**POTENTIAL FOR METHANE DIGESTERS
ON U.S. DAIRY FARMS**

by

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ABSTRACT

Methane digesters are a potential investment for a dairy farm. A digester can lower

greenhouse gas emissions, manage manure waste, generate energy, provide fertilizer and

recycle bedding. The AgSTAR project of the Environment Protection Agency describes

anaerobic digesters as a solution to a problem dairy farmers have always had to solve but

that has become more acute with the innovation of larger scale, confined animal feeding

operations developed in response to the growing food demands of the world's larger and

more prosperous middle class population – what to do with cow manure. Digesters take

cow manure and convert it into energy while also eliminating manure odor.

Energy is the primary economic benefit of a digester. A dairy farmer can use the

electricity or gas generated from the digester to fuel the energy needs of the farm. Selling

gas or electricity on the market is a revenue source that largely determines the level of

profit from investing in a digester.

This thesis will explore the four economic factors required to make anaerobic

digesters a viable economic investment for a 1,500 head cow herd in the United States. It

is imperative that farmers are able to obtain a return on the investment as soon as possible

as many do not have the capital to invest in a nearly $1 million project. Congress may need

to provide additional incentives for farmers and utility companies to take waste and process

to energy.

The future for methane digesters looks profitable when energy and carbon markets

are available and allowed to trade competitively. The federal government may consider

focusing on incentives for the utility companies' infrastructure to make purchases of

renewable energy from a digester more economically attractive and efficient. Today, an obstacle for increasing the number of digesters in the United States is the cost associated with moving the energy from the digester and into the national natural gas to grid. Natural gas companies may need to be compensated for that expense plus the potential difficulties of dealing with multiple suppliers or digester owners.

Electricity companies have a grid in place to power rural and urban communities. They have spent billions of dollars and decades to establish efficient routing of power to residents and businesses. Manure digesters are mostly located in rural areas that would also require an investment in infrastructure to move the energy from the digester to the power grid. Mandating net-metering would require energy companies to purchase renewable energy, but consumers may see an increase in their cost.

Therefore, the answer to increasing the number of manure digesters in the United States may be to direct the incentives to utility companies to invest in expanding infrastructure rather than increasing digester owner subsidies. Although, the REAP grants are helpful for assisting farmers with startup installation costs, there may not be a need to increase that subsidy in the next farm bill if an energy bill includes incentives for energy companies to purchase renewable energy from digesters.

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DEDICATION

This thesis is dedicated to the memory of my father, David Lee Brooks. He never wanted me to study agriculture. He was concerned that I would not find a job or be able to support myself working in agriculture as a female. He died in a farm accident in 1996. My job is to represent farmers in Washington, D.C. and without my father's story I would not be where I am today.

His love of God, family, country and agriculture are deeply instilled in me. Thanks Dad. You are missed.

CHAPTER I: INTRODUCTION

Dairy cow manure, a waste product, can be used to make renewable energy through a process known as anaerobic digestion. This is not a new technology. As early as the 17th century, scientists documented flammable gas from sediments. In the twentieth century, the Germans patented a holding tank that captured energy to power multiple sources converting biomass to gas (Imhoff Tank n.d.). However, it wasn't until the 1930s that anaerobic digesters became a recognized scientific process for renewable fuel. A methane digester produces biogas as the renewable energy source.

A digester can be a very expensive startup investment. Given the initial cost with unpredictable financial returns, this creates a situation in which dairy farmers may be leery of investing in building anaerobic digesters and manure systems.

This thesis will explore whether federal public policy is required to make anaerobic digesters a viable economic investment for a 1,500 head cow herd in the United States. It is imperative that farmers maximize their return on the investment. Most do not have the capital to invest in a nearly $1 million project. Congress may need to provide additional incentives for farmers to take waste and process to energy, as well as incentivize utility companies to purchase renewable energy from farms.

Methane digesters can be a good investment on a dairy farm. A digester can lower greenhouse gas (GHG) emissions, manage manure waste, generate energy, provide fertilizer and recycle bedding. The AgSTAR project of the Environment Protection Agency (EPA) describes anaerobic digesters as a solution to a problem dairy farmers have always had to solve but has become more acute with the innovation of larger scale, confined animal feeding operations (CAFOs) developed in response to the growing food

demands of the world's larger and more prosperous middle class population – what to do with cow manure.

Energy is the primary economic driver of a digester. A dairy farmer can use the electricity or gas generated from the digester to fuel the energy needs on the farm. Selling gas or electricity on the market is a revenue source that largely determines the level of profit from investing in a digester.

However, there are other positive impacts with a digester. An Informa Economics study for the Dairy Management Inc. concludes that anaerobic digesters may be a profitable, sustainable solution to both the environmental challenges of waste disposal as well as providing for renewable fertilizer nutrients and energy productions. The disposal of manure is costly and environmentally complex on large confined animal feeding operations (CAFOs). Dairy farms must be compliant with the Clean Water Act (water quality legislation).

AgSTAR analyzed the potential of 2,647 dairy farms with more than 500 head herds nationwide for energy production. The study reported that those same 2,647 dairies could contribute more than $4.68 billion net revenue annually.

1.1 How Methane Digesters Work

Digesters work best on confined animal feeding operations (CAFO) where manure is stored and farmers must manage large quantities of animal waste. The basic fermentation process uses water and heat to transform solid waste into biogas. The biogas captured in this anaerobic process, meaning without oxygen, produces approximately sixty percent methane (CH_4) and nearly all of the remainder is carbon dioxide (CO_2) (Key and Sneeringer 2011, 571). The biogas can be processed into heat for local use, electricity to be

sold on the power grid or biomethane which can be scrubbed through a pipeline then used as natural gas or vehicle fuel.

Two following figures depict the anaerobic process from which animal waste is transformed to different renewable energy types: compressed natural gas, pipeline biomethane or electricity. Figure 1.1 is used by The AgStar program at the U.S. Environmental Protection Agency (EPA). AgStar is a collaborative program within the U.S. Department of Agriculture (USDA), U.S Department of Energy (DOE), and the EPA. AgStar is "an outreach program designed to reduce methane emissions from livestock waste management operations by promoting the use of biogas recovery systems (U.S. EPA, The AgStar Program 2012)."

Animal waste goes to the digester then can be separated for two processes. The digester produces digestrate and biogas (Figure 1.1). The digestrate can be separated further into liquid fertilizer, compost or bedding. These are potential revenue sources for the anaerobic digester. The biogas can either be converted to gas or electricity but not both. The energy produced by gas or electricity can be used to offset on farm energy use or sold to utility companies for natural gas, electricity or compressed gas.

Figure 1.1: Basic Anaerobic Digester System Flow Diagram

Basic Anaerobic Digester System Flow Diagram
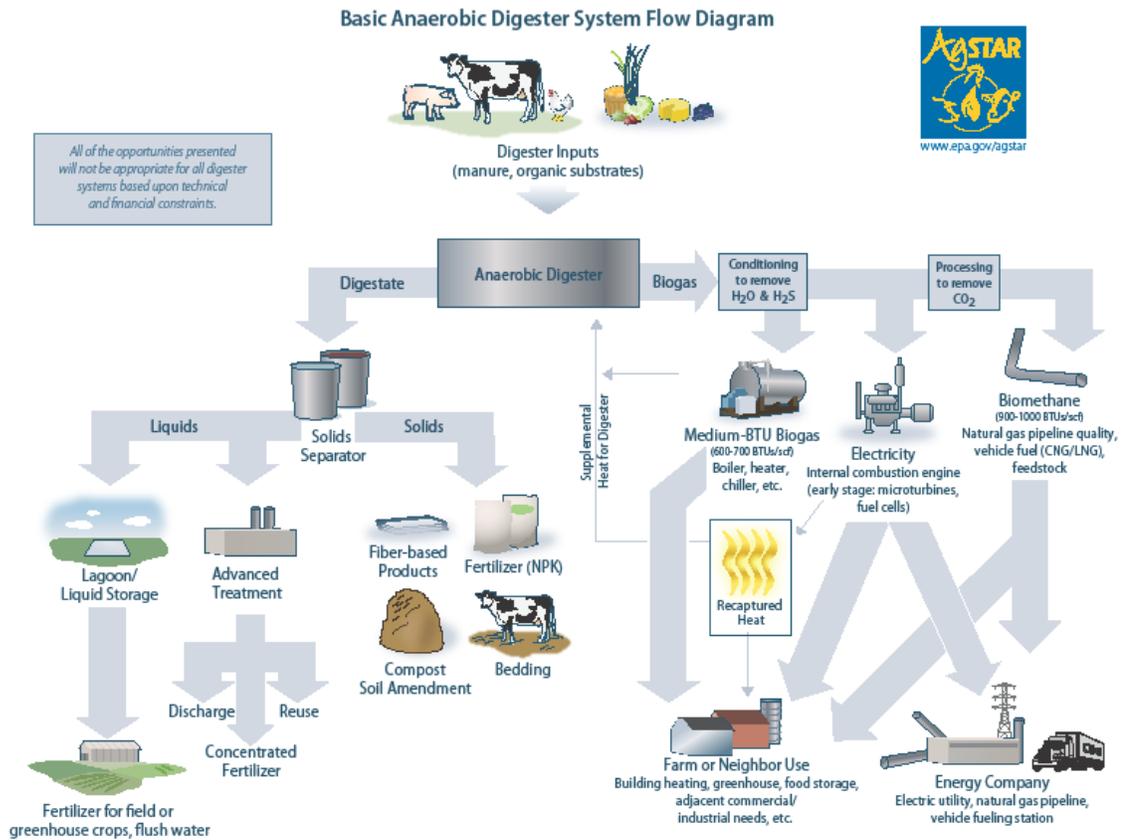
(U.S. EPA, The AgStar Program 2012)

Figure 1.2 shows the same process but may be slightly easier to follow. The two building structures represent heating and separation of the manure. The biogas is released between to the two houses. The solid is moved to the second house to be recycled as fertilizer or bedding.

