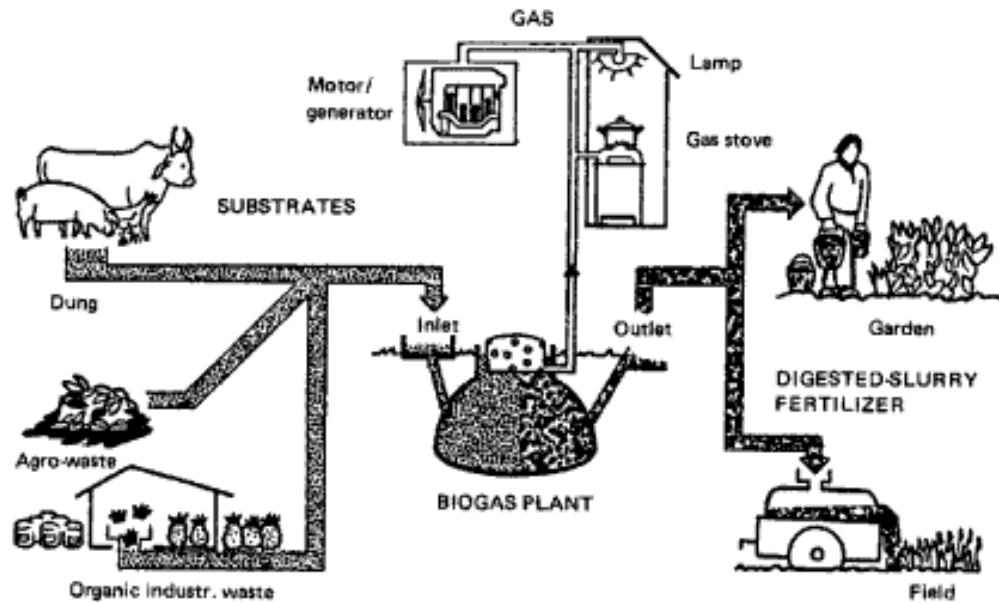


Figure 1: Biogas-General Uses
Source: Biogas Digest, nd

Several economical ways of producing biogas have been devised, all of which use the same basic three stage anaerobic process. It is several groups of bacteria, working together, that perform the actual process of converting the animal waste into useable gas and fertilizer. Notice the Biogas Plant in the center of Figure 1. Most biogas plants that have been designed for developing countries, including Costa Rica, have the same setup. The chamber itself is often made of a strong plastic material; in many earlier designs the chamber was always made of masonry. The Chamber is gas and water tight. On one side of the biogas unit, there is an inlet where waste can be added. On the other side of the biogas unit, there is an outlet where the fertilizer will be removed at the end of the process. At the top of the biogas plant, there is a hose coming of the chamber from which the methane biogas flows (Kossmann et al).

Biogas can be used on all sorts of different sized farms in the tropics. Farms with as few as twenty pigs may be able to keep a biogas plant running that is able to provide enough fuel daily to cook. The environmental benefits of gasification could be significant as it allows for a reduction in non-renewable resources, a source of high nutrient fertilizer, and an environmentally friendly way to dispose of waste (Aguilar, 2001).

In Costa Rica, the dominate type of biogas plant used is a plastic film biodigester that is a very long plastic bag. On one end the waste is put in and on the other end fertilizer flows out. This plant is optimal for small farms as it is inexpensive to build and produces enough energy for a family to use for cooking, lighting, and for keeping young animals warm. There is a large potential for greater use of biogas technology in Costa Rica but even the \$200 US that biodigesters cost is a deterrent for Costa Rican farmers. This is in part due to the lack of knowledge about the cost savings of the plants and possibly a lack of skilled personnel to construct the biogas units in Costa Rica (Huttuen, 2005).

REGULATIONS

There are many types of farms and farming processes. Much of the time, governmental-instilled regulations on farming are put in place to try and control the amount of negative environmental impact the farms have on the community that surround them. Farming regulations help control the formulation and spread of diseases, the quality of the harvested product, and the environmental impact of the farming waste.

Almost all regulations that are imposed on farms and the farming process are done so by the individual countries or communities. International organizations, like the

United Nations and the World Health Organization, utilize regulatory farming information to keep the standard of the product at a specific level. And even further, the regulatory system is only effective for farmers who are subject to and who abide by the regulations. A small farmer could easily sell products without having to adhere to the farming regulations as they can easily avoid the attention of government inspectors. Any operating farm in Costa Rica must adhere to Costa Rican regulations. However, as we will be working with smaller farms in Costa Rica, they may not adhere to these regulations.

To become an operating farm in Costa Rica, a farmer must apply for permission to raise animals. They must have a detailed plan of their buildings, treatment systems and storage facilities. Once this is complete, the farmer can start raising animals within the site-specific restrictions and regulations which mainly deal with the locations of farms in reference to its surroundings. Many of the specific restrictions and regulations can be seen in Table 2.

Table 2: Minimum requirements to property edges of treatment systems.
Source: Bio-energy Technology Evaluation and Potential in Costa Rica, 2005

Type of Treatment		Minimum Distance Requirements (meters)	Type of Treatment	Minimum Distance Requirements (meters)	
Anaerobic Lagoons		50	Flocculation	10	
Lagoon Facilities		20	Drying Beds	10	
Activated Mud		10	Aerobic Digesters	10	
Biological Filters		20	Mud Lagoon	50	
Anaerobic Reactors	<i>Opened</i>	10	Anaerobic Digesters	<i>Opened</i>	20
	<i>Closed</i>	20		<i>Closed</i>	10
Primary Sedimentary	<i>Opened</i>	20	Superficial fields of infiltration		5
	<i>Closed</i>	10			
Septic tanks and their drainages ($Q \leq 14.03 \text{ ms/day}$)		1	Systems of evaporation	10	
			Pumping	5	
Primary sedimentary with built-in digesters ($Q \leq 3.53 \text{ ms/day}$)	<i>Opened</i>	20	Chemical treatment plants		5
	<i>Closed</i>	10			

THE ADOPTION OF NEW TECHNOLOGIES

The adoption of new technologies is crucial to the outcome of pollution control in Costa Rica. There are many theories that explain why people, more specifically farmers, are less likely to adopt new technologies. Farmers, especially, may be reluctant to disturb their usual routines to install a new system that involves new management skills and an initial investment before savings can be seen (Vanclay, 1992).

