BIO-GAS PLANTS AND HOG FARMING IN NORTH CAROLINA

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I dedicate my thesis to my parents and family for helping me throughout my entire Duke career. They were always a step behind me pushing me towards the light. I also dedicate this thesis to the youth who march onward and upward towards the light of education. To many hog farming is more than money, it is tradition and life.

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Introduction

North Carolina stands today as the countries #2 hog producer. In recent years hog farms have generated close to 2 billion in cash receipts (more than tobacco) for the North Carolina community. Hogs over the past few years have surpassed broiler chickens as the No. 1 agricultural commodity in North Carolina. In 1987 there were 2.5 million hogs in North Carolina and by 1997 the number had grown to 10 million.(Hogwatch.com) This industry is unquestionably important for this state. The industry is a vital component of a mainly agricultural economy.

Why has the hog industry grown so rapidly in North Carolina? In 1993 the nationwide hog inventory slightly declined but the number that year in North Carolina grew. North Carolina farmers have a high level of productivity and efficiency. Agricultural schools in North Carolina such as North Carolina State University have supported the industry with research, teaching and extension programs. Their research coupled with entrepreneurs has made North Carolina a leader in the industry. As a leader North Carolina has aggressively adapted new technologies and new production strategies. (Options For Managing Odor)

In 10 years the number of hogs in this state grew by 400 percent. The astonishing growth has lead to many heated debates on the future of the industry in North Carolina. Many other states find themselves at this present time dealing the same issues facing North Carolina. Iowa the #1 hog producer is also tackling the issue of hog waste; specifically the issue of disposal and it effect on the environmental. Currently the University of Iowa is completing numerous studies that should help politicians decide the future of the industry.

Hogs generate approximately 10 pounds of waste daily, about 3,650 pounds of waste yearly. A full-grown hog produces 3 times as much waste as a grown human being. Hog factories produce 19 million tons of waste a year, which approximates to 2.5 tons of hog feces and urine per North Carolina citizen. Waste management for hog farms posses a serious problem for farmers, the environment, and the community surrounding the farms. The geographic concentration of the farms worsens the waste management problem but it is also the concentration that makes a centralized biogas plant a viable solution. Environmentalist argue the alarming amounts of waste can not disposed of effectively, thus causing a large scale environmental backlash. For example hog feces is being identified as the culprit for the increased

amounts of ammonia gas in North Carolina's atmosphere. The gas is believed to be a catalyst in the explosion of alga growth that is choking many of the states rivers and estuaries. Also hog waste is being blamed for excessive amounts of nutrients being found in the soil. Groundwater is a major concern because recent quality tests found evidence of contamination everywhere. Contaminates include nitrate-nitrogen, which causes methemoglobinemi, a disease that can be fatal to infants. (Hogwatch.com)

This paper proposes that in order to effectively battle environment problem economically, North Carolina adopt a system of centralized bio-gas plants that would serve numerous farms in a given area. Biogas plants used efficiently eliminate the environmental risks associated with hog farmers. A centralized biogas plant collects waste from surrounding farms and uses it to produce high quality fertilizer and energy.

Chapter 1

1.1 How does a biogas plant work?

A centralized biogas plant assists surrounding farmers in their disposal of animal manure by digesting it in order to create a homogeneous fertilizer. In addition to the animal manure, the plants also use organic material from slaughterhouse, fishing industry tanneries, breweries, dairies, oil mills, and the drug industry to produce the fertilizer. The mix is normally approximately 80% animal manure and 20% organic material. The farms that provided the animal manure can use the fertilizer or it can be sold to any farm or industry wishing to replace chemical fertilizer with a cheaper alternative. Biogas plants also produce a gas through an anaerobic digestion process. Heating and power plants can use the gas produced to produce to create energy. (Holm-Niesen)

Generally the raw waste material is transported to the biogas plant for disposal. The waste then undergoes anaerobic digestion.

The Anaerobic Digestion Process

The animal manure and organic waste are mixed in a pre-processing tank. The mix is then moved into gas tight digesting tanks where the digestion process takes place. During the digestion process, the mix is heated and bacterial culture, consisting of natural bacteria that adapts to the individual plant over a few weeks or months, are added to ensure digestion. The

digestion process is completely anaerobic, done without oxygen. "In the absence of dissolved oxygen, aerobic micro-organisms lend to ferment biodegradable matter to carbon dioxide and methane." After digestion is completed a useable gas (methane and Carbon dioxide) and a liquid fertilizing agent are produced.

The digestion process is continuos in order ensure a constant supply of bacteria culture and stable gas production. In a given day, the digesting tanks are emptied of gasified material and mixed raw material is pumped in. Raw material takes anywhere from 12 and 25 days to digest completely depending on heat, raw material and bacteria culture. Most plants use thermophilic bacteria operating at 50-53 degrees Celsius as opposed to mesophilic bacteria that requires heat of 30-40 degrees C. The use of Themophilic bacteria has two advantages: the process takes a shorter time compared to mesophilic digestion and the high temperature ensures a sanitary output. (Biogas Plants)

A small portion of the gas released during digestion is used to provide the heat used in the plant. A schematic representation of the process is shown in Appendix 1.

1.2 What caused a centralized system to be established in Ribe Denmark?

In the early 1990s the Danish law of environmental protection changed, requiring farmers to build facilities large enough to store nine months of waste. It also called upon farmers to increase the efficiency of nitrogen in the total nitrogen content in cattle slurry to 45% and 50% Nitrogen efficiency in pig slurry. The law also restricted the spreading of waste to only include March to October. The laws required farmers to build larger storage facilities and that posed a serious challenge to the agricultural sector. (Holm-Niesen)

In addition, Denmark had ample raw materials, a market for the degassed biomass, a responsible organization to watch over the project, and realistic financial calculations. All of these things made it possible for them establish a successful biogas plant.

Historically many Denmark farmers have their land split up in two sections. Parts of the land used for spreading decomposed waste was located on the main farm while the rest were situated far from the main operation. On average approximately 1/3 of the land farmers used as sprayfields were located on the farm and 2/3 located approximately 5 kilometers away on some well drained organic lowlands. For example if I owned 10 acres of land designated as sprayfields, almost 8 acres would be located approximately 5 kilometers away. (Holm-Niesen)

Two of the main ideas regarding the establishing of the Joint Biogas Plant in Ribe were:

- to improve the distribution of slurry to the arable land in the Ribe Area
- to improve the utilization of the plant nutrients in animal manure, if possible.

The Ribe Centralized Biogas Plant project was initiated in 1987, and production started in July 1990. The plant is owned by a limited company. Shares of the company are held by, among others, local farmers supplying manure, a group of slaughterhouse owners, the regional electricity supply company and a public pension fund. Establishment of the Ribe was part of an ambitious demonstration of Danish development in environmental protection and waste utilization by using a Biogas Plant. (A Centralized Thermophilic Biogas Plant In Denmark)

1.3 How is centralized system operated in Ribe Denmark?

The Ribe Plant has 2 primary holding tanks each of 680 M^3 (cubic meters), 1 dosing tank of 150 M^3, 3 reactors each of 1,750 M^3, 2 storage tanks each of 680 M^3, 1 gas storage tank of 1,000 M^3, and 26 local storage tanks. Currently the Ribe Biogas Plant supports approximately 80 farms and 10 industry waste suppliers. In 1992 it supported 56 diary farms, 7 pig farms and 3 mixed farms (had both pig and cattle). (A Centralized Thermophilic Biogas Plant In Denmark)

Farmers deliver their raw waste to a local storage tanks. A tank is used to prevent odor problems, and also to limit nitrogen and ammonia emissions. A local storage can serve anywhere from 1 to 19 farmers. The farmers are responsible for getting the waste to the local storage tank but the plant has the responsibility of transporting the raw material from the storage tank to the plant for digestion. The farmers pay for transportation of the waste to and from the storage tanks while the plant pays for transporting the waste form the tanks to the plant. Once the animal waste is received in the plant's sealed primary holding tanks that prevents offensive odors from escaping, located at the plant, the process of digestions is ready to begin. Before the slurry enters the reactors, where the actual extraction of gas take place, stones are removed and the slurry is mixed into a homogeneous substance through a stirring process. The Ribe plant uses a thermophilic process in order to shorten the degassing period and also to ensure a satisfactory sanitary output. After the anaerobic digestion takes place in the reactors, the digested waste or biomass is treated and tested to find the nutrient content. After the biomass or degassed material is tested, it is moved to a storage tank. From the storage tank the digested biomass is moved to

the local storage tanks located near the sprayfields. (A Centralized Thermophilic Biogas Plant In Denmark)

Once the biomass is in the local storage tanks, farmers have the option of spreading it on their land or selling it. The Ribe-Biomass Distribution Association has very thorough guidelines for selling and buying digested slurry. Most of the slurry is spread on farmland, but some is bought by other agricultural industries to replace organic fertilizer. In some cases industries purchased the degassed materials directly from the biogas plant and the material is delivered for their use. (A Centralized Thermophilic Biogas Plant In Denmark)

The biogas is used to supply both heat and power to more than 400 single-family homes and a small portion is used to provide the heat needed during digestion.

1.4 What are the benefits of the centralized system in Denmark?

Transportation

Before the biogas plant was a constructed farmer had to pay for transportation costs, because their farms were split in many cases. The plant now gives the farmers more options. The local storage tanks allow farmers to swap waste and also to sell waste. For example if my farm was located near your sprayfield and vice versa, it would make sense to for me spread my digested waste on your land and for you to spread your waste on my land. By doing that individual farmers were able to minimize their transportation cost. The biogas plant made coordination between farmers easier and more efficient. (Holm-Niesen)

There was a 65% reduction in time of transport and 95% reduction in the distance of transport. Farmers with excess waste liked the system the most because belonging to system gave then ample space to store, sell or give away their excess waste. Those who do not produce enough of their own animal manure on property can now purchase animal fertilizer and have it delivered near them. Thus it eliminates some of the transportation cost associated with obtaining animal waste. (Holm-Niesen)

Distribution of animal manure

Farms connected to biogas plant have been applying their waste to 21.8% larger area in 1992 than in 1990. Even the nitrogen content in the animal manure went up by 20% due the

addition of organic material during the gassing state, the average supply of nitrogen per hectare has been reduced by 12%. (Holm-Niesen)

Other Benefit

The Ribe plant creates energy by using resources that have not been utilized in the past. It is painting a better image of agriculture environmentally and it solves the legal problems facing the farmers in Denmark. The implementation of the Ribe Biogas plant eliminated most of the odor problems associated with farms, but the biomass smells like ammonia for a short time. (Holm-Niesen)

1.5 Economic analysis of the centralized system in Denmark?

Over 350 million dollars were invested into the Ribe Biogas plant, with 39% coming from a public investment grant. Almost 54% of the investment came from indexed mortgage loans and the rest came from private ownership. In table 2 is the information about Investment and financing for the Ribe Biogas Plant. Data taken from (A Centralized Thermophilic Biogas Plant In Denmark)

Investment and Financing for the Ribe Biogas Plant

Invested Capital	**DKK (at 1990 prices)**	**US Dollars**
Biogas plant	*28,950,000*	*236,649,146*
Equipment for slurry transport	*3,700,000*	*30,245,314*
Slurry storage tanks	*12,600,000*	*102,997,556*
Total	**45,250,000**	**369,892,016**
Financing		
Public Investment grant	*17,700,000*	*144,687,043*
(Grant % of total investment)	*39%*	
Indexed mortgage loans	*24,750,000*	*202,316,628*
Own capital (Shares)	*2,800,000*	*22,888,346*
Total	**45,250,000**	**369,892,016**

Revenue for the plant is achieved by selling the degassed slurry, selling of energy (in this case heat), and fees paid by the suppliers of the animal and organic waste. Operating costs include transportation of substrate, water supply for cleaning the stable and mixing substrate, gas

distribution and utilization, and general day to day maintenance of the plant. Staff expenses are the wages paid to human labor used in the plant.