Figure 1.2: Biogas Energy Systems Flow Chart for Manure to Energy
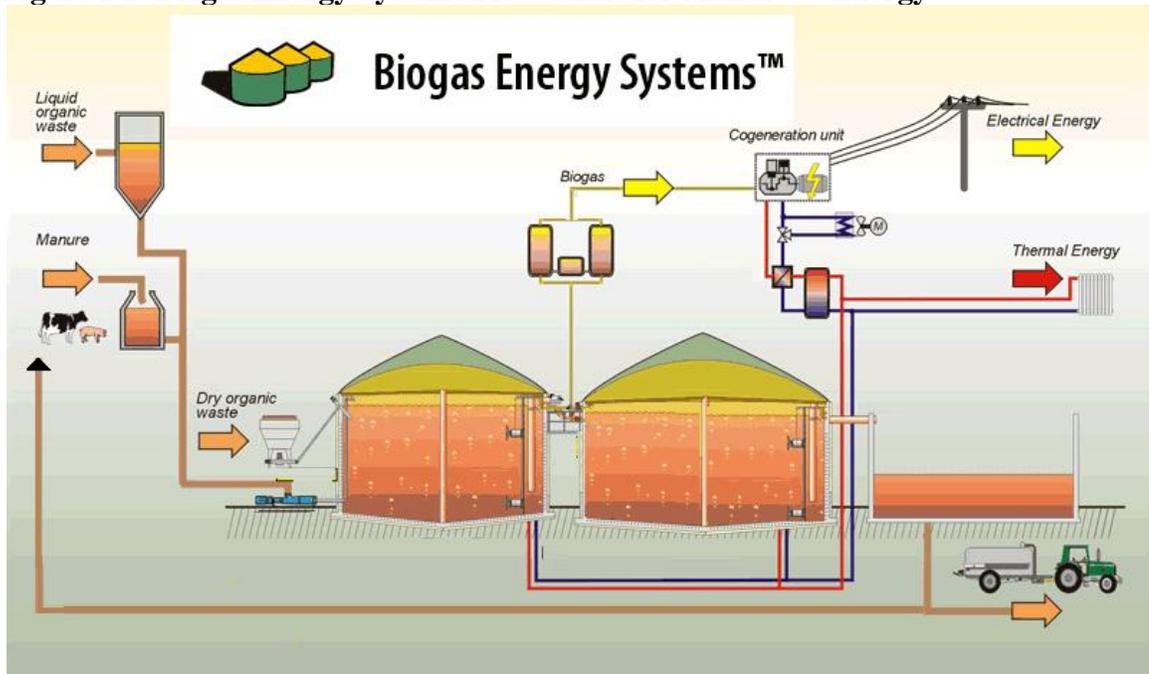
(Biogas Energy Inc 2008)

1.2 Cost of Building a Digester on Farms

There are three distinct types of methane digesters that may be used on a dairy operation: a covered lagoon, complete mix, and plug flow.

In 2009, AgSTAR hosted a national conference in Baltimore, Maryland, reporting the estimated capital cost for anaerobic digesters on a dairy farm. The average project cost of all components was slightly over a million dollars for a complete mix digester. AgSTAR factored in the following input components: a mix tank, manure pumping and mixing equipment, piping, digester, digester effluent system, post-digestion solids separation system, engine-generator set and building, Hydrogen Sulfide treatment, installation labor, estimated utility charges, start-up fuel, contingencies, and engineering and site assistance.

A Dairy in New York built a plug flow digester for $252,000 for 1,000 cows (AgSTAR 2010). The cost components for this plug flow digester system include: mix tax,

piping, digester, engine-generator set and building, estimated utility charges, contingencies, and engineering and site assistance. AgSTAR awarded startup grants to farmers with covered lagoon digesters that cost from $95,000 to $300,000 depending on the size and complexity of the project.

While it is very difficult to determine the exact cost for each digester investment due to size, location and type of digester, AgSTAR developed an equation to assist in calculating an average capital cost from data from forty digesters including 13 Complete Mix, 19 Plug Flow and 8 Covered Lagoons. The capital costs include the digester, engine-generator set, installation, and engineering and site assistance. Table 1.1 indicates the capital cost for a Complete Mix with a capital cost of $563 times the number of cows plus $320,864 costing a 1,000 cow dairy $883,864.

Table 1.1: Formula for Average Capital Cost for the Three Digesters: Complete Mix, Plug Flow, and Covered Lagoon

Digester System Type	Capitol Cost	Total Cost for 1,500 cows
Complete Mix	($563*no. cows)+$320,864	$1,165,364.00
Plug Flow	($617*no. cows)+$566,006	$1,491,566.00
Covered Lagoon	($400*no. cows)+$599,556	$1,199,556.00

Source: AgSTAR 2010

Figure 1.3 is the complete mix digester system. This system requires an enclosed, heated tank with mechanical, hydraulic and gas mixing systems. The complete mix system works best when waste water is mixed with the manure.

Figure 1.3: Complete Mix Digester System
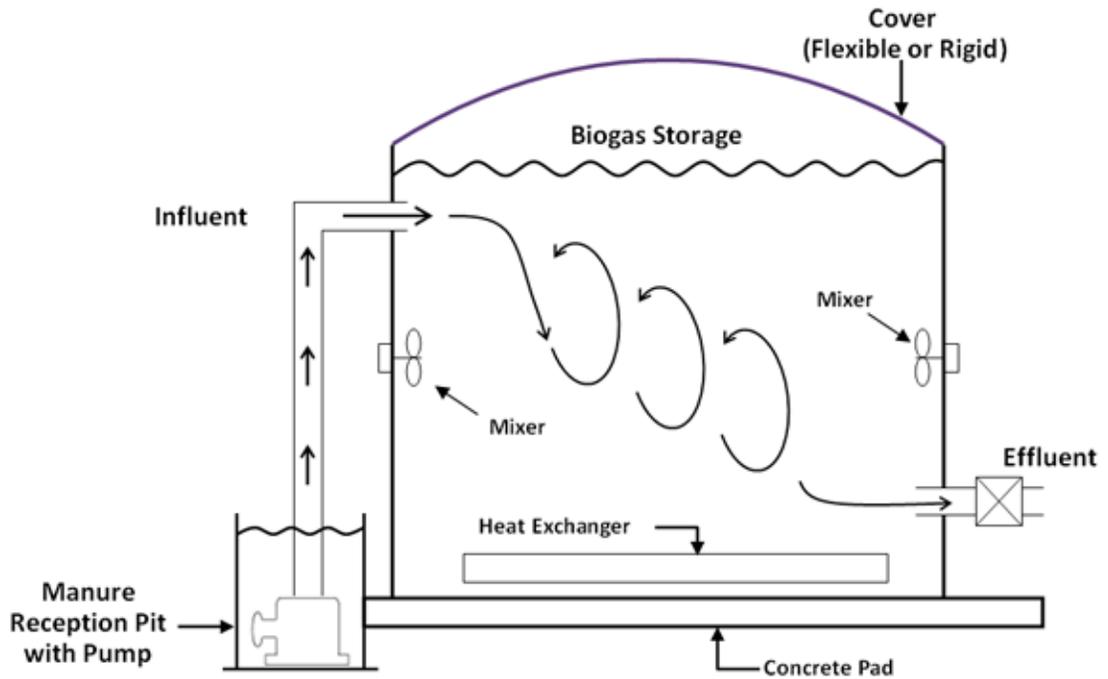
(U.S. EPA, The AgStar Program 2012)

A plug flow digester system is built partially or fully below ground as shown in Figure 1.4. The manure is collected in a long, narrow concrete tank with a rigid or flexible cover. This type of digester is mostly used on dairies that collect manure by scraping. The Fair Oaks Farm digester in Indiana uses this system with 15,000 cows.

