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CARBON CREDITS AND ENERGY SUBSIDIES IN ECONOMIC DECISION MAKING FOR CONFINED ANIMAL FEEDLOT OPERATION WASTE TREATMENT

by

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ABSTRACT

Released waste into the environment has always had a societal cost. Current issues with swine waste suggest that improved treatment is needed as agricultural production has become more industry-like and also as we now globally value the mitigation of global warming. The current need for and the economic support of advanced waste treatment has converged for animal agriculture, and now improved waste treatment is possible with concurrent economic benefit through alternative energy and carbon emissions. Recent changes have resulted in renewal of interest in anaerobic digestion (AD) technology with methane capture and energy production. An economic model was constructed to evaluate the financial potential of anaerobic digestion for swine waste considering initial investments, the associated costs and new revenue streams of carbon credits, renewable energy credits and electricity sales. Current available subsidies were also taken into consideration. The model was formulated based on case specific inputs and was applied to three case studies in central Missouri. The model inputs were also evaluated by experienced vendors (who have developed similar projects) for validity. The results revealed that the present prices of carbon credits and electricity are not enough to prove the financial feasibility of applying AD technology in all cases without the availability of current subsidies. The endeavor also showed that electricity prices have modest impacts on the corresponding NPV of the project. On the other hand, the carbon credit market projections affect the NPV to a greater degree. Clearly, carbon credit markets may play a pivotal role in widespread development and implementation of the technology. In all the three scenarios the projects were profitable with the presence of the current state and federal subsidies. However, since the subsidies may not be available for many years, high CC and electricity prices are probably needed for future profitability of the technology.

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the United States and surely have helped me in every possible way during my graduate career.

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GLOSSARY

AD Technology- Anaerobic Digestion Technology:
Anaerobic Digestion (AD) is a microbial process to decompose organic molecules and volatile solids (VS) in the absence of oxygen. In the process a biogas, composed primarily of methane and carbon dioxide, is produced as a product of digestion.

Additionality:
A project activity is considered additional if anthropogenic emissions of green house gases GHG's by sources are reduced below those that would have occurred in the absence of the project activity.

Baseline:
A baseline is the starting point from which GHG emissions reduction activity is measured. A company's baseline is essentially the level of emissions that it would produce under "business as usual scenario" without any proactive emission reduction activity.

BOD- Biochemical oxygen demand:
BOD is a chemical process to determine how fast biological organisms consume oxygen in a body of water.

BTU- British Thermal Unit:
A British Thermal Unit (BTU) is the amount of heat energy needed to raise the temperature of one pound of water by one degree F.

CAFO's- Confined Animal Feedlot Operations:
CAFOs are animal feeding operations with at least 1,000 animal units -- the equivalent of more than 1,000 head of cattle or 2,500 hogs (NRDC).

Carbon Credits (CC):
Carbon credits are a tradable permit scheme. They provide a way to reduce greenhouse gas emissions by giving them a monetary value. A credit gives the owner the right to emit one ton of carbon-di-oxide. Carbon credits are generated as the result of an additional carbon project that reduces carbon generation.

Carbon Dioxide Equivalent (CO_2e):
The universal unit of measurement used to indicate the global warming potential of each of the six greenhouse gases. Carbon dioxide which is a naturally occurring gas is used as the reference gas against which the other greenhouse gases are measured.

Clean Development Mechanism (CDM)
CDM is an agreement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment (called Annex I countries) to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries. The most important factor of a carbon project is that it should be established that the project would not be financially viable without the additional incentive provided by emission reductions credits.

CER's- Certified Emission Reductions:
A unit of greenhouse gas emission reductions issued pursuant to the Clean Development Mechanism of the Kyoto Protocol, and measured in metric tons of carbon dioxide equivalent.

Carbon Markets:
A popular term for a trading system through which countries may buy or sell units of greenhouse gas emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under voluntary markets, for example European climate exchange and Chicago climate exchange.

GHG's- Green House Gases:
The atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the Earths surface are known as green house gases. Some of the GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and water vapor.

IRR- Internal Rate of Return:
The annual return that would make the present value of future cash flows from an investment (including its residual market value) equal to the current price of the investment is defined as the internal rate of return (World Bank)

Mitigation:
Mitigation refers to the actions to cut net emissions of green house gases in order to reduce global warming potential.

NPV- Net Present Value:
The net present value is defined as the equivalent worth of all cash flows discounted to the present point in time at a relevant interest rate (Sullivan, 2001).