The Ribe Biogas plant is currently stabilized (reached efficient level) and making a profit. In the early years the plant found it hard to show a profit. As the production of biogas got better and the plant began getting higher fees, they were able to make a profit. Since becoming stabilized in 1993, the plant has seen and expects to continue seeing rising profits. (A Centralized Thermophilic Biogas Plant In Denmark)

The table below details the day to day economic of the Ribe Biogas plant for 1991-95. Data Taken from (A Centralized Thermophilic Biogas Plant In Denmark)

Economics of the Ribe Biogas Plant (in 1,000s of DKK, at 1996 prices)

	1991	1992	1993	1994	1995
Revenue	4,378	6,603	6,858	7,189	7,910
Operating Costs	2,198	2,844	2,436	2,569	2,875
Staff expenses	1,708	1,529	1,772	1,726	1,805
Profit	472	2,230	2,649	2,895	3,232
Profit After Interest	(454)	1,668	1,688	2,235	2,648

Economics of the Ribe Biogas Plant (in 1,000s of US, at 1996 prices)

	1991	1992	1993	1994	1995
Revenue	35,788	53,976	56,060	58,766	64,660
Operating Costs	17,967	23,248	19,913	21,000	23,501
Staff expenses	13,962	12,499	14,485	14,109	14,755
Profit	3,858	18,229	21,654	23,665	26,420
Profit After Interest	(3,711)	13,635	13,798	18,270	21,646

On a regional economic level the biogas plant has made many contributions. Primarily it exemplified Danish resolve and pioneering spirit in establishing a centralized system and their commitment to making it work. In establishing the biogas plant as a viable and profitable alternative, it can now replace fuels like kerosene and firewood in heating the home. The energy created is a social benefit created through the plant.

Also the slurry provides a cheap fertilizer that is homogenous and more productive than other forms of animal manure. Due to the increased productivity of animal fertilizer, it can now slowly replace chemical fertilizer and end up increasing profit margin for small farms.

Environmentally the biogas plant decreases the amount of nitrogen applied per hectare, and it decreases some of the smell of the waste by not exposing it to the open air. By having a

centralized system it is easier to keep track of how waste is being disposed. It also creates an incentive for farmers to comply with environmental laws.

1.6 Rokel Pig Farm Biogas Demonstration Plant

The project started in 1996 and ended in 2000 on the Vycia farm in Lithuania in the second largest city of Kaunas. Kaunas has several education institutions such as the Lithuanian University of Agriculture and Lithuanian Energy Institute that make it the perfect place for this demonstration to take place. Involvement of the local institutions was key to sustaining the transfer of technology and operation of the biogas plant. The goal of this project was a demonstration of farm biogas and technology transfer with a direct involvement of the local industry through co-production. The need for this project came from fact that although Lithuanian farms were growing they had made no radical changes in production methods. The Vycia farm, a pig farm, where no arrangement had been made to use the animal waste as fertilizer, was a perfect place to demonstrate the effectiveness of the technology.

Although the plant only served one farm it showed that hog waste could produces enough biogas to supply a farm with electricity. The demonstration was complete success. It showed that a project such as this was sustainable if and only if production of biogas was kept high. Holel farm is evidence that hog waste can be disposed of in alternate ways.(Holel)

Chapter 2

2.1 A brief description of how the system would work in North Carolina.

North Carolina could incorporate a system similar to one found in Ribe Denmark. North Carolina would use a system of centralized plants distributed strategically over the Southeast Region of the state. Again the placement of storage tanks would be done in a way that minimizes transportation cost. All the farmers would provide a pro-rata share of the investment cost based on the size of their farm relative to all the farms in the states. Because residents of North Carolina are affected by externalities stemming from hog farms, the state should invest a percentage comparable to the Danish Government. Any other outside groups or corporations who desires to invest in the centralized biogas system would be allowed to do so.

Farmers utilizing the plant would pay a reasonable fee to have their waste disposed by the biogas plant. Organic material would either be donated or bought in order to improve the

fertilizer and make it a better product. The energy produced by the plant would be used to run either neighboring houses or farms in close proximity to the plant. The Holel farm provides an example that hog farms can be run on biogas power. It is also commonplace for excess power to feed into electrical grids. In Denmark this acted as an incentive for investment by the local electricity supply company. The fertilizer produced would be sold to farms and other industries that are looking to replace chemical fertilizer. A centralized biogas plant is a viable solution for North Carolina because North Carolina desperately needs a universal system that can implemented to combat the rising problems associated with hog farming.

2.2 Why North Carolina needs a better way to dispose of waste

Water Quality

In North Carolina there are 3,800 lagoons and 550 abandoned lagoons. Most of the lagoons are located on lands that drain to the states coastal waters such as the Albermale and Pamlico estuaries that are premiere fisheries.(Hog Lagoons) Most lagoons are also located in the southeastern third of the state, which has sandy soils, high water tables, shallow drinking water and an extensive networks of rivers and streams. The location of the lagoons in North Carolina poses a serious control problem for the functional life of the lagoons.

Problems with Lagoons:

If designed correctly and maintained regularly, lagoons can perform indefinitely. However, poorly designed or abandoned lagoons can pose a serious threat to the environment. North Carolina's lagoon construction standards are set by the U.S Natural Resources Conservation Services (NRCS) but they are not sufficient. For example they do not require any monitoring of a lagoons once built. Land differences from acre to acre can contribute to the leakage of lagoons. The NRCS allows a leakage rate of .003 foot a day, which adds up to about 350,000 gallons an acre, a year or more than 1 million gallons a year for 3 acres. (Hog Lagoons)

In a study done by the North Carolina Division of Water Quality, Ground Water Section, it was found that 6 out of eleven lagoons studied was either moderately vulnerable or vulnerable to leakage.(Impact of Animal Waste) Although the scope of the study was not very large, it does clearly show North Carolina is at risk. Although the study showed that 6 out 11 lagoons were vulnerable, it does not mean they would always eventually leak and cause contamination.

What happens when lagoons are not properly constructed and monitored?

With improper leakage and maintenance the leakage rates are high and large amounts of contaminates such as ammonium and nitrate seep into the ground water. The ammonium sticks to soil until bonded with oxygen then it becomes nitrate. The nitrate does not stick to the soil and washes away into the ground water. Along with nitrate, other pathogens found in animal waste can also seep into the ground water. Later in this report I will discuss how pathogens can be effect humans beings. Shallow wells located in close proximity can be exposed to high levels or nitrates due to leakage. (Jackson)

If not monitored lagoons can overflow and allow raw waste to seep into the groundwater. There are many examples in North Carolina of poorly managed lagoons spilling large amount amounts of waste into surrounding waterways. For example in mid-1995 an 8-acre lagoon spilled 22 million gallons of waste into the Neuse River (Exxon Valdez was 11 million gallons of oil). killing 10 million fish and closing 365,000 acres of coastal waters to shellfish harvesting and commercial fishing. In that same year many other lagoon spills occurred. The Neuse River for several years experienced rapid alga growth due to high levels of nutrients in the water. In 1997 the environmental group American Rivers declared it one of the most threatened rivers in the United States.(Animal Waste Management)

Abandoned lagoons have no check and balances and thus posse the greatest threat to North Carolina. Abandoned lagoons can have nitrogen levels 13 times higher and phosphorus levels 45 times higher and other heavy metals than can seep into the ground water.(Hog Lagoons) In times of heavy rainfall the lagoon may overflow and the heavy metals can run off and seep into the ground water.

Sprayfields

Sprayfields are acres of land where the sludge removed from the lagoons will be applied. (Hogwatch.com) High-powered spray guns shoot the sludge onto the fields to act as fertilizer. Sometimes the manure is directly injected into the soil for better absorption. If this process is done properly, hog manure can be a valuable agriculture asset, but in most cases it is not. If the proper amount of manure is applied routinely hog manure does not posse a threat to the

environment. There are many factors that should go into determining how much manure a field can take

1. Each batch of manure should be assessed for nutrient value. Unlike industrial fertilizer the chemical makeup of hog manure is not known and changes from batch to batch.
2. Periodic soil testing will help keep chemical levels normal. Even with testing of hog manure even distribution posses another major problem. Hog manure is heterogeneous and thus the soil must be tested.
3. Producers should determine application rates based on crop need for nitrogen
4. Phosphorus need should also be considered when applying waste. Often times if waste is applied to meet nitrogen levels, phosphorus is over applied.
5. Detailed record keeping will make the entire process quicker, cleaner and easier to manage. (Swine Manure Management)

When these things are not done it is quite possible for too much manure to be applied. When too much manure is applied to a spray field the environment could suffer as a result.

What happens when manure is applied incorrectly?

If manure is applied in to a field in amounts exceeding the needs of the land, it posses a serious threat to the environment. Nitrates, phosphorus, sodium, potassium, copper and zinc can build up in soil and by run off or erosion, end up in rivers and streams. Although nitrates are vital for the plants, excess nitrates can seep into ground water. It is difficult to asses the impacts of field application of manure on ground water because once contaminants are in the water it is hard to distinguish where they came from. (Jackson 1995)

In addition, depending on the slope of land, soil texture and cover conditions highly soluble nutrients such as sodium could possible find its way into wells and other waterways.

Housing and Buildings

Potential sources of problems are the pits located underneath housing systems. The pits are normally constructed of concrete and they act as holding facilities until the waste can be transported to a lagoon. Lagoons receive most of the attention but pits also pose a serious threat to groundwater. If the concrete in a pit cracks over time, it would be virtually undetectable and

untreated waste could seep into ground water supplies. (Chastain, 1996) In North Carolina this is a serious threat because of the shallow drinking water and high water tables. (Option for Managing Odor)

Carcasses

Dead animals if not disposed of correctly can decompose and leach numerous nutrients and potagens (diseases contracted during life or disease causing bacteria) into the soil and possibly into groundwater. Most carcasses are disposed by land fill, on farm burial rendering, or incineration. Improper disposal can cause infectious diseases to leach into the drinking water. (Options for Managing Odor)

What are the results of nitrate seepage?

Nitrate is made up of Nitrogen and oxygen. Nitrate in soil is essential to crop production. However excess nitrate in soil increases the chance of contamination. Once nitrates are in the ground water the results can be devastating. High nitrate levels in rivers, lakes, and streams can increase or cause algae growth. Rapid alga growth can cause fish and other aquatic organisms and wildlife to die off. Nitrate also posses numerous adverse health effects on human beings. (Nitrate in Soil)

In North Carolina 10 percent of the wells near large hog and chicken operations have abnormally high levels of nitrates in the drinking water. Wells below sprayfields used by hog and chicken farms in North Carolina have nitrate concentration above public health standard. (Water Quality)

What are the results of Phosphorus pollution?