Figure 1.4: Plug Flow Digester System
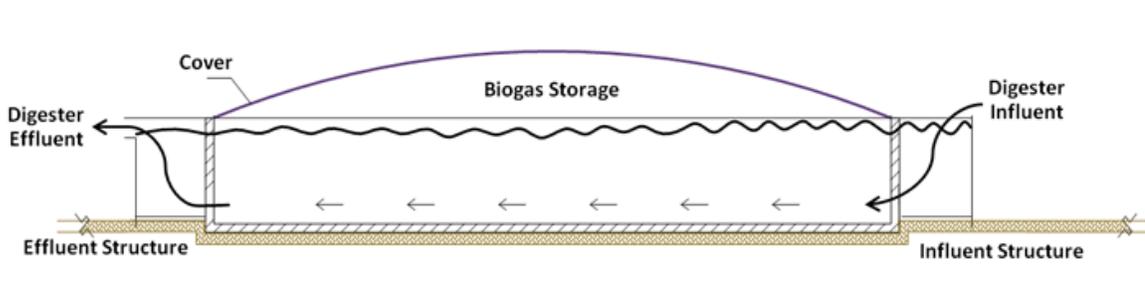
(U.S. EPA, The AgStar Program 2012)

Figure 1.5 is a covered lagoon digester system. This is the most primitive model for a digester. However, it isn't necessarily the cheapest. A lagoon or cell is filled with animal waste then it is sealed with a plastic or flexible cover. The methane is captured under the cover and pressure pushes the gas through the biogas pipe. There may be one to two cells or lagoons used in this system.

Figure 1.5: Covered Lagoon Digester System
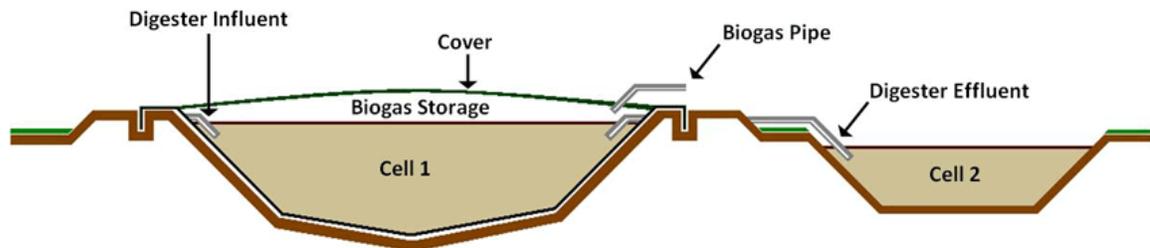
(U.S. EPA, The AgStar Program 2012)

1.3 Financial Support from Federal Policy

There are some federal subsidies and tax support for digester investments. Currently, producers may apply for grants, loans, and tax credits to be used as production incentives.

1.3.1 Rural energy grants and loans (REAP)

The Food, Conservation and Energy Act of 2008 reauthorized Section 9007, including the Rural Energy for America Program (REAP) to be used for grants or loans to farmers investing in digesters. REAP is administered through the USDA Rural Development Agency offering grants, loans, or a combination of both for on-farm renewable energy. Farmers in rural communities may apply for this federal assistance if they produce energy or fuel from solar, wind, geothermal or biomass sources; thus,

digesters qualify. Applicants must receive 50% of their income from agricultural production (Committed to the Future of Rural Economies 2001).

This program authorized nearly $300 million in grants from 2009-2012 for renewable energy projects, with $70 million in 2012 directed to digesters. These grants cannot exceed 25% of costs of production with a minimum of $2,500 grant and $500,000 maximum funding (Committed to the Future of Rural Economies 2001).

Loan guarantees are also authorized through Section 9007. The loan guarantee cannot exceed $25 million with a minimum of $5,000. A combination of a loan and grant cannot exceed 75% of the cost (Committed to the Future of Rural Economies 2001).

REAP was not extended in the 2013 farm bill extension passed on January 1, 2013. However, when Congress passes a comprehensive farm bill, an energy title may be restored and reauthorized.

1.3.2 Tax Credit (REPTC)

The Renewable Electricity Production Tax Credit (REPTC) is another financial incentive for farmers who generate electricity from livestock waste. The tax credit is equal to 1.1 cent per kilo-watt hour (AgSTAR, Federal Renewable Electricity Production Tax Credit 2012). This program credit expires on December 31, 2013.

1.4 Objectives

An economic feasibility model will be used to determine the level of support by the federal government to incentivize an increase in the construction of anaerobic digesters on dairy farms. An economic feasibility model based on a spreadsheet provided by the University of Florida, Institute of Food and Agricultural Sciences (IFAS) Extension Dairy Science for dairy farmers considering investing in anaerobic digesters will be used in the analysis.

The model will examine the financial impacts of increasing the Rural Energy for America Program (REAP) grants. The current rate is 25% of the total project cost, or a minimum of $2,500 and a maximum of $500,000 (USDA Rural Development 2013). Farmers who were informally surveyed indicated their primary barrier to entry was securing the funding to invest in the project. They asked that the National Milk Producers Federation consider lobbying to increase the REAP grant available per project and to increase the maximum allowable funding per grant.

The model will examine the tax credits currently offered to biomass renewable energy providers to also determine if this rate should be increased and to what level to be more attractive to the investor. Another revenue source that will be factored into the model is the price that electric companies currently pay for renewable energy from digesters versus a more competitive market price to farmers for this electricity.

The fourth variable examined in the model will be carbon credits. Methane gas released into the atmosphere becomes a greenhouse gas (GHG) that is 21 times more polluting than the same amount of carbon (Informa Economics 2012). Methane digesters can be GHG offsets for urban sources of emissions known as "cap and trade" in legislation. There are some voluntary markets providing potential revenue for digester operations. The markets trading carbon are occurring in the $1 per MT of carbon equivalent gas, although there have been instances of contracts higher than $10 per MT.

Digesters have a potentially profitable future. Regardless of the outcome of this thesis model, hundreds of thousands of dollars are being invested into the research and technology for the construction of digesters in the United States.

The key components to increase revenue for dairy farmer digester owners may be increased grants available for initial startup construction, aggressive carbon credit trading, greater tax credits for digesters comparable to wind energy credits, as well as requiring electric companies to purchase more on-farm renewable energy at a rate that is closely aligned with the market prices for electricity per kWh.

CHAPTER II: LITERATURE REVIEW

The Innovation Center for U.S. Dairy has extensively studied the economic

feasibility and sustainability of methane digesters on farms. The Innovation Center is

funded through Dairy Management Inc. (DMI) using dairy producer check-off dollars.

This thesis draws on DMI's documented resources online and staff to assist the study. The

Innovation Center refers to on-farm methane digesters as "Dairy Power" (Innovation

Center for U.S. Dairy 2010-2012). The Innovation Center has a goal of 1,300 operating

digesters in the U.S. by 2020.

In August 2012, Informa Economics released a private report prepared for the

Innovation Center for U.S. Dairy to "identify the production possibilities and market value

of the various products of the mature anaerobic digester industry based on large US dairy

farms" (Informa Economics 2012). This report looked at the value of all inputs and

potential outputs on a state by state basis to determine the economic returns and the

sustainability benefits of digesters. The report quantifies the value of electricity,

biomethane, compressed natural gas (CNG), eco-system market and nutrient production.

The Innovation Center shared the data for this thesis project.

The research determined anaerobic digesters are a solution to manage cow manure

in large scale, confined animal feeding operations (CAFOs) while monetizing manure

through the creation energy products, fertilizer nutrients, fiber, and eco-system products.

The results are electricity that can be sold to utility companies from digesters at a current

market value of $813 million. The value of pipeline biomethane was estimated at $419

million per year and compressed natural gas (CNG) had an estimated value of $747 million

per year.

Informa Economics valued the nutrient stripping technology under development to allow for nitrogen and phosphorus to be separated into a storable or transportable form. The value of nitrogen is estimated to be $477 million and phosphorus at $331.5 million per year. Fiber separated from the mass would be used for bedding or peat moss substitutes at a likely market value of $217 million per year.

Eco-system markets are another potential strategy reported by Informa Economics for producers if and when government policies encourage cooperatives to reduce environmental contamination using trading systems for nutrients and emissions. Digesters could take advantage of subsidies from greenhouse gas (GHG) offset credits valued at $349 million, Renewable Energy Credits (RECs) at $35.2 million, Renewable Identification Numbers (RINs) at $1.02 billion and Low Carbon Fuel Standards (LCFS) credits at $43.8 million.

Informa Economics reports that $598.6 million could be saved from tipping fees by monetizing organic substrates. Tipping fees refer to the payment made to landfills for dumping waste. If organic substrates are dumped into landfills versus going through anaerobic digester, the result is higher GHG emissions and potential contamination leakage from the landfill to water resources. An estimated 20.7 million tons of organic substrate could be diverted from landfills to digesters lowering the tipping fees and increasing revenue from digesters.