There are many barriers that stand in the way of a farmer adopting a new technology: economics, farming subculture, risk, and implementation costs. The more economically beneficial the technology is, the more likely it is to be adopted. Farmers will not want to adopt a new technology if they will not gain any profits or savings from it. This loss or gain of profits also includes the risk involved. The greater the risk of the technology failing the less likely it is to be adopted. The farmer will not want to lay out the initial investment if there is a chance that he will not be able to gain any savings because the machine fails. The farming subculture will be the greatest tool that can be used to get farmers to adopt the new technology. Farmers often say that other farmers are one of their greatest sources of information on new technologies and new methods of farming that can be beneficial. By showing one farmer the benefits of the new technology he will be able to tell other farmers and word-of-mouth will allow the new technology to be adopted throughout the farming community (Vanclay, 1992).

In addition to the barriers faced by the farming community, different people adopt technology at different times. According to Everett Rogers' Diffusion of Innovations Theory, there are five main classifications of people: innovators, early adopters, the early majority, late majority, and laggards. Innovators are venturesome and very willing to take risks. The early adopters are quick to adopt the new technology and need very little convincing of its benefits. The early majority are the first part of the mainstream population and the late majority are the second half of the population (Orr, 2003). The late majority adopts the new technology from peer pressure or because they have not become as economically viable as the early majority. The laggards are slower to adopt the technology if they adopt it at all. The laggards are usually isolated from the

population or are very traditional. Usually, the early adopter and the mainstream population are the examples that the laggards will follow. The Diffusion of Innovations Theory points out that the adoption of new technologies takes place over time as members from the different groups communicate to each other (Clarke, 1999).

Rogers' theory states that there are different stages and certain characteristics that the new technology must go through and have in order for it to be adopted into the majority of the population. There are five stages through which the innovation must pass. The first is knowledge, the population must be aware of the existence of the new technology. Next is persuasion, the potential user must be convinced that this technology is a good idea. Third is decision, where the technology is actually adopted. Next is implementation, where the technology is used. Finally, there is confirmation, where the use has shown positive results (Clarke, 1999).

The five characteristics that the technology should have may affect the rate at which it is able to pass through the different stages. The relative advantage is the degree to which it is perceived to be better than the technology it supersedes. The compatibility is the consistency with existing values, past experiences and needs of the population. Next, the complexity is difficulty of understanding and use of the innovation. The trialability is the degree with which it can be experimented. Lastly, the observability is the amount that the results and benefits of the new technology can be seen (Clarke, 2000).

CHAPTER THREE: METHODOLOGY

Our goals for this project were to reduce the environmental impact of hog farm waste and to implement an alternative source of energy from the waste. In order to accomplish these goals, we utilized three objectives that are listed below. The objectives were achieved through a variety of techniques and processes as discussed in the main body of the methodology.

- 1) Develop an understanding of current waste handling practices.
- 2) Investigate new uses for the waste.
- 3) Create an education program for the farming community with our results.

SAMPLE OF FARMS

Our group examined a sample of hog farms that were classified as medium in size. In our initial research we found that the size of a hog farm is generally classified based on the number of birthing hogs, also known as ‘hembras’. Farms with fewer than five hembras are considered to be informal because they are usually unregistered with the government. Generally, their farm products are used only within the farm’s family. These farms are classified as *small* farms. The group that we are studying, the *medium* hog farms, contained five to approximately thirty five hembras. The last classification of hog farms is the *large* group which would contain over thirty five hembras.

This classification of farm size was extremely important to our project. Small farms tend not to have a steady flow of production because the number of hogs is not consistent throughout the year. This is because the small farms may only contain one or two birthing hogs that give birth only a few times a year. The number of hogs is directly

proportional to the amount of waste and waste water that is produced on a farm. A small farm may not have the steady flow of waste production that yields the information necessary for this study.

However, large farms may also provide information that cannot be used in this study. Large farms tend to raise hogs for mass consumption that are sold to the wholesale retail market. The amount of waste that is created on a large farm is quite significant due to the high number of hogs. For example, a larger farm could have 40 hembras, each having a litter of 10 chanchillas, also called piglets, which could possibly yield an overall population of 440 hogs. Due to the number of hogs, the waste would have to be handled in different, more industrial, ways such as transporting the waste to processing plants.

There is another classification of farms that did not prove beneficial to our study. This classification of farms does not breed hogs but buys piglets from the breeding farms to raise them for market. These non-breeding farms are not the type of hog farm we were interested in studying because the farm raises the majority of their hogs during specific times of the year and have very few hogs at other times of the year. In Costa Rica, the demand for pork is generally greater in the months of December and January. In the months of February and March the demand is generally less. For example, if a farmer has fifty growing hogs on a farm in late summer, then from late summer to December that farmer would be feeding these growing hogs so that they would be ready for sale in December. This means that the waste generated from September to December would be relatively high. However, once December arrives, all the hogs would be shipped out for sale and the number of hogs on that farm would drop to zero. This drop in hogs would lead to a drop in the amount of waste and waste water. This would yield information that

would not be beneficial for our study because there would not be a constant flow of waste water annually, which is needed for a successful biodigester.

The grouping of medium hog farms that we studied did not utilize the same production methods as the farm mentioned in the above paragraph. The medium hog farms that we studied raised hogs on a more distributed timeline. Growing hogs are raised throughout the year, rather than at two or three specific times. This means that the waste production from these medium hog farms contains fewer fluctuations than the hog farms described in the preceding paragraph. The farms with a consistent number of hogs annually were ideal for the data we were trying to collect.

With this set of criteria for selection of farms in mind, we used snowball sampling to select farms. The first farm that we visited was owned by Ricardo Montero. We read about his farm in the Tico Times, a Costa Rican newspaper. Mr. Montero's farm contained a biodigester, so was not used in our final sample. He introduced us to three other farms in the same area that did fit our criteria. One of these farmers pointed us to two more farms. This completed our sample of five farms.

SURVEY DEVELOPMENT

We modified Quick Scan, a methodological tool used to perform a comprehensive analysis of industry, to make it specific to hog farms and added a section on biogas. This modification of Quick Scan, please see Appendix C, created an overview of each of the farms we visited that covered the farm's basic information, hog population, water usage, waste handling, energy consumption, and attitude towards biogas.