Phosphorus is essential for all living plant life but in excess it also becomes a contaminant. Over abundance of phosphorus contributes to excessive growth of algae and other plants, accelerating the eutrophication of surface waters. Eutrophication is a process by which a body becomes rich in dissolved nutrients and, often deficient in oxygen. Eutrophication due to plant growth and subsequent decomposition limits the use of surface waters for aesthetic recreational, industry, and drinking. (Voss 1998) The recent spills such as the Nuese River exemplify the fact that phosphorus can quickly become a problem for North Carolina.

Air Quality

Odor on hog farms is associated with ammonia, hydrogen sulfide and heavier compounds maybe such as skatole and indole. Even though they are associated with them, they do not always correlate well with the human perception of odor. It would seem that swine manure odor consists of a complex mixture of organic compounds. They are other complex things going on that ammonia and hydrogen testing cannot account for. Environment, the compounds present in the manure, and the decomposition process itself will decide mixture of compounds in the air and the resulting odor. Hydrogen and ammonia testing are not good ways to regulate or identify a strong or a weak odor. In fact no chemical test or compound marker have been identified which is applicable to a wide range of odors. The alternative would be to use electronic sensory nodes that can measure relative emissions. (Option For Managing Odor)

Air Emissions From Lagoons

Lagoons increase the exposure of anaerobic liquid to the atmosphere, which will increase the opportunity to release large amounts of pollutants into the air. The bigger the lagoon the larger the surface and the higher the concentration of the organic compounds down wind. Lagoon have been known to release as much as 150 volatile compounds, most of which are presumed to be product of anaerobic, microbial degradation of waste constituents. (Spoelstra 1980) There is a direct connection between the compounds found in the air around hog farms and the compounds found in the waste. This supports the assumption that the odor around hog farms arises from the waste. The large number of lagoons and their concentration creates a significant odor problem.

Spray field

If the manure applied to fields have received adequate treatment odor should not be a problem. When under treated anaerobic sludge is spread across a field, compounds may volatize rapidly. The volatile compounds may rise and move downwind and cause a disturbing smell. The smell will subside in a couple of days. (Jackson 1995)

Carcass Disposal

A hog farm with 1000 sows on can produce over 40,000 pounds of dead pig annually Dead pigs in North Carolina are often disposed of by landfill, on farm burial, rendering or incineration. From the time of death to disposal, if the carcasses are allowed to decay, they will release an offensive odor.

Buildings and Holding facilities

If waste accumulates in the hog houses decomposition begins and odors intensify. Also if manure builds up inside, the animals themselves will begin to emit disturbing odors. This part of pig handling like all the others, if done wrong will produce strong smells. (Options for Managing Odor)

Methane Gas and the atmosphere

The most abundant gas in the atmosphere is methane and humans are major source of it. Methane is a more potent greenhouse gas than carbon dioxide on a molecular basis (21 times) and on a mass basis (58 times). (Jackson 1995) Hog farms do contribute to the emissions of methane into the atmosphere but the portion of the total emissions is very small. Aerobic treatment, soil incorporation and lagoon covering could achieve reduction of methane.

Ammonia

Ammonia is not a major greenhouse gas. Ammonia readily combines with acids such as hydrochloric acid, nitrous acid, and sulfuric acid to form ammonium aerosols. As an aerosol it can be transported over long distances making it a large-scale pollutant. The deposition of certain aerosols can potentially be more acidifying for soils than strong acids such as sulfuric acid. Deposition of these aerosols can seriously effect the health of the surrounding vegetation. (Protect our Waters)

Prior to reaction, ammonia can penetrate clouds and form acidic clouds which leads to acidic mists. The mist can potentially harm foliage. Ammonia emitted from livestock operations contributes to the problem of acid precipitation and ammonia disposition contributes to excess nitrogen fertilization. Excess fertilization can also lead to leaching of nitrates through the soil into the ground water. (Melvin 1995)

Nitrogen

Lagoons typically release 70-80 percent of original nitrogen to the atmosphere.(Jackson 1995) Most is lost as ammonia, but a small portion is lost as nitrous oxide, and a very small portion as dinitrogen gas. Plants can immediately use nitrogen in rain that falls on crops. When nitrogen does fall on roads, streets, lakes, streams and ponds it can cause negative environmental impacts. It can trigger alga blooms that could destroy coastal waters. Nitrogen can also fertilize unwanted plants that could choke off wanted plants. It could make wild grass grow faster creating problems in forests and parks. (Jackson 1995)

Social

Citizens are concerned about the health risks associated with living near hog farms for an extended period of time. Concerns about human health stems from extensive exposure to odors, water contamination, poor air quality, destruction of waterways, and flies. Researchers are challenged to determine the exact relationship between hog farms and human health. They must determine whether there is a direct causal relationship or a weak correlation. Determining the exact relationship between hog farms and human health will play a pivotal role in the future of the industry. Today most studies have concentrated on the health challenges facing farm workers. Not many studies have concentrated on the health and mental effects of living near large hog farms because it is difficult to determine the point origin of pollution. Point origin is a determination of exactly where the pollutant came from or what produced the pollutant. Although there has been work done, much more research is needed in order to reach a definite answer about hog farms and human health. Work is needed to determine specific issues such as whether or not the incidence of asthma increase with the concentration of hog farms. Studies are needed on a large scale over an extended period of time. In addition the studies would have to use a study group large enough and diverse enough to draw a statistically valid conclusions.

Although nothing definite can be said about the relationship between hog farms and human health, there are however several definitive issues pertinent to human health raised by people living in close to hog farms. In this section of my paper I will try to flush out some of possible health issues facing North Carolina with respect to hog farming.

Physical health of Workers and Air Quality

The health issues facing workers have become more pronounced as the industry continues to grow in size and concentration. In the 1960's the industry began moving to confinement growing houses and away from older conventional livestock houses. Confinement houses are more enclosed and tightly constructed. They also house a larger numbers of animals, allowing farms to grow more hogs. Today's houses can have anywhere from 800 - 4000 hogs per house. The animals spend, 24 hours a day, seven days a week, the duration of their lives in the confinement houses. The buildings are equipped with waste management systems that flush the animal waste into a holding pit until movement to a lagoon for decomposition is possible. Also the buildings are heated and ventilated using large machines, but often times both are poorly done. Due the large number of animals being housed in a single confinement unit, and the high amounts of waste produced by the hogs, air quality quickly becomes a problem. (Okum 1999)

Air quality is not only a threat to the workers but to animal health and productivity. Hogs grow faster with better air quality. (Donham 1993) Air quality is a problem because of the large number of gases present inside a confinement house. Over a hundred identifiable gases can be found in a standard confinement house. Employees who work in these hog growing structures are exposed to the Threshold Limit Value (A value that represents gas concentration). Proper, effective ventilation will limit the possibility of the gases exceeding that Limit Value.

- How and what the animals are fed: The food an animal eats will determine the make up of their waste and thus the gases released.
- How well the facility is managed: A better-managed facility is a safer one.
- Animal waste management including frequency of wash: If the waste is flushed out of the building routinely then gases will be limited.

Large numbers of gasses and/or particles are emitted from swine intensive livestock operations. The gases and/or particles are a well-documented problem for those who work on hog farms. Workers have been shown to experience scratchy throat, morning phlegm, cough, burning eyes, wheezing, and shortness of breath and chronic bronchitis. Also workers in confinement house have been found to experience increased organic dust syndrome. Organic dust syndrome is characterized by symptoms including fever, malaise, muscle aches and pains, headaches, cough and tightness of chest. Symptoms can occur directly after or up to six-hours

after working in a confinement house for a duration of time. Symptoms are more likely after working in excessive dusty operation such as handling, moving, or sorting the animals. The dust found in confinement house primarily consists of hog epithelium, but bacteria are also present. Endotoxins are the primary lipid component of the outer membrane of Gram-negative bacteria and are the cause of cause of chronic respiratory symptoms of workers employed in swine containment facilities.

In a study from the University North Carolina at Chapel Hill, School of Public health, cough and phlegm were experienced by 12-55% of the workers depending on the particular intensive livestock operation studied:

> Coughing, chest tightness, nasal and eye symptoms can occur within 30 minutes of entering the confinement structures, but typically require two or more hours of exposure. Symptoms usually disappear after one to two days; however, they can persist for long term employees. Workers symptoms in response to employment in swine growing houses are more frequent and severe among smokers and by those who work in large swine operations. Health effects are also greater among those with preexisting respiratory problems, such as hay fever and bronchitis and among those with heart trouble or allergies. (Okum 1999)

In addition health effects such as bronchitis is experienced by 25% of all swine confinement workers

A major concern for workers is exposure to hydrogen sulfide. Hydrogen sulfide at high levels can cause sudden collapse and is associated with respiratory paralysis and pulmonary edema and even death. Hydrogen sulfide becomes present when hydrogen is released and reacts with the necessary compounds, during the decomposition of waste.

Prolonged exposure to the dust found in confinement houses, where the dust exceeds a threshold of .23 milligrams per cubic meter, a worker's lung function decreases significantly over the course of a workday but lung function normally returns to normal soon after. Over a long period of time the body will not longer be able to completely heal and permanent damage will result. (Okum 1999)

Hog farms present a clear and documented threat to the health of those employed in them. This part of the issue has received little or no attention because those employed hog farms are often times low income community residents or immigrant workers who have very little political influence.

Physical health effects for neighbors

There is a disagreement among researchers on how odors affect the physical health of those living near the farm. Due to the low concentrations of gases, some believe that there is no significant risk to health, and odors only represent a degradation of quality of life nuisance rather than a present health threat. (Okum 1999) Some would like to attribute health effect supposedly caused by hog farms to the agricultural community at large. This argument is based on the fact that it is almost impossible to distinguish what effects are caused by hog farms rather than by some other form of agriculture. However recent studies have shown that living adjacent to hog operations may directly pose some adverse health threats.

A study done in Dr. Thu of Iowa University suggested that residents living in close proximity to hog farm incur certain health risks. In the study, people living in close proximity complained of symptoms similar to those found in workers in the confinement houses. Eighteen people living in a two-mile radius of a 4000 sow production were interviewed in their homes and other places. They were compared with a control group of 188 people who did not live near hog farms. The interviews were done in three sections. Section one elicited factual information such as name, employment, residential history and previous occupational exposure. The second section elicited symptoms indicative of health status. The third section elicited qualitative information by asking very open-ended questions. The study group reported 14 out of the 18 symptoms know to represent toxic or inflammatory effects on the respiratory tract, more frequently than the control population. They did not find a correlation between distance from the hog farm and the frequency of the symptoms. The test concluded that people living in close proximity more frequently show symptoms similar to workers of hog farms.

The study was criticized because of the small sample. Many researchers believe that a large sample is needed in order to draw definite conclusions about health effects Although study's methods of interviewing people in their homes provided the best opportunity of collecting reliable information, the researchers also concluded that further study is needed..

Mental Health Effects of Odor

Living in the vicinity of a hog farm and being continuously bombarded with the sights and smells of hog farming could potentially cause stress. The perception that your property values are declining, along with the increase presence of rodents and insects could possibly cause more stress. Given peoples emotion attachment to their community and the financial investment involved in their homes, it is not surprising that this issue could effect ones mental health. The smell of hog farms for those living near them is often associated with loss of control over their lives. Paranoia triggered by recent reports about the effects of breathing polluted air makes the possibility of hog farms having adverse mental effects, real. (Schiffmann 1995) For example reports are the adverse effects of second hand tobacco smoking makes people fearful of even slightly polluted air.