The results of running three different valuation scenarios show that if 2,647 dairy anaerobic digesters were built in the U.S. that in a low valuation scenario this would produce annual net revenue values of $1.35 billion, a mid-valuation scenario would produce annual net revenues of $2.9 billion and the highest valuation would produce net

revenues of $4.69 billion. The results were all calculated by converting energy to electricity.

The AgStar Program website, www.epa.gov/agstar, is a resource for determining competitive costs, startup support and best practices for managing manure for a profitable digester investment on the farm. The AgStar Program is a coordinated and collaborated effort by the U.S. Department of Agriculture (USDA), U.S Environmental Protection Agency (EPA), and the U.S. Department of Energy (DOE). AgStar provides a comprehensive agency for farmers, investors and researchers to apply for grants or loans, or learn about emerging technology.

The Congressional Research Service (CRS) provides reports to congressional offices on any subject requested by Members of Congress or their staffs. In 2011, the CRS published a report that highlighted the need for more federal support to make digesters profitable for dairy producers. This thesis will be examining a couple of the obstacles mentioned in the report such as: "lack of economic return" and "identifying financial support" (Bracmort 2011).

The CRS report concluded that Congress will consider legislation addressing clean energy and the environment. The report specifies three points for Congress to consider:

1. Identifying the primary benefit offered by digester systems. Selecting a primary benefit (renewable energy generation or greenhouse gas emission reduction) may assist with determining a policy vehicle to support digester technology (e.g., energy legislation, climate change legislation, agricultural legislation). A single message regarding the technology benefit may encourage farmers to invest in digesters.

2. Determining if the methane captured from the technology will be a carbon offset. The climate change debate in previous Congresses included carbon offsets as a potential GHG emission reduction strategy.

3. Identifying whether alternate sources of financial support for technology implementation are appropriate. Most of the federal financial assistance are loans and grants. A shorter payback period for a digester system may occur if producers receive a larger monetary sum for energy generated. The report suggests additional tax credits or increasing the premiums from utilities companies for electricity rates.

Another useful report, Carbon Markets and Methane Digesters: Potential Implications for the Dairy Sector (Key and Sneeringer 2011), provides data and background on a cost-benefit analysis using carbon markets with methane digesters. The report by Key and Sneeringer uses net present value (NPV) to assess the profitability of a digester to predict adoption rates and revenue by size and region. The simulation indicates that a carbon offset market could increase the number of dairy producers willing to invest in a methane digester. The results suggest that at a carbon price of $13/t approximately 934 dairies would be profitable and that carbon offset sales would represent 62% of the present value of gross returns.

The University of Florida Extension IFAS dairy extension specialists, de Vries, Giesy, Wilkie and Nordstedt, built an economic feasibility spreadsheet for Florida farmers. The Florida Dairy Extension's "Solutions for Your Life" spreadsheet (de Vries, et al. 2012) was a base for this thesis to build an expanded model spreadsheet that can be modified with

potential federal policy scenarios. The spreadsheet is designed to help inform and educate producers on the economic returns versus the investment cost for a digester.

An issue for small dairy operations to consider is that a centralized digester shared by nearby farms could assist in reducing the construction and maintenance cost, increase marketing leverage in negotiating electricity sales, and improve access to financing, tax credits or grants. The drawback to a centralized digester would be the cost of transporting manure which is bulky.

The University of Wisconsin- Madison, Department of Agriculture and Applied Economics, Energy Analysis and Policy Program provided a great deal of insight into the economic feasibility for manure digesters on small and mid-size farms. In 2002, Aashish Mehta published the report, "The Economics and Feasibility of Electricity Generation using Manure Digesters on Small and Mid-size Dairy Farms." While it was determined that there was little economic incentive for dairy farmers to install a digester on farms, some of the technology has improved in the last decade. The amount of electricity calculated per year in this research is determined by using 262 kwh/cow annual electricity consumption as reported in Mehta's research (Mehta 2002).

CHAPTER III: THEORY

The EPA has publically released analysis through AgSTAR reporting that there could be as many as 2,647 dairy farm digesters installed in the U.S. EPA considers farms with 500 or more cows and includes the most basic digesters (U.S. EPA, The AgStar Program 2012).

Currently, there are only 162 operating on-farm digesters. In the 1970s, 100 on-farm digesters were constructed with only a 20% success rate. By 1995, only ten digesters were in operation. By 2000, 100 digester systems were operating. Kurt Roos, Agriculture Methane Program Team Leader for AgSTAR, reported in 2010 that the 2,600 digesters proposed by EPA would require a $2.6 billion investment and return $544 million per year in renewable energy revenue alone, assuming 8 cents/kilowatt hour (kWh) (Roos 2010).

In 2010, the 162 on-farm digesters in the U.S. generated 453 million kWh of energy. This is the equivalent of powering 25,000 average-sized homes. By comparison, the EU subsidizes anaerobic digesters to produce biogas for energy converted from agriculture, industrial and municipal wastes. Germany has approximately 6,800 large-scale digesters in operation (Figure 3.1).

Figure 3.1: The Number of Operating Digesters in European Countries
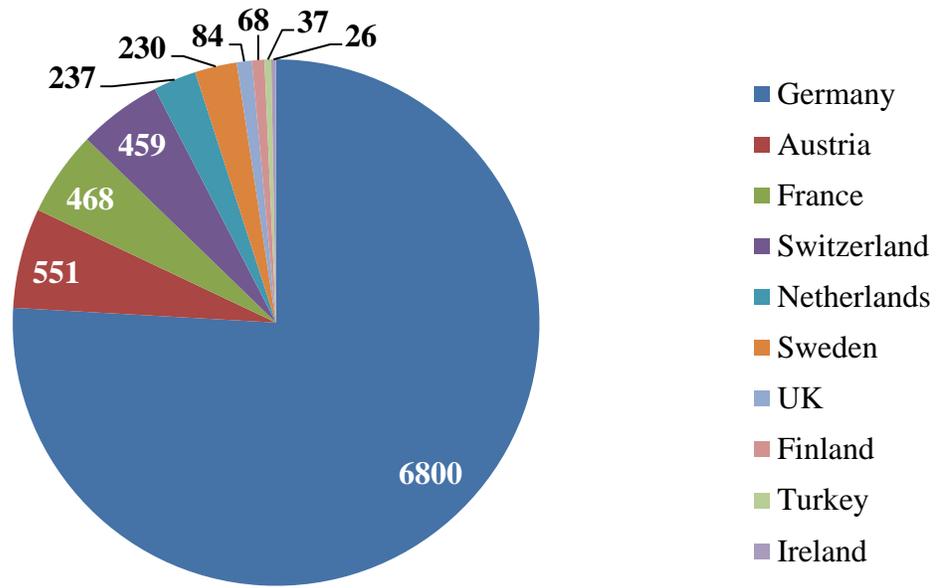
Source: Center for Climate and Energy Solutions

Given the digester industry in Europe, one may expect the U.S. to have many more than a hundred operating digesters. During a three week visit in Germany touring mostly dairy farms, digesters were praised by German farmers and reported to be profitable by dairy farmers and government officials (personal communications).

Germany's Green Party requires "green" energy or renewable fuel to be used within the country. Their Parliament passed laws nearly two decades ago that pay farmers to produce methane to power the electricity grid. The Renewable Energy Sources Act mandated electric companies to purchase this renewable energy at a rate that profits the farmer who also uses the energy to power the farm. In 2011, more than 20 percent of Germany's electric supply was produced from renewable sources and was expected to be 35% by 2020.

If U.S. farmers believed investing in digesters would be profitable and provide energy at a reduced cost to their farms, wouldn't they be willing to construct on-farm digesters? What are the real barriers of entry? Why won't U.S. electric companies purchase more renewable energy from farms? Should Congress intervene with more public policy incentives for farmers, electric companies or consumers to encourage the investment in the digester industry?

This thesis will examine what incentive will make digesters profitable on farms. The key components to increased revenue may be increased grants and loans available for initial startup construction, greater tax credits for digesters comparable to wind energy credits, as well as requiring electric companies to purchase more on-farm renewable energy at a rate that is closely aligned with the market prices for electricity per kWh.

An Excel spreadsheet is used to calculate the economic feasibility of digesters on a dairy farm can determine the net revenue, the benefit-cost ratio and the internal rate of return. Adjusting the tax rate to assume higher tax credits for renewable fuels, Rural Energy for America Program (REAP) grants and loans, carbon credits and electricity retail price in the spreadsheet will affect the profitability.

A spreadsheet must include conversions for output of solids, methane (CH_4), and electricity generated. Building on the University of Florida feasibility model, the investment analysis will include a fixed current tax rate at 35%, discount rate of 8%, 10 year duration, and minimum salvage value of $10,000 (de Vries, et al. 2012). The natural gas price, electricity retail price and electricity used on the farm will be a national average for a 1,500 cow farm.

The investment criteria for economic feasibility model includes net present value (NPV) for electricity and gas generation sales. Net present value is the difference between the present value of cash inflows minus the required investment or present value of cash outflows. The benefit-cost ratio will be calculated with the criteria of greater than 1. The internal rate of return (IRR) will be included as a profitability measure. IRR is defined as the rate of discount that makes NPV equal zero (Brealey, Myers and Allen 2011).