DATA ENTRY

To analyze the hog farms and to collect the desired data from our sample, we used the questions and observation points from our modified version of the Quick Scan process. With a CNP+L engineer and a biogas expert, we visited each hog farm and recorded the data on our Quick Scan sheets. We did not conduct a formal interview with the farmers, but chose to have an unstructured interview where the questions mentioned above were answered. Most of the questions we were able to answer by simply observing the farm. The remaining questions were discussed during the tour of the farm.

DATA VERIFICATION

When we returned from the farms, we immediately reviewed our data that was collected through our modified Quick Scan sheets to ensure that we added any information that we were not able to enter onto our sheets while in the field. We entered this data into spreadsheets with all five farms lined up in different columns and with all of the Quick Scan questions in the rows. The spreadsheet with our data is in Appendix D. We then consulted with the CNP+L engineer who went with us to the farms to ensure that our data and her data were the same. Any contrasting or missing information was discussed and updated as appropriate.

Using the spreadsheet in this way allowed us to easily compare the information from the farms and to view patterns. We discussed these patterns with the biogas expert to identify specific points of interest and to formulate our recommendations.

PROMOTION OF CLEANER TECHNOLOGY

Education of the farming community was presented in the form of a brochure that contains information about cleaner production methods. The information contained in the brochure was focused to motivate the farmer to find out more information. The brochure does this by showing the farmer all the benefits of the system including how the system will pay for itself. It presents information in a concise and informative manner and also gives the reader the links to further resources on how to implement the methods and contacts of where the reader can get more information.

CHAPTER FOUR: DATA ANALYSIS

After we collected our data, we divided it into six sections so that we could identify any patterns and similarities between the farms. The six sections from the interview questions came from our modified Quick Scan. They include general farm information, hog population, energy consumption, water, waste handling, and biogas.

FARM INFORMATION AND SPECIFICATIONS

We visited five farms in Pacayas de Alvarado, Cartago. Cartago is the former capital of Costa Rica and is located just outside the limits of San José. Pacayas de Alvarado is a rural community that is based on agriculture. The first two farms that we visited were both located on the side of a mountain. At the bottom of the steep slope was a river. Downstream, this river joins with several smaller rivers which all run into a turbine, owned by ICE, which generates electricity. The third farm was on the side of a steep hill, but there was no river at the bottom. The fourth and fifth farms were located on flatter ground with a river nearby that is used to water the fields for their crops.

The families are dependent on the income from their farms. As a result, the farms all have more than one source of income and contain multiple animals. The first farm has one ox in addition to eighty three hogs. The farmer uses the hog waste to produce his own feed for the oxen and a fertilizer that he uses on his fields and sells to other farmers. The second farm has a hog population of fifty in addition to one cow that was used to produce dairy products. The farmers use the cow to produce milk which they sell to another farmer, who has the capability to make cheese. On the third farm there is a hog

population of nineteen along with a small number of cows and worms. The owner of the third farm uses the cows to produce milk that he later makes into cheese. The worms are used to turn the waste into a viable fertilizer that they use on their bean fields and pastures. The fourth farm contained 135 hogs. This farm was a little different from the other farms because it did not raise any other animals, like cows or oxen. However, the fourth farm does grow beans and potatoes that are fertilized from the composted hog waste. The fifth farm we visited has one hundred hogs in addition to eighteen cows. The farm uses the cows to operate a small dairy.

HOG POPULATION

One of the main variables we collected information on was associated with the general farm information was the farm hog population. We examined this information by noting the overall population as well as the individual populations of females, males, newborns and adolescent hogs. The most important population group is the birthing females. This is because the birthing females are what remain most constant on the farm as compared to the total number of hogs which can fluctuate based on whether hogs have recently been sold for slaughter or females have recently given birth. Below is a table of the hog populations at each of the farms we visited.

Table 3: Hog Farm Population by Farm

Farm	1	2	3	4	5
Total Number of Hogs	83	52	19	135	100
Number of 'Hembras' (Females)	15	15	6	32	10
Number of 'Machos' (Males)	3	2	1	3	4
Number of 'Chanchillas' (Newborns)	25	20	11	50	12
Number of 'Crianzas' (Adolescences)	40	15	1	50	75

As can be seen in Table 3, the number of birthing females ranged from six to thirty two, which fit into our criteria of medium sized farms as discussed in the Methodology Chapter. The total number of hogs ranged from 19 to 135. The farm with 6 females has a total population of 19 hogs and the farm with 32 females has a significantly greater total population of 135. This demonstrates how a slight change in the number of females can lead to a significant change in the total population of the hogs.

HOG WASTE

The hog population is directly proportional to the amount of waste produced on a farm. The average sized hog produces 8kg of waste each day. Even though not all of the hogs are the same size and produce the same amount of waste, over all, the waste averages out to 8kg per hog. The fourth farm, with 135 hogs, produces over 1000 kilograms of waste each day. Table 4 shows the amount of hog waste produced at each of our sample farms. The full Data Analysis Table can be found in Appendix E.

Table 4: Data Analysis Table- Hog Waste

Farm	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
Total number of hogs	83	50	19	135	100
kg of waste produced per day	659	397	151	1073	795

Every farm has some form of waste management system in place to remove the waste and waste water from the pig pens. Every farm had some sort of canal or pipe system in place that moved the waste from the pens. The first two farms had grates or slats in the floor of the pen, as discussed in the Literature Review. We saw two types of slats plastic and metal, which allowed the waste to fall through and collect below. The waste would then flow through canals out of the pens. All five farms that we visited had canal systems that allowed the waste to flow out of the pens to the outside where it could be disposed of in one of two methods. The other waste treatment systems discussed in the Literature Review were not utilized on farms in Costa Rica.

The ways that the waste is treated after it leaves the pens is different from farm to farm. Two of the farms utilized systems to separate the solid and liquid waste. For this system, the waste first comes out of the pipes and runs into a pool. The solid waste then settles to the bottom where it is eventually shoveled onto a cement pad. The excess water is then drained from the waste and it is given time to dry. The excess water in the pool then flows out of the system and in to the surrounding environment. The waste, once fully dried, can be used as fertilizer for the fields or sold.

The other three farms allowed the waste to run through open pipes dug in the ground to the environment. An example of an open pipe can be seen in Figure 2. The

waste water diffused through the fields and the pastures after it left the pens. The waste water would eventually run into small rivers or streams located near the farms.



Figure 2: Open Pipe.

WASHING AND WATER USAGE

One of our interview questions for the farmers when we visited them is how much water they use a month. Unfortunately, none of the farmers were able to tell us this information. This is because the farmers do not receive their water from a source that utilizes a meter that is capable of measuring of how much water comes into the farm. The farms received their water from natural sources, including rivers and groundwater. They pressurized the water using pumps so that they were able to clean the pens.