The two well-known studies done on the effects of hog farm exposure on mental health. On the other hand Dr. Thu of Iowa University (the fore mentioned study) found no such connection in his study. Although the primary goal was determining the health affects of living in close proximity to a hog farm, this study did try to determine whether or not living close to hog farm cause mental health problems. They concluded that little difference in mental problems existed between the study group and the control group. The hypothesis is that constant contact with odors can cause increase depressive symptoms. The Thu study hypothesis found that little difference in symptoms exists between the study and control group. It also found little difference in anxiety symptoms exists between the study and control group. The researchers stated that more research is needed in order to determine a direct relationship. (Thu 1997)

Susan Schiffmann, odor specialist from the Duke University Medical School, conducted a study in which she did find a direct connection between mood and living in close proximity to hog farms. Dr. Susan Schiffman in 1995 studied the effects of environmental odors emanating from large-scale hog operations on the moods of nearby residents. She sampled 44 persons living near a hog farm operation and 44 control subjects who were matched according to gender, race, age, and years of education. Using the Profile of Mood States (POMS), the results indicated a significant difference in mood between persons exposed to swine odors and the control subjects. Subjects who live near the hog farm had significantly more tension, more depression, more anger, less vigor, more fatigue and more confusion than control subjects.

In a paper written in 1998, Schiffman does help us understand the dynamic, health symptoms such as the ones associated with hog farms can be learned. If people are conditioned to believe something is harmful the brain can trigger a response matching the conditioned one. Also due to the huge amount of negative public attention given to hog farms, it is possible for people's environmental attitudes about safety to affect health. Simply the reported beliefs about the safety of an odor can have an effect on its perception.

Water Quality Health Effects

Nitrates and Human Health

The leaching and accumulation of nitrates into the ground, surface or drinking water pose a serious threat to human beings. The consumption of water with nitrate levels above 10ppm in concentration can be harmful to people who drink the water. Children under five, older people and those with suppressed immune systems are the most at risk when consuming water high in nitrates.

In 1996 Dr. Rudo a toxicologist with the Occupational and Environmental Epidemiology group lead a group that tested drinking wells located near North Carolina hog farms. Sampson and Robeson counties, the two counties with the largest hog population, had 10 and 22.5 percent of their wells respectively with 9.5 ppm of nitrate. Three wells in Robeson County have nitrate levels in the 70-100ppm range. Results such as these are of particular concern because people in rural areas are highly dependent on shallow drinking wells. However it was not possible to link the elevated nitrate levels directly to hog farms

If people in rural area are exposed to high concentrations of nitrates they could develop methemoglobinemia, more commonly known as Blue Baby Syndrome. As nitrate enters the human body and produces nitrite, which converts hemoglobin to methemoglobin, which does not transport oxygen as well. Less oxygen in the body is a special concern to vital tissues and the brain because it can cause cyanosis, dysnes, lethargy, coma, brain damage and even death. Children during their first six months of development are more vulnerable because their hemoglobin is more reactive. Also children's bodies facilitate the conversion of nitrate to nitrite faster than adult bodies. Elderly and pregnant women are vulnerable to methhemoglobin.

Pregnant women who consume water with high nitrate levels not only place themselves at risk but also their risk unborn babies. Research suggests that women who consume nitrate-

contaminated water have an increased risk of delivery of an infant with a central nervous system malfunction. In an article in the Raleigh News and Observer in July of 1996, T. Meyer documented that women in India who lived close to hog farms had numerous miscarriages. After stopping their consumption of nitrate contaminated water and replacing it with bottled water, the miscarriages stopped. Of course there was no direct proof that the nitrate contaminated water was caused by the nearby hog farm. History highlights the main problem with linking health problems with hog farms. Once water is contaminated there is no real way of determining what caused it. Unless there is a major lagoon spill, nitrates in water can originate from multiple forms of agriculture.

The problem of water contamination and health trouble is further complicated by the fact that water is not stationary. Contaminated water can migrate via the water cycle or the simple movement of rivers. Humans who spend large amounts of time in potentially contaminated water are at risk. Commercial fisherman, underwater divers are experiencing similar problems, including but not limited to open sores on their skin as a result of contaminated water. (Okum)

Infectious Disease

Many bacteria, viruses and protozoa live in the intestinal tract of hogs and many can be pathogenic to humans. Workers and those who come in direct contact with the animals are primarily at risk. It is however also possible that the during the waste and carcass disposal, infectious diseases can leach into our drinking water. Studies show that over 25 percent of swine studied harbored salmonella species in their feces. Some of the species of salmonella were capable of infecting human beings.

It is also possible for human who comes in contact with hogs to contract a disease. In a study done of North Carolina workers in 1995 found that 19% had contracted brucellosis. Of 154 studied, 105 reported experience symptoms consistent with brucellosis during the previous year. Common symptoms included chills, fever and headache.

2.2 Why are biogas plants a viable solution for North Carolina?

There are no prohibitions on the use of the slurry (animal waster)

North Carolina has no standing laws prohibiting the use of animal fertilizer on plants. Due to the rising cost of chemical fertilizer and increasing emphasis on sound manure

management to protect water quality, organic fertilizer is receiving renewed attention. Organic fertilizer is being looked at a cost effective replacement for chemical fertilizer. If organic fertilizer can produce crops as effectively as chemical fertilizer, a market would develop. Biogas plants produce a homogeneous product that can altered to make better fertilizer, using organic waste from slaughterhouses. In the end a centralized system would produce enough organic fertilizer that a steady market could be formed.

There are no prohibitions in the use of biogas..

In the United States biogas technology is not as developed as in Denmark. Because biogas is not largely produced and used in the United States, there are no restrictions on its use. As a result biogas can be used in North Carolina to produce electricity or heat. .

There is an increasing regulatory trend in politics surrounding hog farms.

1995 - Senate Bill 1080 - The Swine Farm Siting Act Effective October 1, 1995

- This law imposed mandatory statewide setback requirements (unless waived in writing by neighbors) on all new or expanded factory hog farms; Hog houses and waste lagoons: at least 1,500 feet from any occupied residence; 2,500 feet from any school, hospital, or church; 100 feet from any property boundary.
- Waste application (sprayfields): at least 50 feet from any residential property boundary; 50 feet from any perennial stream or river, other than an irrigation ditch or canal.

1996 - Senate Bill 1217 - An Act to Implement Recommendations of the Blue Ribbon Study Commission on Agricultural Waste

- This law imposed several new requirements relating to permitting, oversight, siting, public notice, and enforcement for factory hog, poultry and other livestock operations.
- The law restored partial zoning authority to counties. Authorizes counties to adopt zoning regulations for hog farms with a design capacity of at least 600,000 steady state live weight (or approximately 4,500 hogs).

1997 - House Bill 515 - The Clean Water Responsibility and Environmentally Sound Policy Act

- This law imposed a partial moratorium on new and expanded factory hog farms, directed the state to develop a plan to phase out anaerobic waste lagoons and sprayfields, and imposed additional requirements. The law required setbacks from hog houses and lagoons to be at least 2,500 feet from any outdoor recreational, facility, national park, state park, historic property, or child care center; at least 500 feet from any well supplying water to a public water system; and at least 500 feet from any other well supplying water for human consumption.

1998 - House Bill 1480 - An Act to Provide for the Registration of Swine Farms Associated with Swine Operation Integrators and to Extend the Moratorium

- This law extended the moratorium on new and expanded factory hog farms by six months and required contract hog growers to provide information to the state regarding the swine operation integrator with whom that farmer has a relationship. (Hogwatch.com)

Increasing regulations is making it harder and harder for hog farmers to earn profits. North Carolina's hog industry is dominated by the contract farming and contract farmers make very small profits. In the end policies that increase the cost of farming are going to directly affect the hog farmer. The hog farmer is soley responsible for the disposal of hog waste and thus are the ones being affected by policies to protect the environment. If hog farming is to remain economically viable farmers will need new technologies and financial assistance.

Other Technological solutions are less beneficial.

In a report produced by an organization, it details many other technologies that could be implemented. (Cochran) For example there is a system called Solids Ecoraactor. The system processes animal manure and wastewater into a biosolid that is low in nitrogen and can be applied to land. A system such as this allows excess ammonia to be released into the atmosphere. Ammonia is a greenhouse gas that in excess is bad for the ozone layer. Also Solid Ecoreactor do not attack the major problem of odor. (Cochran)

The major flaw with all the other technological solutions is that they are all done independently. Farmers must implement their own system, thus paying the initial investment costs falls on each farmers. Also larger farms are better equipped to make large investments on waste management while smaller farms are not. Smaller farms will find it harder to cope with conservative legislative trend. Thus implementing a system other than a centralized one will disproportionately hurt small farmers. With a centralized biogas system each farmer does not work independently. Each farmer would invest a pro-rate share based on how much waste they produce.

It is very unlikely that the increasing regulatory trend continue.

The general assembly of North Carolina appropriated funds in 1999 for the demonstration of a highly efficient process to convert animal waste to biogas. The bill titled, "Animal Waste Tech, Demonstration Funds" was passed on April 25, 1999 and gave a sum of $400,000 to the Animal and Poultry Waste Management Center of North Carolina State University. The bill shows that the General Assembly of North Carolina is very much in favor of finding an economically and environmentally attractive way to dispose of animal waste. Once it clear that other technologies exist that are cost effective, the assembly will continue to lay the framework for more environmentally friendly laws.(House Bill 1454)

Governor Jim Hunt in April 1999 released a 10-year framework to replace lagoons and sprayfields with alternative technologies. The plan called for stronger environmental laws and the conversion of all lagoons and sprayfield by 2009. Jim Hunt set the stage in North Carolina for change and the general assembly is slowly responding.

Environmentally the plan will have a positive effect.

Biogas plants will eliminate the problem of odor by storing all the waste in covered containers. The covered containers will limit the amount of ammonia and nitrogen released into the atmosphere. Also after the waste is digested proper integration of the homogenous waste into the soil will reduce ammonia and nitrogen lost. In addition by storing the waste in covered containers instead of lagoons, the problem of leaching is decreased. Leaching can occur if the organic fertilizer is applied to land incorrectly but biogas plants make it a easier proposition to control leaching. Biogas plants produce a homogenous fertilizer than can be monitored

effectively during application process. Environmentally biogas plants would either minimize or eliminate most of the environmental problems resulting from hog production.(Biogas Website)

Water and Air quality would improve because the waste would not come in contact with either until after the digesting process. Or course once the slurry is digested if it is improperly applied to land, it can pose a threat like any other fertilizer. (Biogas Website)

North Carolina's success gives it the ability to pay for new technology.