CHAPTER IV: METHODS

Building an economic feasibility spreadsheet to determine the net present value,

(NPV), benefit-cost ratio, internal rate of return (IRR) and payback period required

collecting data from the Dairy Management Inc. (DMI) and incorporating that with a

spreadsheet designed by Dr. Albert de Vries, UF/IFAS Department of Animal Sciences.

The objective is to determine the rate of return by changing the out-of-pocket expense by

the farmer for building an on-farm methane digester.

A spreadsheet must include conversions for output of solids, methane (CH_4), and

electricity generated. Building on the University of Florida feasibility model, the

investment analysis used a fixed current tax rate at 35%, discount rate at 8%, 10 year

duration, and a salvage value of $10,000 (de Vries, et al. 2012). The natural gas price,

electricity retail price and electricity used on the farm is the national average for a 1,500

cow farm.

The investment criterion for the economic feasibility model calculates net present

value (NPV) for electricity and gas generation sales. Net present value is the difference

between the present value of cash inflows minus the required investment or present value

of cash outflows. The benefit-cost ratio is calculated with the criteria of it being greater

than 1. The internal rate of return (IRR) is also included as a profitability measure. IRR is

defined as the rate of discount that makes NPV equal zero (Brealey, Myers and Allen

2011).

4.1 Manure

The raw input material for creating energy from a digester system is manure. The

American Society of Agricultural Engineers estimates that a lactating cow produces 150

pounds of manure per day. The U.S. produces more than 100 million pounds of dairy cow

manure annually. Dairy manure contains approximately 15% solids. The percentage of solids is determined by the amount of water used to flush the barn. Most digesters use manure that is between 1% and 13% solids (Krich, et al. 2005). For this model, 200 gallons of waste water per cow per day is used to determine the total waste volume per day as determined by the University of Florida (de Vries, et al. 2012). This is an average for most dairy cows. All calculations assume a 1,500 cow farming operation which provides a steady and abundant supply of manure to generate the digester.

(4.1)   Number of cows x 200 gal/cow/d = total waste water volume.

The amount of volatile solids is variable depending on the handling and moving of the manure from the barn to the holding facility. Daily removal is preferred but some farms may only transfer the manure weekly. In fresher manure, the solids are more volatile and return more energy. Of the 15% solids in raw manure, 83% are volatile solids. Following the University of Florida model, this spreadsheet assumes 12 pounds of volatile solids are digested per cow per day (de Vries, et al. 2012).

(4.2)   Number of cows x 12 lbs/cow/d = volatile solids to digester per day

4.2 Energy Generations

Changing volatile solids to methane or biogas requires conversion before marketable products are created. Biogas is a mixture of methane and carbon dioxide that may be converted to power as electricity, pipeline biomethane, or compressed natural gas (CNG).

The spreadsheet calculates the annual amount of methane produced by a digester per cow. It calculates the amount of electricity and natural gas produced, as well as the

amount of carbon dioxide reduced. The amount of electricity and gas generated is calculated by using several standard constants for conversions such as 12 pounds of volatile solids (VS) per cow per day, 4 standard cubic feet (scf) of CH_4 (methane) per pound of VS, 1000 btu per cubic feet of Latent Heating Value (LHV) from CH_4, 3412 btu/kwh electrical value constant times 25% determines kwh/day (de Vries, et al. 2012). Table 4.1 is the conversion results for 1,500 cow dairy farm digester. Each cow generates 3.52 kWh of electricity per day (de Vries, et al. 2012).

Table 4.1: An Excel Spreadsheet Conversion for a 1,500 Dairy Farm Generating Electricity through Methane Digestion to Kilowatt-Hours

Cows and Water	Units	Calculation
Number of cows		1500
Waste water volume	gal/cow/d	200
Waste water volume	gal/d	300,000
Methane and Energy Generation		
VS to digester	lbs/cow/d	12.00
VS to digester	lbs/d	18,000
Conversion factor VS to CH4	scf / lb VS	4.00
CH4 methane yield	ft3/d	72,000
CH4 methane yield	ft3/cow/d	48
Conversion factor LHV	btu/ft3	1000
LHV (Latent Heating Value)	btu/d	72,000,000
Electrical value constant	btu/kwh	3412
LHV conversion efficiency	%	25%
Electricity generated	kwh/d	5,275
Electricity generated	kwh/cow/d	3.52

Source: University of Florida, IFAS Extension (de Vries, et al. 2012)

Electricity is the most common form of energy generated from dairy waste digesters. The price of electricity varies widely depending on the type and size of a digester. The price is determined by state regulations, net metering agreements, or contracts between digester operators and the utility companies. Informa Economics

determined on the low end, electricity may be valued as low as $0.03 per kWh. On the high end, California pays an average of $0.11 per kWh for electricity. Table 4.2 shows the average retail price per state in 2012.

Table 4.2: Average Electricity Price by State for 2012

State	Electricity Price ($/kWh)
Arizona	0.0658
California	0.1101
Colorado	0.0712
Idaho	0.0516
Michigan	0.0736
New Mexico	0.0611
New York	0.0780
Texas	0.0634
Washington	0.0397
Wisconsin	0.0734
Other 40 States	0.0660

(Informa Economics 2012)

To calculate potential electricity sales, the model subtracts the kWh/year needed to run the dairy from the total amount of electricity produced. Assuming each cow's electricity usage is 262 kWh per year, as reported for a 400 cow dairy farm by the University of Wisconsin (Mehta 2002), the annual electricity use cost would be $38,514.

The future retail price may be adjusted as future prices are predicted. The future wholesale price is reported daily and also varies by region with California's high price of $0.051/kWh and the Midwest's lowest price of $0.028/kWh. This model assumes retail prices could rise to $0.15 and the future wholesale price is $0.035/kWh.

The 1,500 cow digester produces 5,274 kWh per day totaling 1,925,557 kWh of electricity annually while only using 393,000 kWh, yielding a net of 1,532,557 kWh to be sold into the market. For complete conversion results see Table 4.3.

Table 4.3: Spreadsheet Data for Value of Electricity from the 1,500 Dairy Cow Digester

Electricity	Units	Calculation
Electricity used	kwh/yr	393,000
Electricity cost	$/yr	38,514
Current retail price	$/kwh	0.098
Future retail price	$/kwh	0.150
Future wholesale price	$/kwh	0.035
kwh used	kwh/yr	393,000
kwh made	kwh/yr	1,925,557
Net electricity balance	kwh/yr	1,532,557
% electricity needs produced	%	490%
Retail value kwh used	$/yr	58,950
Retail value kwh made	$/yr	288,834
Avoided electricity cost	$/yr	58,950
Wholesale value kwh made	$/yr	67,394
Electricity sales at wholesale price	$/yr	53,639

Source: University of Florida, IFAS Extension (de Vries, et al. 2012)

4.3 Gas Conversion

The commercial natural gas retail price average for 2013 as reported by the U.S. Energy Information Administration on February 12, 2013 was $9.04 per 1000 ft^3. However, after surveying digester owners and operators it was determined that the wholesale price offered for digester gas is between $3.00 and $4.00 per 1000 ft^3. Fair Oaks Dairy Farms in Indiana reported receiving $3.90 per 1000 ft^3 in March 2013. The price for natural gas used in this model is $3.90 per 1000 ft^3.

The addition of carbon credits was included because of the potential for future revenue if Congress enacts Climate Change legislation. Methane digesters could be a carbon offset for emitters thus exchanging credits for revenue. The formula for converting methane (CH_4) to the carbon dioxide equivalent (CO_2) is:

(4.3) $((((Total\ CH_4\ /23.6)\ x\ 365\ days)\ /2000\ lbs)\ x\ 21)$.

Source: AgStar (U.S. EPA, The AgStar Program 2012)

Ten years ago carbon credits were trading at $2.00 per MT. In 2011, Key and Sneeringer ran a benefit-cost analysis using $13 and $26 per MT in anticipation that Congress would mandate carbon trading as part of any climate change legislation. Because Congress did not pass that law, there was a collapse in the carbon trading market. Table 4.4 is the conversion for gas and carbon credit value. In the model $0.00 will be the base with $2.00, $4.00, $10.00 and $16.00 per metric ton of CO_2 being analyzed for potential value.

Table 4.4: The Conversion for 1,500 Dairy Farm Values of Natural Gas and Potential Carbon Credits

Gas	Units	Calculation
Price natural gas	$/1000 ft^3	3.90
Value as natural gas	$/d	281
Value as natural gas	$/yr	102,492
CO_2 equivalent	Tons CO_2/yr	11,692
CO_2 equivalent	Metric Tons CO_2/yr	10,605
Carbon value	$/Metric Ton CO_2	2.00
Value of CO_2 reduction (carbon credits)	$/yr	21,210

Source: University of Florida, IFAS Extension (de Vries, et al. 2012)

4.4 Investment Data

In the economic model, the investment data for the following are used for all calculations:

1. Current tax rate is 35% assuming annual income of over $388,350 for a married couple.

2. Annual discount rate is 8% using the same as the University of Florida from 2005. This rate may be adjusted to reflect different current rates.