Appendix D shows information about the cleaning process and water usage for the five farms. This table is located in Appendix D because of its significant detail.

Many similarities were found when analyzing this information. First, we found that each of the five farms clean the hog pens twice a day and use water to clean the pens. This is done by using a series of hoses to spray down the pigs and their pens to clean them of waste. The time that it takes to clean each of the farms varies from 20 minutes to 2 hours with a range of 1 hour and 40 minutes.

Only one of the five farms uses water for something other than washing and drinking. The fourth farm uses small pipes that dripped water into a cement tub that essentially created a bathing area for the hogs. This bathing area is to help cool the hogs down during the day when the temperature in the barn can be high. A picture of this can be seen in Figure 3.



Figure 3: Cooling Bath at the Fourth Farm

Even though the farmers could not directly inform us of the amounts of water used, we were able to calculate the estimated amount of waste water produced each day. At a minimum, the amount of waste water produced is ten times the amount of waste produced on each farm. Table 5 shows how much waste water is produced at

each farm. Notice how even at the smallest farm, with only nineteen hogs, over fifteen hundred liters of waste water is produced each day.

Table 5: Data Analysis Table- Waste Water Production

Farm	1	2	3	4	5
Total number of hogs	83	50	19	135	100
kg of waste produced per day	659	397	151	1073	795
Waste water produced per day (liters)	6598	3975	1510	10732	7950

LIGHTING AND ENERGY USAGE

The next variable we examined was the lighting and energy usage on the farms. All of the five farms use heat lamps to keep the newborn piglets warm. These are used for twelve to twenty four hours a day depending on the temperature of the barn. These heat lamps are used for six weeks after a piglet is born and range from 150 watts to 250 watts in electricity usage. Also, there is generally one heating light per litter of piglets.

Of the five farms, one farm uses lights to illuminate the barn during the evening when necessary. These lights were normal 100 watt light bulbs. Many of the barns also are designed so that natural sunlight can shine in to the barn. This is done through openings in the ceilings and clear or white plastic roofing sheets.

The electricity used on the farms is used for a few different processes. The first and most universal use for the electricity is to power the heating lamps for the newborn piglets. Another process that uses electricity is to power grass cutting machines in the fields. This grass is used for feeding the other animals on the farm. A third process that

uses energy is an electric tail cutting machine is used to dock the tails of the newborn piglets. On the second and third farms, electricity is used to heat water to clean dishes and production supplies from the dairies that are located on the farms.

BIOGAS

The issues concerning biogas are more complicated than the other issues we encountered during our interviews. None of the farms we visited had installed biogas systems even though they were somewhat familiar with the technology. All of the farmers knew the basic concepts of using biodigesters as an alternative method to treat waste water. There were many aspects, however, of which the farmers were not aware, such as the environmental and financial benefits.

The individual reasons for not installing a biodigester are more complex than simply environmental and financial benefits. Each farm had a different set of reasons for not utilizing a biodigester.

- The first farm had just switched owners after the first owner went bankrupt. The new owner is trying to reestablish the business before he spends money on new technologies, such as biodigesters.
- The second farm had attempted to install a biodigester with the help of ICE and Junta Administrativa del Servicio Eléctrico de Cartago (JASEC). Unfortunately, the paperwork was submitted, but the farmer claims that ICE and JASEC never fully processed the paperwork and a biodigester was never installed.

- The fourth farm rents the building in which the hogs are raised. The farmers would have to obtain permission from the landlords before they could construct a biodigester on the property.
- The fifth farm had investigated installing a biodigester and was going to follow through with the installation. The farmer was unable to find the supplies, most notably the plastic bags. Overall, we learned that each farm has its own reasons for not having installed a biodigester.

In order to estimate the value that a biodigester would have to the farmer we needed to calculate the amount of biogas produced by a biodigester. This information would demonstrate that there was a financial incentive for installing a biodigester. It is known that the maximum potential of one kilogram of hog waste is sixty liters of biogas. This potential assumes that the biodigester is operating at its peak capacity and that a constant amount of waste is being added. Table 6 shows the potential amounts of biogas that could be produced on each farm.

Table 6: Data Analysis Table- Potential Biogas Production

Farm	1	2	3	4	5
Total number of hogs	83	50	19	135	100
kg of waste produced per day	660	398	151	1,073	795
Waste water produced per day (liters)	6,599	3,975	1,511	10,733	7,950
Amount of biogas produced per day (liters)	39,591	23,850	9,063	64,395	47,700

To understand the potential application of a biodigester we examined two examples. The first example is a biogas powered cooking burner that can easily replace a similar burner that is powered by propane. A biogas cooking burner uses approximately

325 liters of biogas per hour. By taking the maximum amount of biogas that could be produced in one day we have calculated the number of hours that each farm could keep a biogas burner lit, see Table 7.

Table 7: Data Analysis Table- Potential Biogas Uses

Farm	1	2	3	4	5
Amount of biogas produced per day (liters)	39,591	23,850	9,063	64,395	47,700
Time of cooking gas produced per day (hours)	122	73	28	198	147
Time of heat lamp gas produced per day (hours)	89	54	20	145	107
Potential number of heat lamps per farm	7	4	2	12	9

On all farms there is the potential to operate a biogas powered burner, or numerous burners, for an extended period of time. At a minimum, there is enough biogas to satisfy all of the cooking needs of the farm.

If all the cooking needs of the farm are satisfied through biogas, there can be a substantial amount of savings. In Costa Rica, one liter of propane costs approximately 150 colones. The average farm uses fifty liters of propane each month for cooking. This means that a farmer spends 7500 colones each month on propane. If a farmer did not have to purchase propane for cooking, he could save that money.

The second example, to show the potential application of a biodigester, would use biogas to power lamps to produce heat for the piglets. This type of lamp uses approximately 445 liters of biogas per hour. Based on these values, we calculated the number of hours a lamp could stay lit. This can be seen in Table 7. Currently on the farms, heat lamps run for twelve hours a day. The bottom line of the table shows the

potential amount of biogas heat lamps that could be operated on the farm, assuming that the lamps are lit for twelve hours at a time.

To demonstrate the potential savings if biogas were used for heat lamps, we considered the average farm with three heat lamps. These heat lamps use a two hundred watt light bulb and operate for twelve hours a day. It takes two kilowatt hours to run one of these lamps for twelve hours. This costs approximately one hundred colones. We calculated that in a period of one month, 10,700 colones could be saved.