The replacement of lagoons with new technology should not be viewed as threat to farms in North Carolina. The recent financial success of hog production in North Carolina makes it possible for them to replace lagoons. It can be argued that not only is switching technologies social beneficial, but also economically feasible and even desirable. Hog production in North Carolina is ahead of competition in other statistics due to improvements in hog breeds (higher reproductive efficiency), nutrition (better feeds), management practice, confinement facility design, and contract farming. As a result hog producers in North Carolina have some of the lowest productions costs, which translates into higher profits and a competitive edge over other hog producers. The competitive advantage of hog production in North Carolina is made better by the fact that the current waste management systems externalize most of the costs. North Carolina residents end up paying for the lack of innovation in disposing waste in North Carolina. The U.S Department of Agriculture Resource Management Study provides data on hog operations by region. The date showed that the Southern Seaboard region, a region dominated by North Carolina, has lower total costs than other regions. (Cochran)

Economies of scale provide a significant cost advantage for hog producers in North Carolina. Even if North Carolina hog producers had the same costs as producers elsewhere, they are able to spread them over a larger number of hogs. For example while the southern Seaboard region's farrow to feeder operations sold on average 13,753 feeder hogs the Eastern Upland region producers sold on average 7,220. Operating costs are about 40 percent lower for operations with 10,000 or more head of sales than for operations with less than 500 head sold. This is mainly due to less overhead per hog in larger operations. On average in the Southern Seaboard Region finishing operations sold 10,690 hog while finishing operations in other regions average from 950 to 2,500. Again the large farms saw lower operations costs. (USDA)

The production industry in North Carolina is prospering but contract farmers, the ones who must deal with the waste issue, are doing as well as the integrators. A contract farmer enters a contract with a integrator to raise hogs to market weight. The integrator provides supplies, the hogs, the feed, veterinary services and other inputs and oversees the management of the grower's farm. Contract farmers are paid a set amount per hog, but the price can be adjusted depending on the quality of final product. The integrator owns the hog and virtually all aspects of production but the farmer is responsible for all waste management. The setup enables integrators to focus capital elsewhere, such as improving genetics and feed mixtures. Also it enables integrators to better leverage capital and it eliminates legal risk due to waste. (Cochran)

In fact integrators earn several times time the revenue of contract grower, mainly because they own processing plants. For example the net income per hog varies from -1.14 to 1.92 for contract farmer, compared to 1.59 to 25.62 for the integrator. The current system benefits integrator so much that integrator such as Smithfields made record profits in 1998 even though hog prices dropped sharply. In order for any system to work integrators must be made legally liable for waste. (Cochran)

Overall the hog production in North Carolina is much more efficient than hog producer elsewhere, thus it can better manage waste disposal without losing a competitive advantage.

2.3 Why are biogas plants not a viable solution for North Carolina?

Even though there are numerous strong reasons for a centralized system to survive in North Carolina, there are however impediments that will make the task hard. The political landscape in North Carolina will make it very hard for laws to be passed that will make it possible for a centralized Biogas system to be put in place. For example, Wendell Murphy, Chairman of Murphy Farms, former state senator, and member of the Senate Agricultural Committee in North Carolina, might oppose change that did not favor large hog farms in North Carolina. Before the hog issue was negative framed, he supported a Sales Tax Exemption in 1986 that exempts materials used for repairing or improving livestock structures from sales tax. Also in 1991 he supported the zone exemption (s148) that includes corporate hog production facilities within the definition of "farm" to preclude counties from local control but this law was later overturned. Wendell Murphy is not the only wealthy hog farmer serving in the North Carolina legislature. John M. Nichols, chairman of the State House Environmental Committee,

was building a 2,400 hog farm in 1997. House Majority Leader Leo Daughtry owns interest in a ham curing company. The Pork Producers Association Political Action Committee in 1994 reported that they contributed to 122 candidates: 12 for U.S House of Representatives; 31 for the North Carolina Senate; 75 for the North Carolina House of Representatives; and 4 for county commissioners. (Thu)

The major players in the pork industry would rather not have major change. If integrators were made liable for waste, they could potentially loose a great deal of money. Today contract farmers are responsible foe waste clean up, a very large expense, while integrators make up to 10 times the profit. If the current arrangement between integrator and farmers stays the same, this is an unfair assignment of environmental responsibility.

2.4 What needs to be done in order to make it a viable solution of North Carolina?

For this plan to be a viable solution for North Carolinians, every farm must participate, integrators must be held accountable, and lagoons must be phased out. All farmers in North Carolina with more than 300 hogs will have to participate regardless of what technologies they are using. The use of other supplemental technologies will not be outlawed but unless they threaten the environmental integrity of the project by exposing the environment to undue risk.

Integrators would by law become liable for waste disposal. Integrators would have to become co-signors of all permits pertaining to waste management and disposal. There are numerous ways that integrators could be held liable. For example Environmental Assurance Bonds is one idea that would require firms to purchase bonds that cover unintended environmental damages. If no unintended damages occur the money is returned along with accrued interest. (Cochran)

Phasing out lagoons is vital because of the threat they pose to the environment and the surrounding community. Any decisive change will require that lagoons be phased out permanently. Lagoon design leaves too much variables to the farmer and exposes the public to unnecessary risk from water contamination, leaching and possible pathogenic agents.

2.5 What are the benefits of the biogas plants?

Once a biogas plant is constructed and energy production is stabilized, it yields a range of benefits for their user, the society and the environment in general. Biogas plants produce energy

that can be utilized for range of things. For example in Denmark they used the energy produced is used to provide heat for a small community. The energy can be incorporated into the power grid. The production of energy without the consumption of fossil fuels or commercial fuels has many advantages. Biogas plants transform simple organic waste into high quality fertilizer that has been argued to improve yields by 6-10% and in some cases 20%. Because bio-gas systems keep waste contained and away from soil until digesting takes place, they improved hygienic conditions through reduction of pathogens, worms and flies. (Biogas Website)

Environmentally, centralized biogas plants can protect soil, water, air and woody vegetation. If the slurry is kept contained in sealed tanks, it prevents nitrogen from being released into the air. Also the problem of lagoon leaching would be eliminated and odor would be non-existent. Biogas plants can decrease the consumption of commercial fuels, thus saving our limited supply of fossil fuels.

Microeconomic benefits from biogas plants stem from fertilizer substitution, additional income sources and job creation. Substituting organic fertilizer for chemical fertilizer benefits consumers because organic fertilizer is cheaper than chemical. Cheaper input costs allow producers to make a larger profit in the short run. The additional income produced by biogas plants makes it a viable investment opportunity. Biogas plants like any industry needs labor and thus it creates jobs. The creation of employment has only positive effects of the local economy. (Biogas Website)

The biggest benefit of a Biogas plant is the alleviation of the social cost associated with hog farms. For example the stress associated with having a hog farm in your neighbor would be lessened because odor would be minimized or alleviated. The health effects associated with air quality problems will also me minimized due to how the slurry will be stored. Socially biogas plants will help make hog farms more acceptable. If farmers embrace the idea of a centralized biogas system, it will be seen as a neighborly thing to do. Currently farmers are viewed as caring very little for the community but embracing the biogas system will be viewed as a step in the right direction.

Chapter 3

3.1 Introduction

The implementation of the centralized system depends on many economical, social and legal issues. Each issue has sub issues that act as a catalyst. In the chapter we will develop a model that will look at the probability of each issue being resolved in a manner that will cause farmers to look favorable on a centralized system. We concentrate on farmers because without their support the system will not operate efficiently. Each outcome is weighted through a points system. The high the amount of points the great the influence of the issue on the outcome. For example, a high enough profit is given 5 points while which outside investor involvement is only given 2 points.

Each time the model is run the points are added to find if farmers are in favor or against. A point total over ten will be interpreted as a vote in favor of the system. The maximum point in the absolute best case is 20.

3.2 What factors should be considered in developing a model for the behavior of farmers?

The model for hog farms will consist of three factors:

The Profit Margin: Depending on how large a profit margin per hog a farmer is making will effect his willingness to accept a centralized system. Over 93% percent of all hogs produced in this region are under contract. As a result in this model looks solely at how contract farmers will react under certain economical, political and social situations. Studies have shown that the profit margin per hog ranges from -1.14 to 1.92. Although no information can be found on the distribution of profits, the model will assume a uniform distribution where the probability of getting any given profit is equal. The model assume that anything can happen because the commodities market is volatile, fluctuating day to day. It is possible for a disease to wipe out an entire herd at any given time. As a result, the model will randomly generate a profit per hog ranging from -1.14 to 1.92.

Investment Cost: Investment costs are quite important to farmers. If farmers are asked to finance the entire project, it is less likely that they will be in favor of the system. The model

concludes that there are four options for financing and each ones involvement is positive but weighted differently. Either the government, farmers, outside businesses, integrators or a combination of all four will finance the project. Each combination will have an effect on the overall future of the project. For example if the government is involved in financing the project then it is highly probable that we will have implementation because farmer have more incentive to adopt a centralize system. The greater the financial assistance to farmers the more likely they would be to adopt the system.

Lagoon Phase out. Lagoon phase out is a necessary catalyst for implementation of any new system designed to effectively utilize or dispose waste. Based on Governor Hunt's 1999 announcement, it is very likely that lagoons will be phased out. We estimate that there is a 75 percent chance of a phase out.

Other legislative considerations are implied in other parts of the model. The important challenges are implied in the investment cost portion of the model. For example if the government becomes involved in financing the project, then it is safe to assume that the environmental lobby won or vice versa. If the integrators become involved then it is safe to assume that the laws making them liable were passed. Based on the history of integrator, they do not want to be held liable for environmental issues.

For this model we will be using a program called crystal ball. “Crystal Ball 2000 Standard is an easy-to-use simulation program that helps you analyze the risks and uncertainties associated with your Microsoft Excel spreadsheet models. As a fully integrated Excel add-in program with its own toolbar and menus, Crystal Ball picks up where spreadsheets end by letting you perform Monte Carlo analysis (a standard technique for simulating real-world situations involving elements of uncertainty).” http://www.decisioneering.com/crystal_ball/

3.3 Outline and Description of the model.

Profit Margin

Profit for contract farmers range from -1.14 to 1.92. Using Crystal ball a number between -1.14 and 1.92 is randomly generated and based on the number a certain amount of points will be given. For example if the number generated was 1.91 then five point would be given. If -1.12

were generated then 0 points would be given. The rational is that the more profitable a farm is, the more likely they will accept a new system of waste disposal.

Points were given based on the following:

1.14 to 0 = 0 points

>0 to .5 = 2 points

>5 to 1 = 3 points

>1 to 1.5 = 4 points

>1.5 to 1.92 = 5 points

Investment and Lagoon Phase Out.

Lagoon phase out and the four options of financial involvement are each assigned a probability of occurring in way that is favorable. Then a number for 0 to 1 is randomly generated by crystal ball and based on the generated number a certain number of points will be given. For example if the probability for government involvement is 50%, a randomly generated number greater than .5 will mean yes and a randomly generated number below .5 will mean no. If a yes is produced then a predetermined amount of points is given. Of the four possible financial participants, government involvement was weighted the most and farmer involvement carried the least weight. Farmer and outside investor involvement were weighted the lease because neither group is willing to produce the resources needed. Government and integrators were given highest weight because they could be forced legal to finance the project and they posses the resources do it.

Points were give by the following system

Integrators (65%) if yes = 3 points

Government (50%) if yes = 5 points

Outside Investors (20%) if yes = 2 points

Farmers (35%) if yes = 2 points

The Lagoon phase out is done the same way as the investment options and lagoon phase out produces 4 points.

Each time the model runs all the points from the three sections are totaled. If the totals points is greater then 10 then the project will be accepted. Our goal is see after running the model

for 1000 trials, how many times the project passes or fails based on our criteria and a random world. For the randomly generated numbers we always use a uniform distribution in order to make it truly random.