3. Operating and maintenance cost average 10% including one full time employee.

4. Electric installation average cost is $500/cow, Gas installation average cost is $300/cow as reported by Informa Economics and AgriStar.

5. Salvage value $10,000 for the scrap metal and other parts for resale at the low end.

6. Duration of investment is 10 years. Again, this was used in the original model by University of Florida and can be adjusted as the duration may be extended.

4.5 Summary

The results are generated by comparing the farmer's part of the investment cost at different percentages. Most scenarios include maintaining the current law of 75% cost at owners expense assuming the Rural Energy Investment Project (REAP) grants cover 25% startup installation. Scenarios 12, 14 and 15 reduce the owners cost by an additional 5 percent from the REAP grant to 70% cost to farmer and scenario 13 assumes no assistance or 100% owners cost.

Increasing the wholesale price from the electric companies will positively adjust the feasibility of investing in digesters. The model will include electricity sales by Congress mandating electricity companies to purchase "green" energy at current wholesale price or $0.035/kwh. Mark Stoermann, digester manager at Fair Oaks Farms, and Mike McCloskey, owner of Fair Oak Farms reported to a group of 60 farmers in April 2013 that the Midwest receives approximately $0.03 per kWh but costs $0.05 to make electricity so they use the

electricity to power their farm. They calculated that is would require electric companies to pay them $0.08-$0.09 per kWh to be profitable. Therefore, this thesis used $0.035 as the baseline market price but included $0.037, $0.040, $0.05, and $0.09 per kWh in some of the scenarios.

If Congress passes laws to require carbon trading as offsets to global warming in climate change legislation, the value of CO_2 reduction may increase the farmer's revenues. Three levels of value assumed in the model will be a zero credit baseline, $2 credit per metric ton (MT) CO_2, $4/MT CO_2, $10/MT CO_2 and $16/MT CO_2. The long-term equilibrium price for GHG offsets is $10/MT CO_2 (Informa Economics 2012).

Tax credits are included as a profit contributing factor. The Renewable Electricity Production Tax Credit (REPTC) is another financial incentive for farmers who generate electricity from livestock waste. The tax credit is equal to 1.1 cent per kilo-watt hour (AgSTAR, Federal Renewable Electricity Production Tax Credit 2012). This program credit expires on December 31, 2013. In the model, investment tax rates are adjusted from the 35% current rate to 34% in scenarios 10 and 14, and 33% in scenarios 11 and 15. This is a simple reduction and may require considerable changes in tax laws by Congress.

The feasibility model for this thesis includes calculating the net-present value (NVP), benefit-cost ratio (B-C), internal rate of return (IRR), and payback period in years for each of the fifteen scenarios. The NPV is the present value including the salvage value less the investment cost.

(4.4)   NPV= - Initial Investment + (Cash Flow/((1 + Discount Rate)^{Time})))

Source: Principles of Corporate Finance

The benefit-cost ratio is a profitability index. The higher the ratio the better. However, the benefit-cost ratio alone can be misleading and may not reflect the actual value of the return but only the index. This is why the NPV and IRR are also considered when determining whether to invest in a methane digester project.

The internal rate of return is another profitability measure but the IRR depends solely on the amount and timing of the project cash flows (Brealey, Myers and Allen 2011). The higher the percentage of the IRR, the greater the return which increases the desirability of the project.

(4.5) $$0 = P_0 + P_1/(1+IRR) + P_2/(1+IRR)_2 + P_3/(1+IRR)_3 + \ldots + P_n/(1+IRR)_n$$

where P_0, P_1, . . . P_n equals the cash flows in periods 1, 2, . . . n, respectively; and IRR equals the project's internal rate of return.

Source: www.investinganswers.com

The payback period is the number of years required for the project to recover the initial investment (Brealey, Myers and Allen 2011). The duration of the digester projects for this thesis is 10 years. The lower the payback the quicker turnaround in profits.

One profitability index alone may not show the true potential project results. Even if all four of these indexes are positive there may continue to be barriers to entry that would prohibit a farmer from investing in a digester.

CHAPTER V: RESULTS

The results of 15 scenarios are compared to determine the affect of combinations of carbon credit, REAP grant, tax credit and net metering income on the profitability of digester investment. The economic feasibility of each scenario is determined by calculating net present value (NPV), the benefit-cost ratio, Internal Rate of Return (IRR), and payback period. For every scenario there are energy results and gas results. A methane digester cannot produce gas and electricity simultaneously so the farmer must choose whether to sell gas or electricity.

There are 15 scenarios in this analysis. There are 4 factors that will be adjusted. The Carbon Credits factor includes rates of:

- $0.00 carbon value per metric ton of Carbon Dioxide (CO_2).

- $2.00 carbon value per metric ton of Carbon Dioxide (CO_2).

- $4.00 carbon value per metric ton of Carbon Dioxide (CO_2).

- $10 carbon value per metric ton of Carbon Dioxide (CO_2).

The Net Metering implementation rates are:

- $0.035 current wholesale price per kilowatt hour.

- $0.037 per kilowatt hour.

- $0.04 per kilowatt hour.

- $0.05 per kilowatt hour.

- $0.09 per kilowatt hour.

The Renewable Electricity Production Tax Credit (REPTC) rates of:

- 35% current tax rate fixed or no tax credit.

- 34% tax rate that includes REPTC.

- 33% tax rate with an increased REPTC that would be more comparable to wind and solar tax credits.

The REAP Grants factor includes rates of:

- 100% installation cost paid by the farmers or no REAP grant.

- 75% installation cost paid by the farmer or the current REAP grant rate of 25%.

- 70% installation cost paid by the farmer or an increase in the REAP grant by 5% to 30%.

Scenario 1 is the current market solution of $0.0 carbon credits, the net metering wholesale price of $0.03, the current tax rate of 35%, and 75% of the installation cost paid by the producer.

Scenario 13 is the worst market case scenario. The worst case scenario has zero carbon trading, lowest electricity rate, highest tax rate and no REAP grant assistance. This reflects no federal support should the REAP assistance fail to be reauthorized this year and no carbon trading markets in the future.

Scenario 15 is the optimistic scenario. This scenario assumes a higher carbon credit trade, the electricity rate as suggested by Fair Oaks Farms, the lowest tax rate assuming an increase in renewable energy tax credits, and an increase in REAP grants by 5%. Table 5.1 shows the combination of all fifteen scenarios considered in this thesis.

Fifteen scenarios were chosen as the best representatives of current federal policy authority and future federal policy changes. First, there are 5 different carbon trading prices that were compared in the model with the other three factors at current market value (Scenarios 1-5). This was used to determine the significance of carbon trading. The 113th

Congress may take up climate change legislation so this information was important to reflect the opportunities for farmers participating in carbon trading. Net-metering is the next factor that could be influenced by federal policy. There are five options for electricity to show the significance in electricity purchases from the farmer by the utility companies (Scenarios 1, and 6 through 9). Only three tax credit variables were used- the current rate, 1% below current rate and 2% below current rate (Scenarios 1, 10, and 11). Given current federal budget deficit, it is most unlikely this Congress will agree to reduce tax rates for renewable energy. Plus, the changes to tax credits weren't as significant as the other factors. Therefore, the model includes the tax rates of 33% and 34% in only four of the fifteen scenarios. The REAP grant percentage was maintained at 75% for all but four scenarios (Scenarios 11, 12, 14, and 15). Increasing the rate to 70% could be difficult due to the federal budget deficit. Federal programs are reducing their spending as a result of sequestration. It may not be possible to secure more funding for REAP but this model shows that maintaining the current rate of 75% with increases in carbon credits and the electricity is the most attractive scenarios with the best NPV.

Table 5.1: Fifteen Scenarios Comparing Carbon Credits, Electricity Rates, Tax Rates, and REAP Grant

Scenario	Carbon Credit ($/MT CO2)	Electricity Rate ($/kwh)	Tax Rate (%)	REAP Grant (%)
1	0	0.035	35	75
2	2	0.035	35	75
3	4	0.035	35	75
4	10	0.035	35	75
5	16	0.035	35	75
6	0	0.037	35	75
7	0	0.040	35	75
8	0	0.050	35	75
9	0	0.090	35	75
10	0	0.035	34	75
11	0	0.035	33	75
12	0	0.035	35	70
13	0	0.035	35	100
14	2	0.050	34	70
15	16	0.090	33	70

Table 5.2 shows the electricity NPV, Benefit-Cost Ratio, IRR and Payback for all 15 scenarios. Electricity generated from the digester sold at less than $0.05 per kwh has very low to negative NPV that would not likely attract farmers to invest in methane digesters under the current market situations. The most positive NPV resulted from the $0.09 per kwh electricity sales (Scenarios 9 and 15). Electric companies are not purchasing renewable electricity at a level except in Vermont.