If there is enough biogas produced, then both applications of biogas can be utilized. A farmer could potentially save 18,200 colones each month. To many farmers this is a significant amount of money that would pay for the initial cost of the biodigester within a year.

ADOPTION OF NEW TECHNOLOGY

Based on this information and the possible financial benefits, we next analyzed the reasons why more farmers have not adopted the use of biodigesters. To help us do this, we have looked at the Adoption of New Technology curve adopted from Everett Rogers' Diffusion of Innovations Theory (Orr, 1995). This model describes the rate of adoption of a new technology versus the time it takes societal groups to adopt the new technology. The theory is discussed in great detail in the Literature Review. Costa Rica is currently situated between the Early Adopters and the Early Majority, as can be seen in Figure 4.

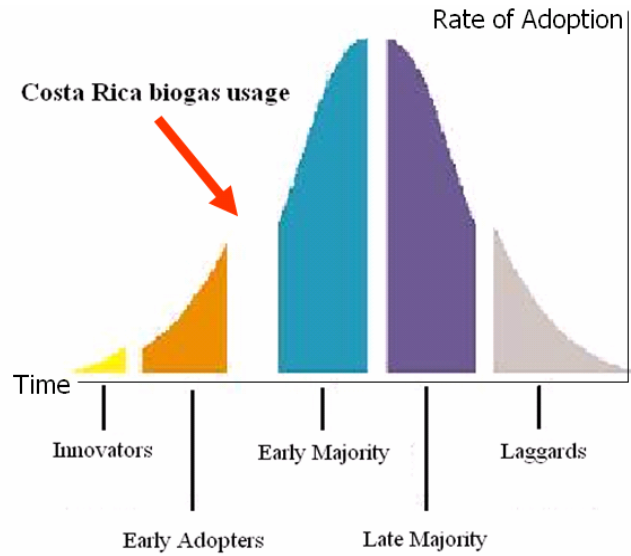


Figure 4: Adoption of New Technology Curve

Farms that currently use biodigesters would be considered early adopters. They researched the technology and chose to install the system even though there was a large risk involved. The farms we sampled are all unwilling to take the risk of installation without being sure of the potential benefits of a biodigester.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

BIODIGESTERS IN COSTA RICA

Based on our analysis of the data we collected, we conclude that the biodigester is the best waste water treatment system for medium-sized breeding hog farms in Costa Rica. Our conclusion is based on the fact that the biodigester will work well in Costa Rica, with a tropical climate, for two main reasons. The first reason is the environmental benefits of cleaner waste water. The second reason is the economic benefit to the farmer.

The most important reason for our conclusion is that the biodigester is an excellent method to treat waste water. On average, the biodigester produces water that is eighty five percent pure. The system also produces a quality fertilizer that is pathogen-free and therefore safe to use on fields and to sell at the market.

In addition to the environmental effects, there are also many benefits to the farmer. The main benefit is that biodigesters can save the farmer money through the replacement of traditional energy use with that of biogas. On any of the farms sampled, the biodigester can produce enough biogas to run multiple applications. One more benefit is that the fertilizer produced can be sold at market, adding to the products that the farm produces. These are the benefits that are going to demonstrate the financial incentive motivating the farmer to pursue this cleaner technology.

As well as the benefits that a biodigester is capable of providing, it also can be installed on many farms with relatively little effort. The biodigester is a tool that utilizes relatively inexpensive and simple materials. The biodigester that we determined is the best option is constructed from a long plastic bag to serve as the digestion chamber, a

series of pipes to direct the flow of waste into and out of the biodigester, and a series of tubing and gaskets to transport the biogas. An example of this type of biodigester can be seen in Figure 5.



Figure 5: Plastic Bag Biodigester.

ADOPTION LIMITATIONS

Based on the analysis of the Adoption of New Technology Curve, we have concluded why this new technology has not been implemented on farms in Costa Rica. In our Data Analysis, we explained how Costa Rica is currently between the Early Adopters and Early Majority on the adoption curve. There are several reasons why Costa Rica is in this position. The first is that the farmers do not fully realize the financial benefits of biogas and how it can save them money. The second is that farmers do not

understand the positive environmental impact of the biodigester and how it can successfully treat the waste water.

There are also more logistical problems that prevent the installation of a biodigester. In Costa Rica, the materials to construct a biodigester are often hard to locate. In addition, the installation process can be difficult without the help of technical assistance. There are also financial issues involved with the installation of a biodigester. The initial installation costs can deter the farmer from pursuing biodigesters. Many of these problems exist because there is a lack of interest from the private sector. Involvement of the private sector could easily open doors to the solution to the problems listed above.

RECOMMENDATIONS

Based on these conclusions, we have formulated several recommendations. We recommend that CNP+L locate the appropriate organizations that would have the responsibility to do the following:

Education

Our first recommendation is to educate the farmers about the benefits of biogas. The farmers need to be educated about the basics of biogas so they become motivated to pursue installing a biodigester on their farm. Part of this education will be in the form of a brochure that advocates for their implementation of biodigester on their respective farms. This brochure will be distributed with CNP+L, La Cámara de Porcicultura, and any other applicable organizations. We have created a brochure that contains information about the basics of biogas, a comparison of current energy uses to biogas, environmental

information, and resources for farmers to gain more information about biogas (See Appendix F).

Workshop

Our second recommendation is the development of an interactive workshop where farmers can see how biodigesters are constructed and purchase biodigester materials. It is necessary for farmers to gain first hand experience with the installation of a biodigester. In a workshop with a small number of farmers present, it is possible to demonstrate the step by step construction of a biodigester. Along with the demonstration, the materials to build a biodigester should be available for immediate purchase.

Finance System

Our final recommendation involves the advancement of a finance system that is able to assist farmers with the costs of installing a biodigester. Currently, El Ministerio de Agricultura y Ganadería, El Banco Central, and El Banco Popular have rural development programs. However, a liaison between the farmers and these organizations does not exist. If the farmers are to benefit from these programs an intermediary is necessary facilitate the process.

CHAPTER SIX: SOCIAL IMPLICATIONS

It is important to understand the implications that our recommendations would have on Costa Rica and to the world.