Assumptions:

Investment Cost

Integrators Liable (65%): There is a 65% chance that integrators are going to be held liable. Contract farming makes it possible for integrators to make large profits at the expense of the community and small farmer. If integrators are brought in, then 3 points will be added to overall total. Integrators are given a mid range number of three because if they are in control based on their history, the environment will not be fully protected. Integrators to have the moral responsibility to take an active role in waste management yet they do not. The only conclusion is they are more concerned with the bottom like and thus will unlikely without government force take part in this project.

Government Subsidy (50%): The government is being pushed in two directions. The integrators and farmers have lobbyist asking the government to help, and environmental lobbyist arguing that the industry should clean up after itself. As result there is 50/50 chance of the government going either direction. Integrators and farmers will argue that the government should help because without their help hog farmers will have to relocate or go out of business and that would be more detrimental to the local economy. While at the same time environmentalists argue that farmers should be accountable for their own mistakes.

Outside Investors (30%): Outside investors will be asked to help, but it is unlikely they will since nothing like this has been done in the U.S. This project is highly risky and thus there is only a 30% chance of them becoming involved. They only receive 2 points for involvement because in the case they are involved, only small amounts of money can be expected.

Individual farmers (30%): Most individual farmers lack the resources to do this by themselves. I do think they will be asked to contribute. If they are asked to contribute, only a

small fraction of the total cost can be expected. Based on the current setup of contract farming, hog farmers do not make enough profit to effectively invest in waste disposal.

Lagoon Phase out (75%): Governor Hunt started the momentum towards phasing out lagoons. It is highly likely that in the coming years they will be phased out. If they are phased out 4 points will awarded towards project implementation. Without lagoons farmers would have to search for new cost-effective technologies that will solve most of the problems associated with lagoons. As a result farmers will be left looking for new ways of disposing waste. Thus the phase out of lagoons will cause people to gravitate to this system.

The overall structure of the points system is summarized below;

3.4 Results

After running the model for 1000 trials the following results were produced. In 584trials out of 1000, the project would have all the necessary requirements needed to begin the project. A majority of the times the model produced economic and social conditions under which hog farming would be acceptable. The rest of the findings can be found in Appendix Report 1.

3.5 Discussion

The model tells us that over 50% of the time conditions will exist where farmers would be in favor of a centralized system. Because the probability of the farmers accepting the system is above 50, it is only reasonable to discuss behavior after the system is put in place. There are two issues at hand that will determine the behavior of farmers once this has been implemented. The first issue is one of a public good and the second is the issue of collective action.

Public good:

A centralized system qualifies as a public good because its benefits are non-excludable and non-rival; a person's consumption does not diminish another person¹s ability to consume that benefits of the system. The entire state stands to benefit from this system. North Carolina from 1995-2001 spent over $73 million in the department of Environment and Natural resources. Of

this almost 50% was targeted at animal waste management. The money saved by the state after the implementation of a system such as this would result in redistribution of funds by the state to other important programs. The state could possibly redistribute some of the money to education or addressing other environmental problems.

The centralized system also reduces some social costs associated with hog farms. The reduction of odor will improve the health of those living in close proximity to hog farms. Also property values will regain some of the lost value because the odor will not present a nuisance.

Since the system by design forces farmers and integrators to internalize costs, the public good problem begins to play a larger role. Farmers are receiving a net benefit less then the rest of society because they are internalizing most of the cost. With lagoons the farmers made more money and society paid the social environmental cost. Implementing the centralized system will effectively cause farmers to pay the social environmental costs while society pays less environmental social costs (almost none). Because a centralized system is a public good, farmers alone can not be allowed to control it totally. If farmers were given the opportunity to run the system totally, they would potentially implement in a way that would be hurt the environment. For example if the waste is not held in closed holding tanks prior to transport to a local storage tank, you risk loosing a large portion of the nitrogen content. Less nitrogen means a less quality fertilizer will be produced. A lesser fertilizer will not contend well on the open market. A lesser fertilizer would get less money and could be detrimental to the overall cash return on the project.

Based on the public good problem, even the model suggests the system would be adopted, it is imperative that government cured the public good problem. In Denmark the state still plays an active role. Farmers might be persuaded to accept the centralized system, but they will not persuaded to stop acting selfishly.

Collective Action Problems

A large group of farmers with prodding from the government will have to create an efficient system that forces them to internalize some of the external costs associated with production. Obviously the more cost that are internalized will result in a smaller profit at the end of the day. The classic collective action problems present themselves after the decision to implement is made. The collective action problem is based on the fact that people working in groups will act selfishly in order to maximize their own happiness. Often times this will lead to

an equilibrium outcome that is not pareto optimal. That is, it will lead to an outcome where the individuals involved have no regrets about their decision but another groups of decisions could make all involved better off.

Dominant Strategy: (The choice made regardless of what the other person does)

All farmers have an incentive to deviate from the plan. From example if you move a storage tank closer to your farm, you are able to minimize your cost and increase profit margin. Because farmers are not organized in a perfect circle, arguments will arise over placement of local storage tanks. This might lead to the building of too many storage tanks, or tanks being place in inefficient locations. If the system is not efficient, it longevity is shortened and a good solution might fail. Small farms might find their best strategy is to hold large farms hostage, by threatening to leave and produce something else, thus allowing larger investment costs to fall on the shoulders of each large farms.

Hog Farms might shut down and then join in after implementation:

The free rider problem is present because once the system is implemented farms can join in. If a farm is opened after implementation, they might not have to pay an initial investment costs like other farms. This problem can easily be handled by those involved by forcing them to pay pro rata share investment costs.

A farmer might sell dispose of another farm¹s waste without getting authorization. This presents a problem because if a farmer pays a fee based upon the cost of disposing his waste, the additional waste is being disposed of for free. For example if I registered to dispose of just my waste but a new hog farm sets up show across the street, I might dispose of his waste on my contract and collect a fee for myself.

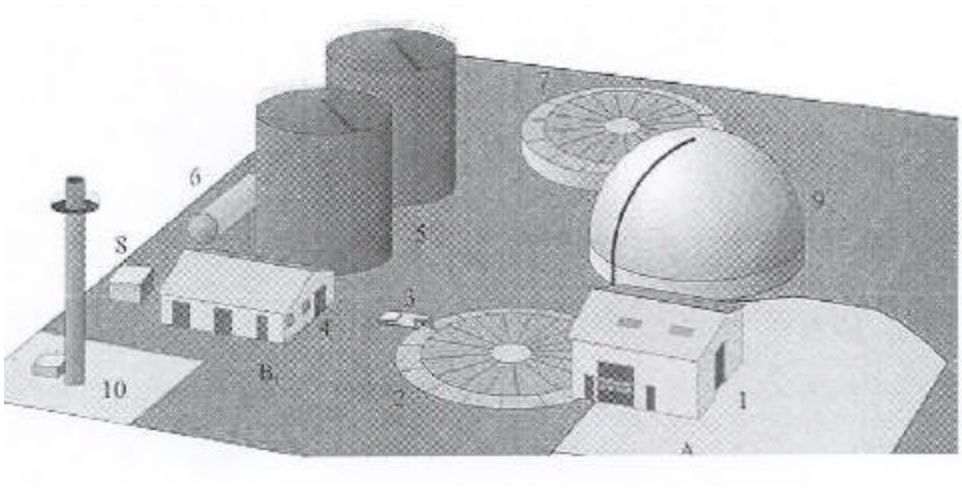
Some farmers might increase farm size

A farmer that previously only contracted out for 4000 hogs might not expand production to 6000, while still only paying waste charges based up his 4000 hogs. A trend like this could present serious problems for cash flow.

The problem of defection is highly present in the situation of a centralized system. While collective action is flawed, government involvement is not always needed. In this case I believe

that all we need to do is employ the Coase Theorem. It states that if property rights are issued, and the market allowed to work freely then externalities will be solved. If each farmer were issued permits limiting the amount of waste they could dispose using the centralized system, then the collective action problem will be lessened. Farmers would have to purchase enough permits for their farm but when they go below permit level, they can sell the difference to another farmers who needs it.

Appendix 1



Organic waste - flow

1. **Reception building**. Organic waste is received in a closed building with a cover that prevents all odors from penetrating into the surrounding environment.
2. **Mixing tank and pre-storage tank**. The waste is loaded directly into the outer tank where it is mixed into a homogeneous substance. Subsequently it is pumped into the inner pre-storage tank where the biomass is mixed.
3. **Pump we** ll. Stones are removed with a stone separator and a macerator comminutes the biomass, which is pumped further on in the system.
4. **Technical building**. The biomass is heated via a heat exchanger that reuses the heat from the degassed biomass
5. **Biogas reac**tors. This is where the actual extraction of gas from the biomass takes place. The process takes place during continual stirring and during the process the temperature as well as the pressure are controlled.
6. **Tank for hygienic after-treatment**. The biomass is heated in an orator to obtain a hygienic product.
7. **Storage tank**. Storage of degassed biomass, now ready to be used as manure.
8. **Biogas reactors**. The produced biogas is removed through the trap of the biogas reactors.
9. **Gas purifying tank**. The gas is cooled and the amount of H2S (hydrogen sulfide) is reduced by adding iron compounds.

10. **Storage for biogas**. From this point biogas is sent to a decentralized district heating plant.
11. **Gas torch**. It is part of the plant's safety system and it turns on in the case of positive pressure.

(Taken from http://www.bioplan.dk/biogas1.htm)

Appendix 2

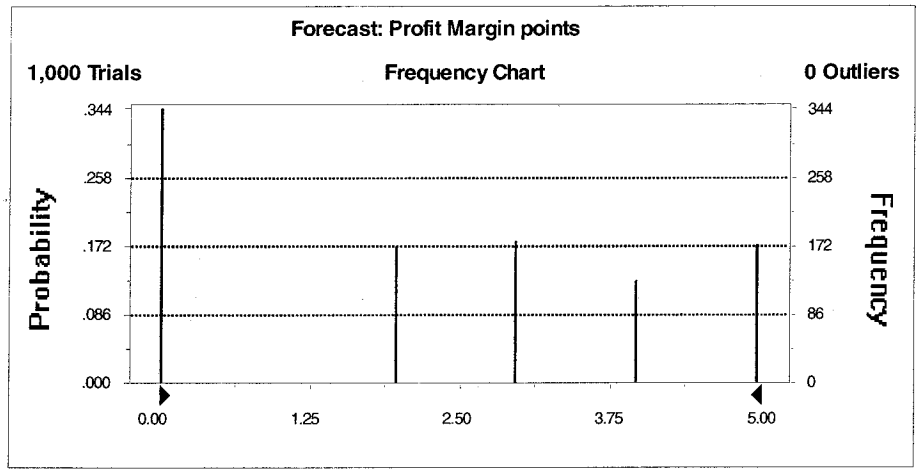
Excel Models

Crystal Ball Report
Simulation started on 4/9/01 at 2:53:37
Simulation stopped on 4/9/01 at 2:54:13

Forecast: Profit Margin points

Summary:
Display Range is from 0.00 to 5.00
Entire Range is from 0.00 to 5.00
After 1,000 Trials, the Std. Error of the Mean is 0.06

Statistics:	Value
Trials	1000
Mean	2.28
Median	2.00
Mode	0.00
Standard Deviation	1.89
Variance	3.58
Skewness	0.03
Kurtosis	1.57
Coeff. of Variability	0.83
Range Minimum	0.00
Range Maximum	5.00
Range Width	5.00
Mean Std. Error	0.06