Table 5.2: The Results for NPV, Benefit-Cost, IRR and Payback Period Data for Electricity

Electricity Scenarios	NPV	B-C ratio	IRR (%)	Payback (yr)
1	$ (11,659.00)	0.097	7.31	7.01
2	$ (11,659.00)	0.097	7.31	7.01
3	$ (11,659.00)	0.097	7.31	7.01
4	$ (11,659.00)	0.097	7.31	7.01
5	$ (11,659.00)	0.097	7.31	7.01
6	$ 1,709.00	1.000	8.10	6.76
7	$ 21,762.00	1.060	9.25	6.42
8	$ 88,606.00	1.240	12.94	5.48
9	$ 355,979.00	1.950	26.09	3.46
10	$ (9,909.00)	0.097	7.42	6.98
11	$ (8,158.00)	0.980	7.52	6.95
12	$ 7,469.00	1.020	8.46	6.66
13	$ (107,303.00)	0.790	3.03	8.65
14	$ 111,195.00	1.320	14.55	5.14
15	$ 390,256.00	2.120	28.92	3.19

Figure 5.1 graphs the NPV for electricity in all 15 scenarios.

Figure 5.1: Graph for Electricity NPV for Scenarios 1-15.
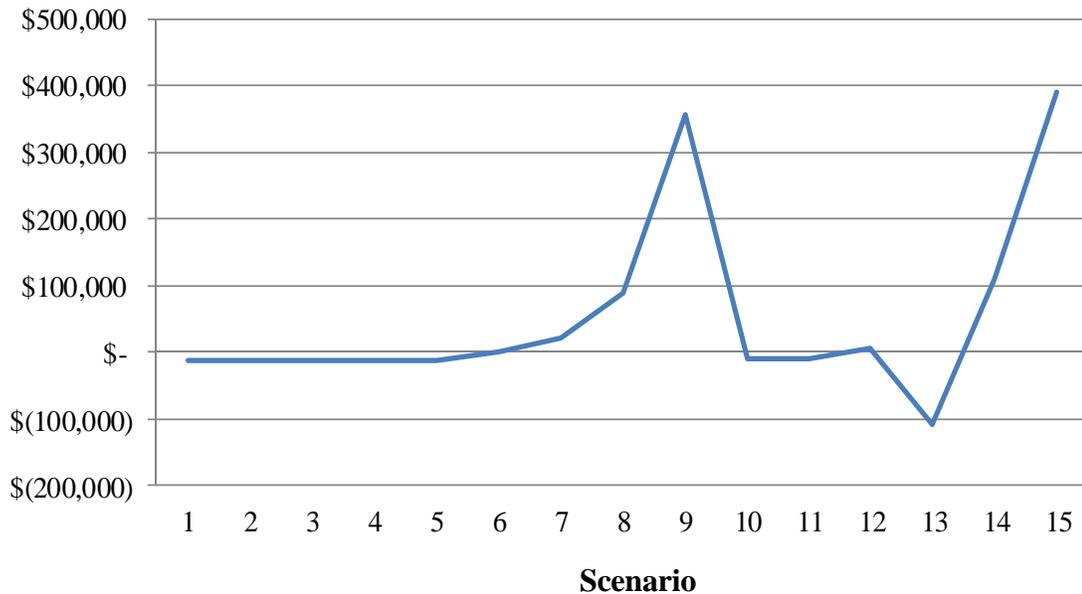

Scenario

Table 5.3 lists the results for natural gas. All of the scenarios used a natural gas price of \$3.90 per 1,000 ft^3. The NPV, Benefit-Cost ratio, IRR and payback period show that natural gas would be the better of the two energy options in the most scenarios to produce and sell.

Table 5.3: The Results for NPV, Benefit-Cost, IRR and Payback Period Data for Gas

Gas Scenarios	NPV	B-C ratio	IRR (%)	Payback (yr)
1	\$ 146,303.00	1.650	20.74	4.12
2	\$ 238,811.00	2.060	27.93	3.29
3	\$ 331,320.00	2.470	34.77	2.74
4	\$ 608,845.00	3.710	54.23	1.82
5	\$ 886,370.00	4.940	73.01	1.36
6	\$ 146,303.00	1.650	20.74	4.12
7	\$ 146,303.00	1.650	20.74	4.12
8	\$ 146,303.00	1.650	20.74	4.12
9	\$ 146,303.00	1.650	20.74	4.12
10	\$ 149,735.00	1.670	21.01	4.08
11	\$ 153,146.00	1.680	21.29	4.04
12	\$ 157,780.00	1.750	22.53	3.88
13	\$ 88,917.00	1.300	14.12	5.24
14	\$ 255,234.00	2.220	30.51	3.06
15	\$ 927,663.00	5.420	80.19	1.24

Figures 5.2 shows the NPV for natural gas for scenarios 1-15.

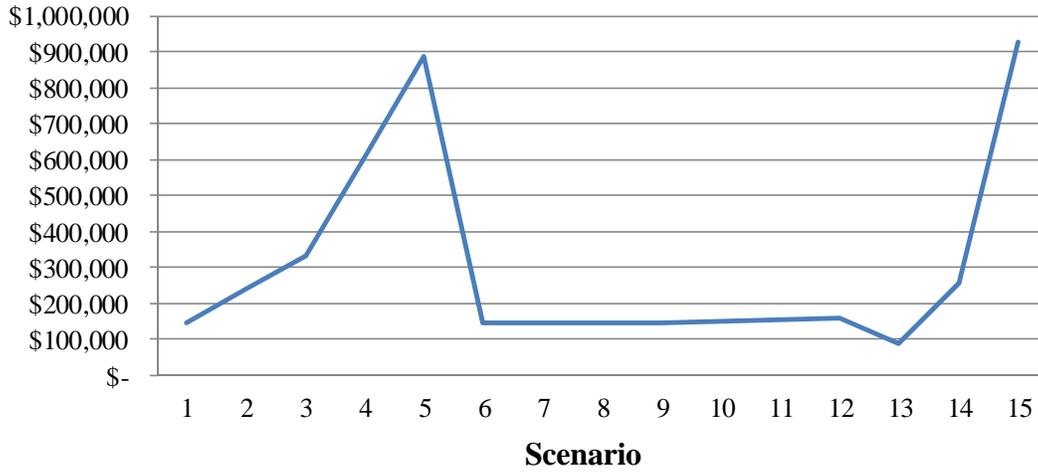**Figure 5.2: Graph for Gas NPV for Scenarios 1-15**

Figure 5.3 compares the benefit-cost ratio profitability index for electricity and natural gas. Natural gas is higher than electricity in all scenarios except in the comparison of scenario 9. Scenario 9 has the highest net-metering electricity price of $0.09/kWh with zero carbon credits. The best benefit-cost ratios are scenarios 5 and 15 for natural gas. Those are the scenarios with the highest carbon credits of $16/MT CO_2.

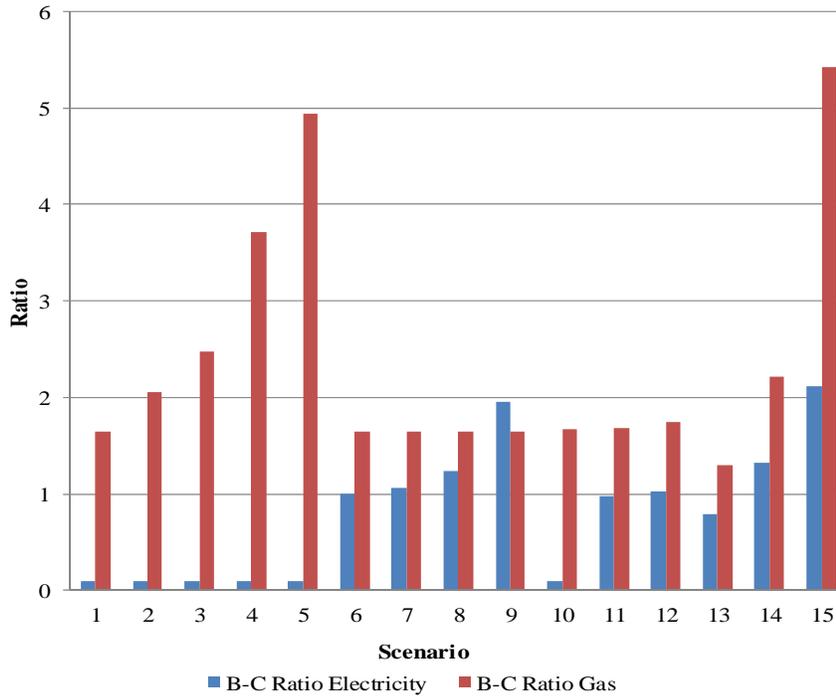**Figure 5.3: Comparison of the Benefit-Cost Ratio of Electricity and Natural Gas for Scenarios 1-15**

Figure 5.4 compares the IRR for electricity and gas. This graph is very similar to the benefit-cost ratio. The IRR is less than 10% for 11 of the 15 scenarios. Only twice does the IRR for electricity go above 25%. An electricity only digester would not be as attractive to a farmer or a lender as an investment as a natural gas digester. The IRR for natural gas tops 70% on scenario 5 and 15. This shows the significance of carbon credit trading.