COSTA RICA

If biodigesters become a common tool on farms in Costa Rica, the goal towards a cleaner environment will be reached faster. The negative environmental impact of hog farm waste water will be reduced as the water released from a biodigester is eighty five percent pure. This means that the problems with contaminated water causing problems in hydroelectric turbines and drinking water sources have the potential to decrease significantly.

In addition to a cleaner environment, the use of non-renewable energy sources on farms in Costa Rica will decrease, allowing the farms to be more self-sufficient. Instead of using propane, which is imported from overseas, farmers would be able to use the biogas from their biodigesters as a renewable and domestic source of energy.

Another implication for Costa Rica would be an increase of involvement from the private sector in biogas technology. If the demand for biogas technology is higher, there would be a need for a company to supply the necessary information, support, and products. This has the potential to open the door for entrepreneurial farmers, who are familiar with biogas technology, to start small businesses related to biogas. This also has the potential to allow corporations to take the use of biodigesters to Costa Rica to a higher level. Both of these options will add jobs that require skilled workers to the Costa Rican economy.

THE WORLD

There are many countries with the same waste water problems as Costa Rica. These countries are in a similar situation with the use of biogas technology, that many people have not adopted the new technology. However, there are some countries, like China and India, which have widespread adoption of the technology. This is through the government's realization that biodigesters are a proven technology with many benefits to the farmer and the environment. Governments in China and India have subsidized the cost of biodigesters so that the farmers can afford the system. This has proven successful, as many farmers have adopted the technology on their farms.

If more countries advocated the use of biodigesters, there would be a reduction of the world's reliance on fossil fuels. This would help to solve global warming with the reduction of the amount of methane released to the atmosphere. Biodigesters have certain requirements like temperature and an adequate water supply. However, with the advancing technology, like the ability to regulate the temperature of the biodigester, this technology could be adapted for almost any climate. This means that biodigesters are not limited to the use of tropical climate zones, but could be adapted to climates with a more fluctuating temperature. The use of biodigesters can improve the environment of the world making it a cleaner and safer place for future generations.

APPENDICES

APPENDIX A

El Centro Nacional de Producción Más Limpia

The United Nations Industrial Development organization (UNIDO) is the international organization under which all National Cleaner Production Centers have been founded (National Cleaner Production Center, 2005). UNIDO funds centers all over the world from Southeast Asia to the Americas to parts of Europe and the Middle East. In total, thirty five enterprises in ten countries have been formed (The NCPC Programme, 2005). UNIDO aims at implementing green business practices in all sectors of production. The organization forms relationships between trade organizations and the government to enhance development of new technologies. UNIDO works in mostly developing countries to show how a reduction of waste and pollution can lead to better profits in the future and a cleaner environment for the countries population.

To accomplish these tasks, the centers must work closely with local governments and banking systems (The NCPC Programme, 2005). The center in Costa Rica was founded in partnership with the Chamber of Industry in Costa Rica (CICR). The Chamber of Industry was founded in 1943 to keep all sectors of industry organized and successful (Información General, 2005). It monitors national policies that directly affect industry. With the aid of international, local and public institutions the Chamber has started many new initiatives that improve competitiveness of small and medium sized businesses. These initiatives include the Eurocenter, which builds a relationship between Latin American industry and the European Union, the Excellence Award, which awards

businesses that have excellent business practices and labor policies, and the National Center for Cleaner Production (CNP+L) (Información General, 2005).

Another partner in founding the Costa Rican Cleaner Production Center is the Swiss government. In 2003, the Swiss government was funding twelve centers around the world. They choose which center to fund based on the different policies of the country. They chose Costa Rica based on their commitment to environmental protection, their emphasis on education, and the fact that they do not have an army (Benvenuti, Labbe and Michaels, 2003).

El Centro Nacional de Producción más Limpia (CNP+L) in Costa Rica was founded in 1998 (National Cleaner Production Center, 2005). The center wishes to identify more environmentally friendly ways of production. The center offers assistance to the industries so that they may implement their own green production methods. It wishes to reduce the amounts of raw materials consumed while at the same time improving the quality of products made. In addition to being more environmentally friendly, the center also wants to improve conditions for the labor force. CNP+L wants to decrease accidents in industry and health hazards for the workers (Integrando el Ambiente al Proceso Productiva, 2005).

As of 2003, CNP+L had a \$1,000,000 budget from UNIDO. Eventually, the Costa Rican center would like to be independent of the UNIDO. In order to do this, the center needs to save money on its own and create sources of income. The income of the center mainly comes from consulting and training industry officials (Benvenuti et al, 2003). Their budget pays the salary of the three main positions; the executive director,

the technical director and the project official. In 2003, the center also employed about thirty consultants who work on projects based on their expertise of a given subject.

APPENDIX B

Quick Scan

The Quick Scan is an assessment tool used to identify potential for cleaner production in industry. It addresses the environmental impact of different processes, the economic feasibility of the processes, and if there are any prerequisites for cleaner production in the industry.

There are seven objectives to the Quick Scan process. The first is to gain a basic understanding of the business sector and processes that the sector uses. The next is to inspect the actual plant. This involves collecting specific data about that particular business. Third, the data collected has to be analyzed with the help of a qualified engineer. Next, the data will be written into flow charts, specifically the materials and energy used by the plant. Fifth, with these flow charts, specific production points will be chosen to improve. Next, all of this information is written into a general summary. The final step is to decide if cleaner production methods should actually be implemented.

There are a number of types of information that Quick Scan investigates. First Quick Scan records the contact information of the business owners and their business partners. Next the environmental policy of the organization is looked at and the names of those in charge of the environmental processes are recorded. Also as part of Quick Scan, working methods are investigated thoroughly. Finally, it is essential to know if the employees are informed of any health risks and if there are ailments common to the work area. Overall, Quick Scan is a powerful tool for recording the required information so it will be further accessible for further analysis (Yvonne, 2004).

APPENDIX C

Quick Scan Questionnaire

Section 4.1 General Information

- Name of farm?
- Number of employees and working hours?
- Contact person?
- Contact Information?
- What is produced on the farm?
- Location of farm and surrounding area?
- Client Profile

Section 4.2 Environmental Policy

- What do you feel is the environmental impact of your farm?
- Have any environmental evaluations been performed?
- What do you think could be improved environmentally on your farm?

Section 4.3 Evaluation of Working Methods

- Are losses of waste evident?
- Are there waste-related process problems?
- Do employees or family members suffer from health problems?