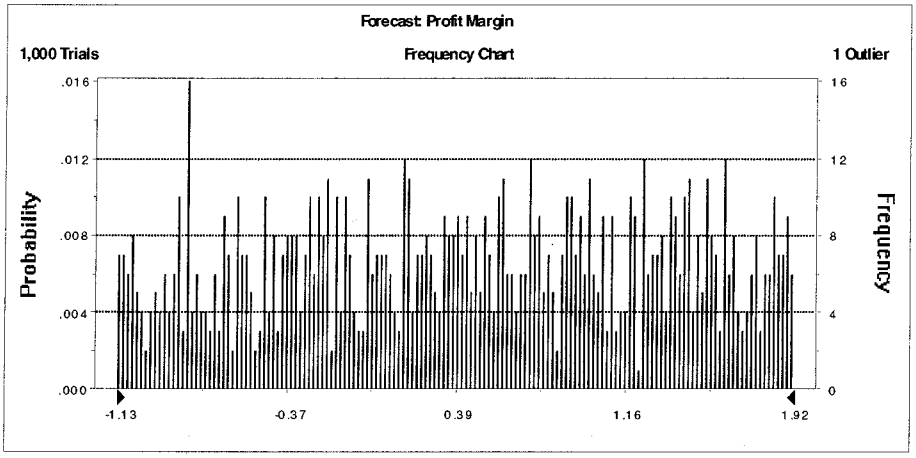


Forecast: Profit Margin

Summary:

Display Range is from -1.13 to 1.92
Entire Range is from -1.13 to 1.92
After 1,000 Trials, the Std. Error of the Mean is 0.03

Statistics:	Value
Trials	1000
Mean	0.44
Median	0.45
Mode	---
Standard Deviation	0.86
Variance	0.74
Skewness	-0.06
Kurtosis	1.86
Coeff. of Variability	1.96
Range Minimum	-1.13
Range Maximum	1.92
Range Width	3.05
Mean Std. Error	0.03

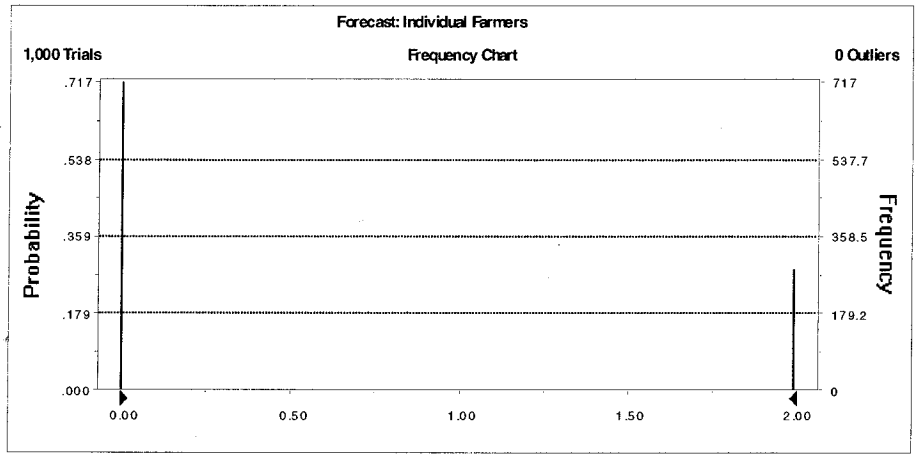


Forecast: Individual Farmers

Summary:

Display Range is from 0.00 to 2.00
Entire Range is from 0.00 to 2.00
After 1,000 Trials, the Std. Error of the Mean is 0.03

Statistics:	Value
Trials	1000
Mean	0.57
Median	0.00
Mode	0.00
Standard Deviation	0.90
Variance	0.81
Skewness	0.96
Kurtosis	1.92
Coeff. of Variability	1.59
Range Minimum	0.00
Range Maximum	2.00
Range Width	2.00
Mean Std. Error	0.03

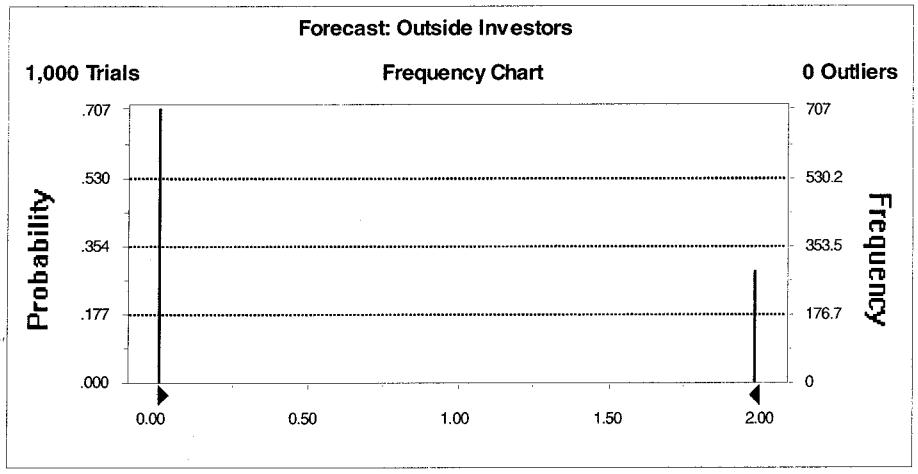


Forecast: Outside Investors

Summary:

Display Range is from 0.00 to 2.00
Entire Range is from 0.00 to 2.00
After 1,000 Trials, the Std. Error of the Mean is 0.03

Statistics:	Value
Trials	1000
Mean	0.59
Median	0.00
Mode	0.00
Standard Deviation	0.91
Variance	0.83
Skewness	0.91
Kurtosis	1.82
Coeff. of Variability	1.55
Range Minimum	0.00
Range Maximum	2.00
Range Width	2.00
Mean Std. Error	0.03

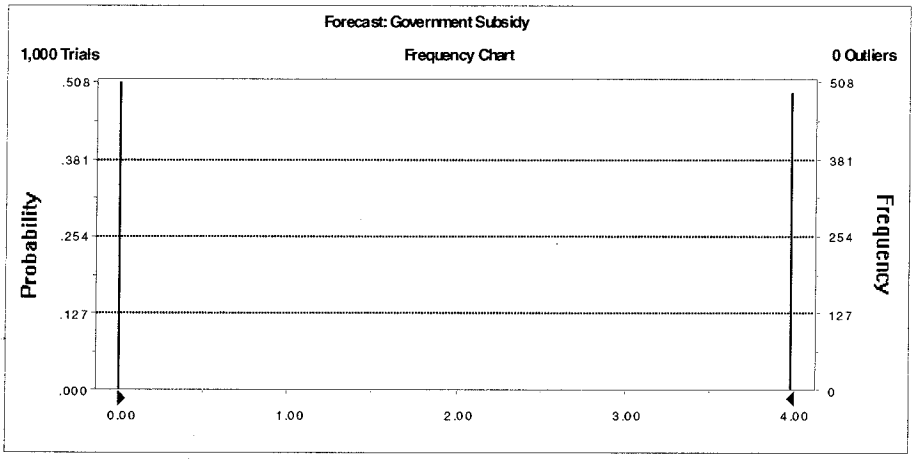


Forecast: Government Subsidy

Summary:

Display Range is from 0.00 to 4.00
Entire Range is from 0.00 to 4.00
After 1,000 Trials, the Std. Error of the Mean is 0.06

Statistics:	Value
Trials	1000
Mean	1.97
Median	0.00
Mode	0.00
Standard Deviation	2.00
Variance	4.00
Skewness	0.03
Kurtosis	1.00
Coeff. of Variability	1.02
Range Minimum	0.00
Range Maximum	4.00
Range Width	4.00
Mean Std. Error	0.06

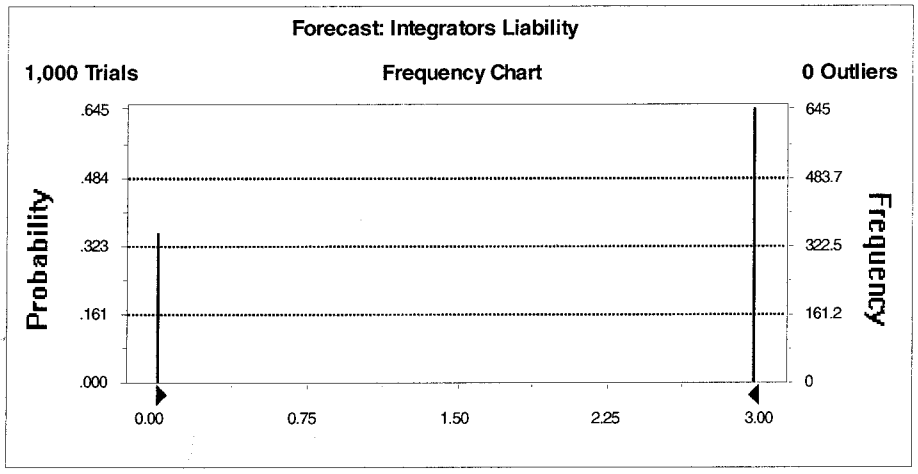


Forecast: Integrators Liability

Summary:

Display Range is from 0.00 to 3.00
Entire Range is from 0.00 to 3.00
After 1,000 Trials, the Std. Error of the Mean is 0.05

Statistics:	Value
Trials	1000
Mean	1.94
Median	3.00
Mode	3.00
Standard Deviation	1.44
Variance	2.06
Skewness	-0.61
Kurtosis	1.36
Coeff. of Variability	0.74
Range Minimum	0.00
Range Maximum	3.00
Range Width	3.00
Mean Std. Error	0.05

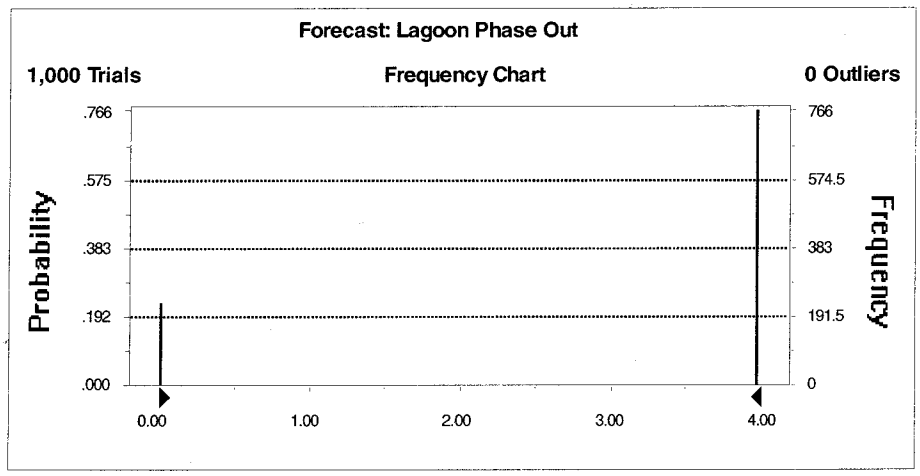


Forecast: Lagoon Phase Out

Summary:

Display Range is from 0.00 to 4.00
Entire Range is from 0.00 to 4.00
After 1,000 Trials, the Std. Error of the Mean is 0.05

Statistics:	Value
Trials	1000
Mean	3.06
Median	4.00
Mode	4.00
Standard Deviation	1.69
Variance	2.87
Skewness	-1.25
Kurtosis	2.57
Coeff. of Variability	0.55
Range Minimum	0.00
Range Maximum	4.00
Range Width	4.00
Mean Std. Error	0.05