Figure 5.4: Comparison of the IRR between Electricity and Natural Gas for Scenarios 1-15
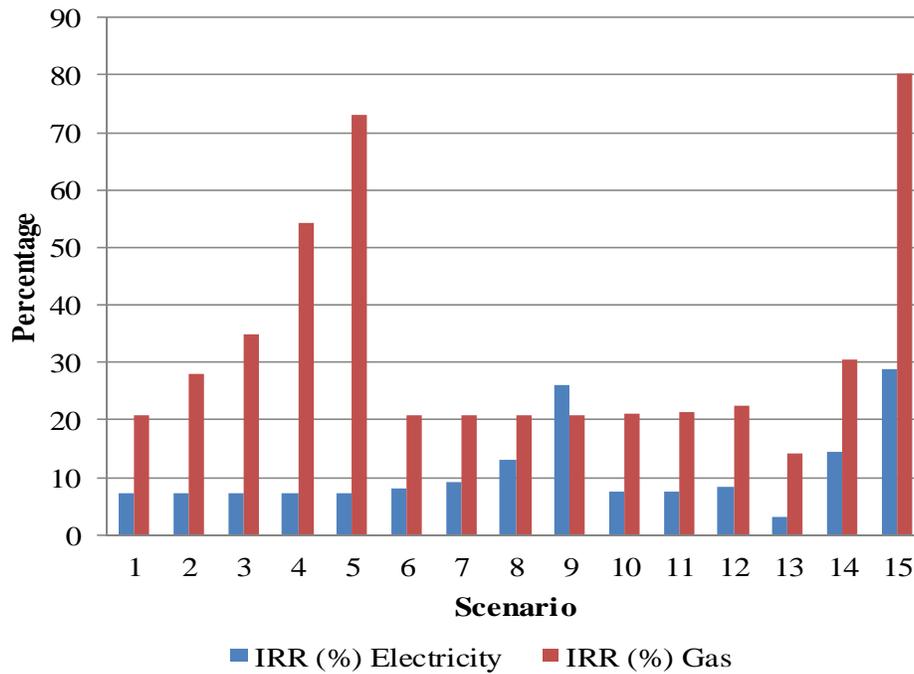
In all scenarios but number 9, producing and selling gas would be the most profitable method with the earliest payback period. Figure 5.5 illustrates the payback period in years for scenarios 1-15. Scenario 13 is the worst for both methods but gas still has a more favorable payback period than 12 of the electricity scenarios.

Figure 5.5: Comparison of the Payback Period for Electricity and Natural Gas for Scenarios 1-15
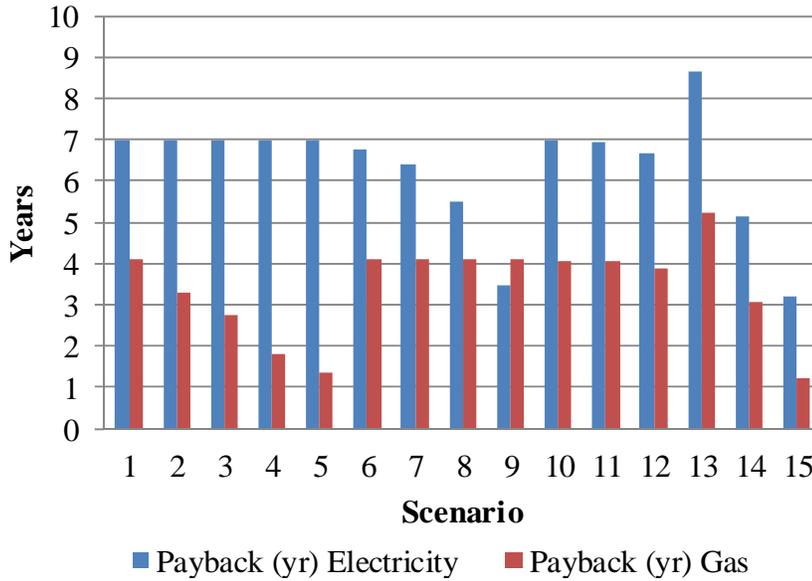
The higher returns and shorter payback period are incentives for farmers to invest in methane digesters on their farms. The most profitable factors that may increase construction of methane digesters are to mandate net-metering by electric companies to purchase more renewable energy and to open markets for carbon trading by passing "cap and trade" legislation.

CHAPTER VI: CONCLUSION

On January 7, 2013, the National Journal energy blogger reported that President Barak Obama said that "after the fiscal cliff, energy is the third-ranking policy priority for his next four years, after immigration and economic growth (Harder 2013)." Christine Todd Whitman, Former EPA Administrator and New Jersey Governor, wrote "with domestic electricity demand scheduled to rise 22 percent by 2035, there is no better time for our country to lay the groundwork for sustainable energy future than now (Whitman 2013)." "Citizens support for clean, renewable energy – support that is strong and bipartisan as we know from consistent polling numbers – should mobilize political leaders to adopt long-term renewable energy legislation," says Dennis McGinn, President of the American Council on Renewable Energy. The American Biogas Council is hosting a conference in May 2013 to assist digester investors in ways to increase their revenue streams to make the investment viable.

Moving forward in the 113th Congress, energy policy could be one of the few bipartisan legislative efforts. Dairy farmers may be able to secure increased funding for REAP grants to cover 30% of installation costs as shown to be a significant economic benefit for digester profitability. The most aggressive and profitable approach may be to legislate carbon trading, renewable energy purchases, and higher tax credit for manure anaerobic digesters.

The electricity scenarios studied in indicate that the NPV ranges between a maximum value of $390,256 to a minimum value of negative $11,659. The gas NPV ranges from $88,917 and $927,663. Therefore, the results of subsidizing all four factors annually improve the electricity NPV by $401,915 and gas NPV by $838,746.

The best results for a digester to reach the maximum revenues in the model are higher wholesale electricity payments or net-metering and carbon credit trading at $10 per metric ton or more. The tax credit reductions in scenarios 10 and 11 did not result in increasing the NPV for electricity or natural gas to an attractive level for farmers. The NPV for electricity remained negative.

Vermont incentivizes "Cow Power" by paying farmers for every kilowatt-hour requested by customers and provided by a Vermont farm. Green Mountain Power pays the farmer for the energy at rates set by the state, plus the Cow Power charge of 4 cents for the environmental and renewable benefits of the generation (Green Mountain Power 2013). No other state offers this high rate of approximately $0.12 per kwh for electricity generated from a methane digester. Since 2004, Green Mountain Power has partnered with 12 farms in Vermont for cow power.

The electricity rate in the Midwest for methane digester electricity is currently only $0.03 per kwh. The model results show that $0.09/kwh in scenario 9 would have an IRR of 26.09% with no other changes to other factors. The electricity usage per year on the farm could be higher or lower for each digester and farm operation. This estimate could be an input that may be undervalued in the model. The electricity in this model was an average from data collected for working digesters from University of Wisconsin (Mehta 2002) and AgStar (Digester Performance Evaluations 2012).

Carbon credit trading is most profitable at the $10.00/MT CO_2 and $16.00/MT CO_2 with IRRs of better than 54% and 73%, respectively. Those rates are not unrealistic for future carbon trading should Congress pass "Cap and Trade" legislation. In mid-April, the

Capitol Hill publication, Politico, reported the President's budget supported cap-and-trade policy (Goode and Restuccia 2013).

The future for methane digesters looks profitable when energy and carbon markets are enacted. The federal government may consider focusing on incentives for the utility companies' infrastructure to make purchases of renewable energy from a digester more economically attractive and efficient. Today, an obstacle for increasing the number of digesters in the United States is the cost associated with moving the energy from the digester and connecting that natural gas to a pipeline. The natural gas companies would have to be compensated for that expense plus the potential difficulties of dealing with multiple suppliers or digesters owners.

The electricity companies have a grid in place to power rural and urban communities. They have spent billions of dollars and decades to establish efficient routing of power to residents and business far and wide. Manure digesters are mostly located in rural areas that would also require an investment in infrastructure to move the energy from the digester to the power grid. Mandating net-metering would ensure energy companies of purchasing renewable energy but consumers may see an increase in their cost.

Therefore, the conclusion may be to direct the incentives to utility companies to invest in expanding infrastructure rather than increasing digester owner subsidies. Although, the REAP grants are certainly helpful for assisting farmers with startup installation costs, there may not be a need to increase that subsidy in the next farm bill if an energy bill includes incentives for energy companies to purchase renewable energy from digesters.

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