Section 4.4 Production

- How many hogs do you have on your farm?
- How much waste is produced per day?
- What do the hogs eat?
- How much do the hogs eat?
- Where are the waste and waste-water emissions released?
- Where are the hogs kept?
- How much waste water is produced? (Cleaning hogs, pens, etc.)
- How often are the pens cleaned out?

Section 4.5 Handling of Materials

- How are the materials handled? (Description of process)
- How much water is used in handling the materials?

Section 4.6 Storage

- Where is the waste stored?
- Does a storage concept exist?
- Is the waste stored temporarily? If so, where?
- What environmental safety equipment is installed, if any?

- What is the environmental impact of the waste?

Section 4.8 Energy Supply

- What type of heating equipment is used?
- What kind of interior or exterior lighting is used?
- Are alternative forms of energy production used?
- How much propane do you use a month?
- How much does it cost per month?
- How much do you spend on electricity a month?
- Do you use any energy for the production of other farm products?
 - If so, what do you use?
 - How much do you use?
 - How much does it cost you?

Bio-energy

- Are you familiar with biogas and bio-energy?
- Has anyone ever demonstrated to you how a biogas reactor works?
- Do you know the benefits of using biogas?
- Why don't you utilize a biogas reactor?
- Would you be interested in learning more about the technology?
- Would you be interested in installing a biogas reactor on your farm?
- Do you have the finances to pay for the initial set up costs of installing a biogas reactor?

Laws

- Do you know of any laws concerning hog farming?
- Are there any laws that you know many farmers do not follow? Why don't they follow them?
- Are there any laws that are too cumbersome to follow or seem unnecessary?
- Are there any penalties for not following the laws?

Other Farms

- How many other farms like your exist?
 - Do you know of any farms that are considered informal?

APPENDIX D

Data Table of the Sample Hog Farms

	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Farm information					
Name of Contact Person(s)	Martin Zuniga Chavez, Carlos Montenegro	Adia Gavita Zuniga, Javier Montenegro Zuniga	German Chacon Ramirez	Miguel Garita Zuniga	Don Fernando Sanchez
Phone number		839-1318 cell, 815-4779 home	847-9952	301-1014	843-0195 (Cristobal Sanchez- Son)
Location of Farm	Pacayas de Alvarado	Pacayas de Alvarado	Pacayas de Alvarado	Pacayas de Alvarado	Pacayas de Alvarado
Farms Specifications					
Other animals on farm	yes	Yes	yes	no	yes
Oxen	yes	No	no	no	no
Cows	no	Yes	yes	no	yes
Worms	no	No	yes	no	no
Other products from farm	Fertilizer	Milk for Cheese	Milk, Cheese, Beans, Fertilizer	Potatoes, Beans	no
Hogs					
Total Number of Hogs	83	50	19	135	~100
Number of 'Hembras' (Females)	15	~15	6	32	10
Number of 'Machos' (Males)	3	~1 – 2	1	3	4
Number of 'Chanchillas' (Newborns)	~25	~20	11	50	~12
Number of 'Crianzas' (Adolescents)	~40	~15	1	~50	75
Washing					
Type of Cleaning	With water	With water	With water	With water	With water
Number of washes a day	2	2	2	2	2
Time of one wash	1 hour	20 mins	30 mins	2 hours	1 hour

Water Usage					
Water used to clean pens	yes	Yes	yes	yes	yes
Other water uses (besides drinking)	no	No	no	yes (cooling pigs)	no
Water Usage/month					
Size of water pipes	1"	½"	1/2"	1"	3/4"
Pay for or free	free- Flowed down hill	free- flowed down hill		free (Pump)	free (Pump)
Hog Feed					
Type of feed used	Concentrated	Concentrated	Concentrated	Concentrated	Concentrated
Feed supplements	Tortillas	None	none	none	none
Waste					
Waste Management system in place	yes	Yes	yes	yes	yes
Pipes and canals transport waste out or barn	yes	Yes	yes	yes	yes
Grates or slats in the floor of pens	yes (metal)	Yes (red plastic)	no	no	no
Separation of solids from liquids (Initial purifying process)	yes	No	no	no	yes
Use waste to feed other animals	yes	No	no	no	no
Where does the water run off to	field, river	field, open pipe, river	field, bean growing	field, bean growing	waste tank, open pipe, field

Lighting					
Types of lights used on farm	Heating lights	Heating lights	Heating lights	Heating lights, normal lights	Heating lights
Heating lamps used	yes	Yes	yes	yes	yes
Size of heating lamps	250 Watts	200 Watts	200 Watts	200 Watts	150 Watts
Number of heating lamps used on farm	~3-4	~1-2	~1-2	5	2
Hours/Day heating lamps are used	12 to 24	12	12	24	12
Number of weeks heating lamps are used with newborns	6	6	6	6	6
Energy Usage					
Amount of electricity used per month	not available	5000 colones/month	not available	1,500 to 10,000 colones/month	not available
Electricity used for	Heating, Grass Cutting	Heating, Tail-cutting, Sanitizing water for cleaning	Heating, Sanitizing water for cleaning	Heating	Heating, grass cutting
Biogas					
Biogas usage on farm	no	No	no	no	no
Familiarity with the biogas process	yes	Yes	yes	yes	yes
Interest in installing biogas on their farm	yes	Yes	yes	yes	yes
Why biogas hasn't been installed already	Farm went bankrupt and had a new owner	Problems with the paperwork with ICE and JASEC	Maybe lack of space?	Rents building	Problems getting supplies
Lack of information	no	Yes	yes	yes	no
Financial issues	yes	No	yes	no	no
Lack of physical instillation knowledge	no	No	yes	yes	yes
Enough Land Area to install bio-digester	yes	Yes	Yes	yes	yes

APPENDIX E

Data Analysis Table

Farm	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
Total number of hogs	83	50	19	135	100
kg of waste produced per day	660	398	151	1,073	795
Waste water produced per day (liters)	6,599	3,975	1,511	10,733	7,950
Amount of biogas produced per day (liters)	39,591	23,850	9,063	64,395	47,700
Time of cooking gas produced per day per burner (hours)	122	73	28	198	147
Time of heat lamp gas produced per day per light (hours)	89	54	20	145	107
Potential number of heat lamps per farm	7	4	2	12	9

Para más información sobre biogas, contacte, por favor, so oficina regional del Ministerio de Agricultura y Ganadería.