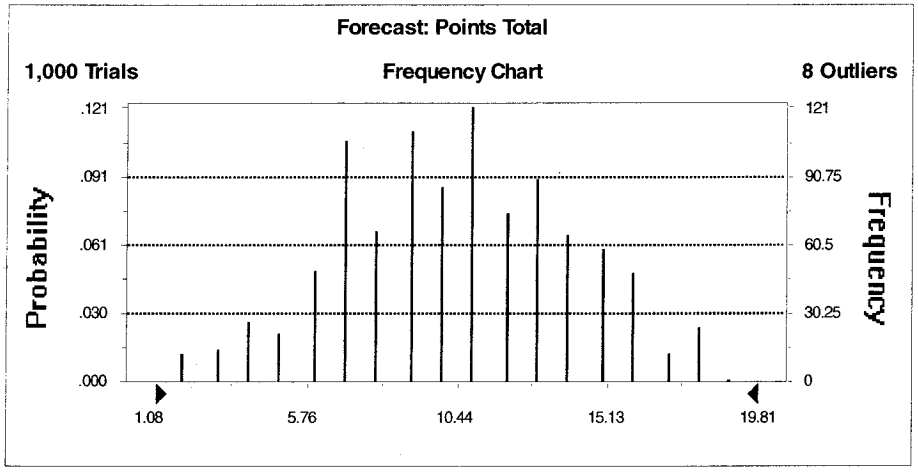


Forecast: Points Total

Summary:

Certainty Level is 0.00%
Certainty Range is from -Infinity to +Infinity
Display Range is from 1.08 to 19.81
Entire Range is from 0.00 to 20.00
After 1,000 Trials, the Std. Error of the Mean is 0.12

Statistics:	Value
Trials	1000
Mean	10.40
Median	10.00
Mode	11.00
Standard Deviation	3.69
Variance	13.59
Skewness	-0.09
Kurtosis	2.68
Coeff. of Variability	0.35
Range Minimum	0.00
Range Maximum	20.00
Range Width	20.00
Mean Std. Error	0.12

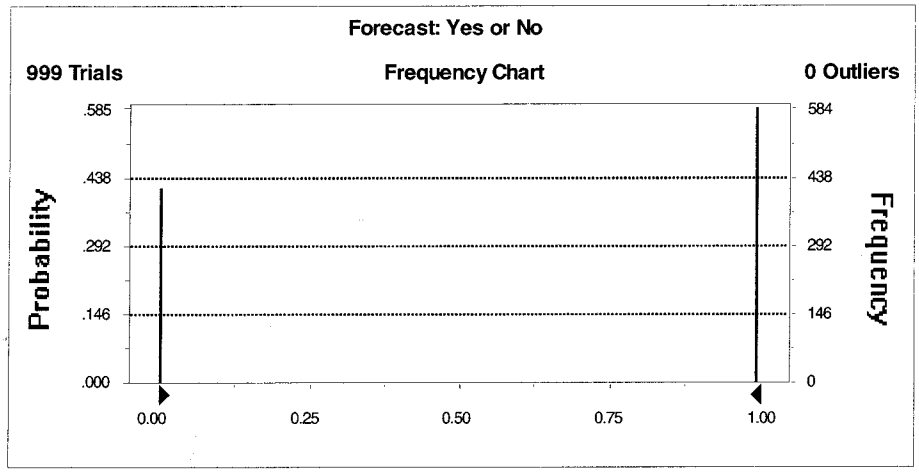


Forecast: Yes or No

Summary:

Display Range is from 0.00 to 1.00
Entire Range is from 0.00 to 1.00
After 999 Trials, the Std. Error of the Mean is 0.02

Statistics:	Value
Trials	999
Mean	0.58
Median	1.00
Mode	1.00
Standard Deviation	0.49
Variance	0.24
Skewness	-0.34
Kurtosis	1.12
Coeff. of Variability	0.84
Range Minimum	0.00
Range Maximum	1.00
Range Width	1.00
Mean Std. Error	0.02



Bibliography

Animal Waste Management and the Environmental Background for Current Issues Environment: *Congressional Research Service Issue Brief for Congress* "http://www.cpie.org/nle/ag-48c.html

Chastain J. P., Jacobson L. D., Site Selection for Animal Housing and Waste Storage Facilities University of Minnesota Extension Program "http://www.bae.umn.edu/extens/acu/acu6.html

Delind L., (1995) The State, Hog Hotels and The Right to Farm: A Curious Relationship. *Agriculture and Human Value* 12(3):34-44

Donham, K.,(1998)Living in the Vicinity of Swine Production Units. The University of Iowa http://www.ctic.purdue.edu/Core4/nutrients/ManureMgmt/Paper75.html

Donham, K., (1993). Respiratory disease hazards to workers in livestock and poultry confinement structures *Seminars in Respiratory Medicine*. Vol. 14, No. 1, 49-59

Environmental Justice Case Study: *Hog Farming in North Carolina* http://www.umich.edu/~snre492/statter.html#TOC

Hog Lagoons Pitting Pork Waste Against Public Health and Environment *A Report by the Environmental Defense Fund North Carolina Office*, June 1999

Hogwatch.com

1. "Raising Hog Rights: Finding Solutions for North Carolina" Hog Watch, http://www.hogwatch.org/getthefacts/factsheet/solutions.htm
2. "Municipal Human Waste Versus Hog Waste" Hog Watch, http://www.hogwatch.org/getthefacts/factsheet/solutions.htm
3. "Hog Factories and Government Regulation: The Straight Poop" Hog Watch, http://www.hogwatch.org/getthefacts/factsheet/solutions.htm
4. "The Big Picture on Jobs and the Economy" Hog Watch, http://www.hogwatch.org/getthefacts/factsheet/solutions.htm
5. "Factory Hog Farming -- The Big Picture" Hog Watch http://www.hogwatch.org/getthefacts/factsheet/solutions.htm

6. Hog Watch, "Hog Factories and Government Regulation: The Straight Poop" http://www.hogwatch.org/getthefacts/factsheet/solutions.htm
7. Hog Watch, "Report on Forum on Hog Waste and Environmental Quality in North Carolina," http://www.hogwatch.org

Jackson, L., Hallberg, G., Huffman, R., Keeney, D., Lanyon, L., Lynch, N., Schulte, D., (1997) Water Quality. *Understanding, The Impacts of Large Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop* June 29-30, Des Moines, Iowa

Lasley, P., Duffy, M., Ikerd, J., Kliebenstein, J., Keeney, D., Lawrence, J., (1997) Economic Development. *Understanding, The Impacts of Large Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop* June 29-30, Des Moines, Iowa

Melvin, S., Bundy, D., Casey, K., Miner R., Schiffman, S., Sweeten J., (1997)Air Quality. Understanding, *The Impacts of Large Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop* June 29-30, Des Moines, Iowa

Meyer,T. (1996 July).. Hog waste may have aborted pregnancies. Raleigh *News and Observer*

Nitrate in Soil and Water http://www.gov.mb.ca/agriculture/livestock/publicconcerns/cwa01s02.html

Okun, M., (1999). Human Health Issues Associated with the Hog Industry. *Prepared for the North Carolina Association of Local Health Directors* http://checc.sph.unc.edu/room/library/docs/hogs/hogs_hhealth.html

Options for Managing Odor (1995) *A report from the Swine Odor Task Force* http://www.ces.ncsu.edu/whpaper/SwineOdor.html

Protect Our Waters. NCPIRG's *Campaign to Clean up Corporate Hog Farms* http://www/pirg.org/ncpirg/hogs/

Thu K., Delind, L., Durrenberger E. P., Flora, C., Flora, J., Hefferman, W., & Padgitt, S., (1995) Social Issues. *Understanding, The Impacts of Large Scale Swine Production: Proceedings from an Interdisciplinary Scientific Workshop* June 29-30, Des Moines, Iowa

Thu, K.,(1995) "The Social Consequences of Large Swine Production." Paper prepared for the Swine Workshop Botanical Center

Schiffman, S. S., (1998) "Livestock Odors: Implications for Human Health and Well-Being." *Journal of Animal Science*, 76, 1343-1355

Schiffman, S., Sattely Miller, E. A., Suggs, M.S., &Graham, B. G. (1995). "The Effect of Environmental Odors Emanating From Commercial Swine Operations on the Mood of Nearby Residents." *Brain Research Bulletin*, Vol. 37, No. 4. Pp. 369-375

Spoelstra, S. F., (1980) "Origin of objective odourous components in piggery wastes and the possibility of applying indicator components for studying odour development." *Agriculture and Environment* 5:241-260

"Swine Manure Management Planning," Purdue University Cooperative Extension Service and Indiana Soil Conservation Service INK "http://www.agcom.purdue.edu/Agcom/Pubs/id/ID-205.html"

Thu, K., Donham, K., Ziegenhorn, S., Reynolds, S., Thorne, P. S., Subramanian, P., Whitten, P., & Stookesberry, J., (1997) "A control study of the physical and mental health of residents living near a large-scale swine operation." *Journal of Agricultural Safety and Health*, 3(1), 13-26

"Water Quality and the North Carolina Swine Industry," North Carolina State University http://www.ces.ncsu.edu/whpaper/Wqswine.html

Voss R., & Griffith B., "Phosphorus and Surface Water. A Project for Illinois Agriculture," http://www.ifca.com/programs/phosporus.html

Merkel, J. A. et al (1969) "Identification of gases in a swine confinement building atmosphere." *Transactions of the American Society of Agricultural Engineers* 12(3): 310-315

Ribe Biogas Plant, Denmark http://www.kruger.dk/doc/References/ribebio.htm

Biogas Plants http://www.bioplan.dk/bioga.htm

Barker, J. C., Hodges, S. C., Walls, F. R., (2001) Livestock manure production rates and nutrients content, *2001 North Carolina Agricultural Chemical Manure*, Chapter 10 - Fertilizer use http://ipmwww.ncsu.edu/agchem/chptr10/1011.pdf

"A Centralized Thermophilic Biogas Plant in Denmark." Caddett-Renewable Energy Technical Brochure No. 43 http://www.caddet-re.org

Holm-Niesen, J., Halberg, N., Huntingford, S., Al Seadi, T., (1997) "Joint Biogas Plant Agricultural Advantages." Danish Energy Agency, Revised and emendated addition, Aug. 97

Cochran, K., Rudek, J., Whittle, D., (2000) "Dollars and Sense- An economic Analysis of Alternative Hog Waste Management Technologies," Environmental Defense

Escobar J. G., Heikkila A. M., (1999) "Biogas production in farms through anaerobic digestion of cattle and pig manure." Case Studies and research activities in Europe. A report for TEKES, OPET Finland

House Bill 1454- Animal Waste Tech Demonstrations Funds (April 29, 1999) General Assembly of North Carolina Session

Biogas Website

Articles Used:

"Costs Of A Biogas Plant"

"Economic Viability"

"Bio-gas Framework Conditions"

"Financing And Public Support"

"The Benefits For Biogas Users"

"Biogas Basics"

"Macroeconomic Evaluation"

U.S Department of Agriculture (USDA) (1998) "Hog Costs and Returns: 1998 Costs of Production for the Agricultural Resources Management Study." Economic Research Service, U.S Department of Agriculture, Washington, DC