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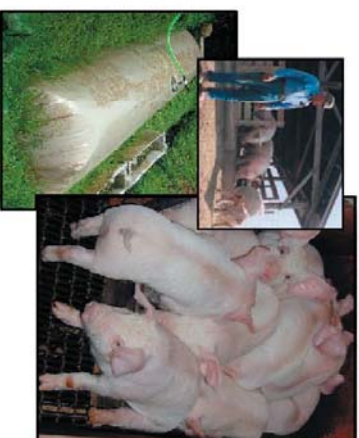
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¿Cómo Puede Mejorar mi Finca de Cerdos el Biogas?



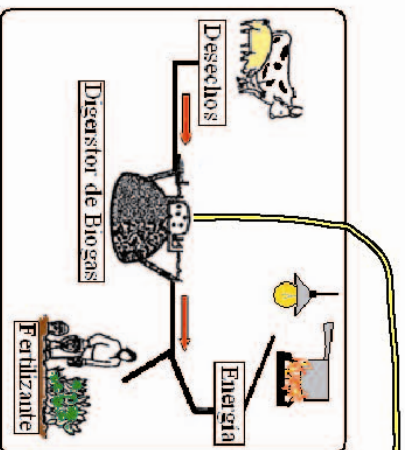
Este folleto ofrece información sobre biogas y los beneficios para los productores de cerdo.



APPENDIX F







Brochure: Spanish

¿Qué es el biogas?



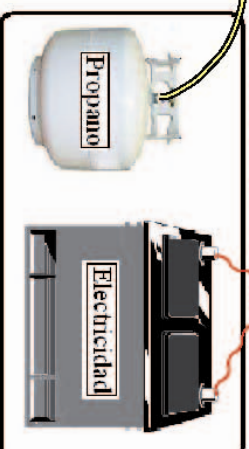
- El biogas es producido por la descomposición de los desechos animales.
- El biogas es producido en un biodigestor. Los productos son metano y fertilizante.
- Puede usar el biogas en vez de gas.
- Puede usar el fertilizante en sus cosechas y pastizales

¿Para qué puede usar el biogas?

	Con Biogas	Sin Biogas
	 Biogas	 Electricidad
	 Biogas	 Propano
	 Ahorro de dinero	 Gasto de dinero

- Biogas reduce el impacto ambiental de su finca
- Biogas ahorra dinero para Ud.
- Biogas es fácil para usar
- Biogas es un proyecto de bajo tiempo

¿Puede trabajar en mi finca el biogas?



Los biodigestores trabajan mejor en fincas con ciertas características:

- Producción consistente de desechos durante el año
- Una área bastante grande y llano para el biodigestor (las dimensiones aproximadas están 10 m de largo por 1.5m de ancho)
- Necesita separar los desechos de otros contaminantes, como la suciedad, porque sólo los desechos pueden entrar el biodigestor

For more information on biogas, please contact your regional MAG office.

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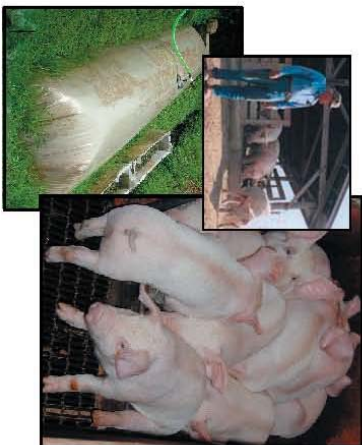
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How Can Biogas Improve My Hog Farm?

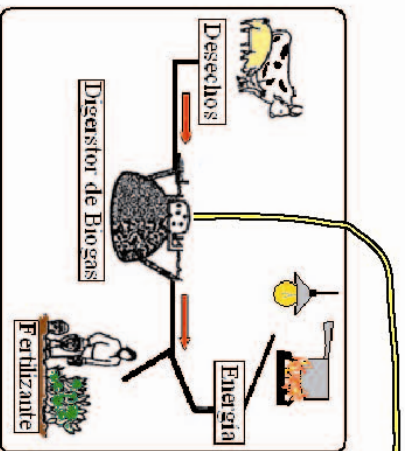


This pamphlet offers information on biogas and its benefits for the pork producing community.



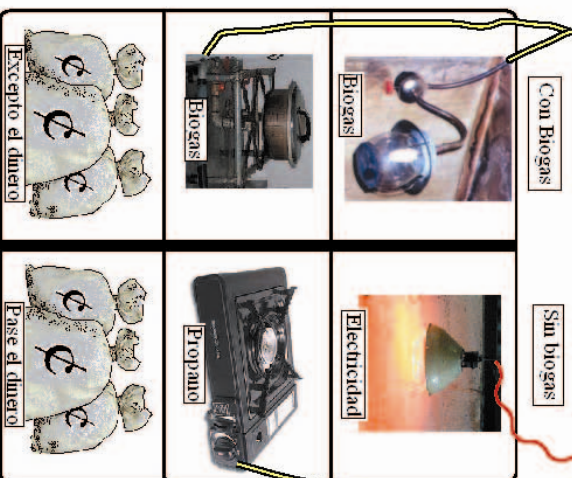
Brochure: English

What is Biogas?

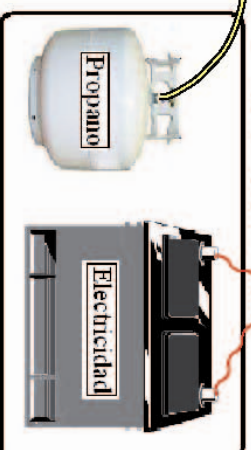


- Biogas is produced through the decomposition of animal waste.
- Biogas is produced in a biogas digester. The resulting products from a digester are methane gas and fertilizer.
- Biogas can supplement the use of propane.
- Fertilizer can be spread on fields.

What Can Biogas Be used for?



- Biogas reduces the environmental impact of you farm
- Biogas saves you money
- Biogas is easy to use
- Biogas is a short term payback of investment



Will Biogas Work on my Farm?

Biogas digesters work best on farms with a certain set of characteristics:

- Consistent production of hogs waste over the year
- Flat plot of land large enough for the digester (approx dimensions are 10 m long by 1.5m wide)
- Be able to separate animal waste from contaminants, like dirt, to ensure only animal waste reaches the digester

GLOSSARY

Anaerobic- breakdown of organic material under oxygen free conditions

Eutrophication- when a body of water is flooded with dissolved nutrients, such as phosphates, which stimulates the growth of algae. When the algae dies and decomposes it leads to a depletion of oxygen in the body of water

Flocculation- the process used to turn manure into lumps or masses

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