RPS- Renewable Portfolio Standards:
Renewable Portfolio Standard (RPS) is a state policy mandating a state to generate a percent of its electricity from renewable sources.

Validation:
The assessment of a project's Project Design Document, which describes its design, including its baseline and monitoring plan, by an independent third party, before the implementation of the project against the requirements of the CDM (Bank).

VER's- Verified Emission Reductions:
A unit of greenhouse gas emission reductions that has been verified by an independent auditor, but that has not yet undergone the procedures and may not yet have met the requirements for verification, certification and issuance of CER's (in the case of the CDM).

Verification:
The periodic independent review and ex post determination by an independent third party of the monitored emission reductions that have occurred as a result of a registered CDM project activity during the verification period.

AGENCY/COMPANY ABBREVIATIONS:

CCX- Chicago Climate Exchange

ECC- Environmental Credit Corporation

EFI- Environmental Fabrics Incorporation

NASD- National Association of Security Dealers

EPA- Environmental Protection Agency

MASBDA- Missouri Agricultural & Small Business Development Authority.

MELO - Managed Environment Livestock Operation

EQIP- Environmental Quality Incentive Program

NRCS- National Resource Conservation Service

1. INTRODUCTION

1.1. BACKGROUND

As a result of domestic and export market forces, technological changes, government regulations and industry adaptations, there have been substantial changes in America's animal production industry. Various factors which include integration and concentration of livestock industry have prompted the expansion of Confined Animal Feed Lot Operations (CAFOs) in U.S.(EPA, 2000). In 1966, 57 million hogs lived on one million American farms; by 2001, roughly the same numbers of hogs were on just over 80,000 farms, and fewer than 5000 farms accounted for more than half of all hogs produced in United States (Osterberg, 2004). Waste from agricultural livestock operations has been a long- standing concern with respect to contamination of water resources. The recent expansion of CAFO's has increased the risk to water quality because of the increased concentration of waste and contaminants such as antibiotics that may have both environmental and public health importance (Burkholder, 2007). For example, excess nitrate in drinking water contribute to the human disease, manure contains nuisance odor and some nutrients and pathogens contribute as a health threat. Waste that reaches groundwater can also lead to increase in level of problematic gases such as hydrogen sulfide and ammonia.

Current farming practices are responsible for an estimated 70% of the pollutions in the nation's rivers and streams (Osterberg, 2004). US Environmental Protection Agency (USEPA) states that "improperly managed manure has caused serious acute and chronic water quality problems throughout the United States" (Osterberg, 2004). Microbes breakdown the nitrogen in the manure into nitrate, and research has shown both waste lagoons and cropland application of manure correlate with groundwater nitrate levels (EPA, 2002b). Infants and others drinking nitrate contaminated water can develop “blue-baby syndrome” a potential fatal condition for infants. CAFO related water pollution can result from manure lagoon spills or leaks, from direct runoffs from buildings, and from fields where manure is applied. The nitrogen and phosphorus from spills can also exert downstream water impacts. The projected Gulf hypoxia, which is an expanse of oxygen depleted waters that cannot sustain marine life in the Gulf of Mexico, is largely a result of Midwest nutrient application to fields (Osterberg, 2004).

Air borne pollutants odors, dust, methane and ammonia are also an issue from animal waste treatment. A study on the effects of CAFO’s on human health shows that workers in confined livestock operations have a risk for traumatic injuries, noise-induced hearing loss, carbon monoxide poisoning and a variety of chronic respiratory diseases like Sinusitis, irritant rhinitis, Pharyngitis, Alveolitis (Donham, 2000). Apart from the workers there have been numerous health complaints from community neighbors of livestock operations. One study showed adverse altered mood states of humans, and another showed evidence of respiratory illness similar to what workers experience (Donham, 2000). Odors are also considered to be a nuisance waste issue in many agricultural areas, including Missouri where a series of county health ordinances essentially put a moratorium on new CAFO’s or expansions of existing facilities. In discussions on the ordinances, odors were listed as a primary concern relating to health. Due to these effects people are getting more reluctant in buying properties in rural areas, which are near animal operations. This has been confirmed by Secchi’s research which shows that there may be approximately 10 percent loss in property value if a new livestock feeding operation is located upwind and near a residence (Herriges, 2005). Nuisance and property value concerns have lead to government imposed moratoriums on new facilities or expansions and many NIMBY (Not In My Back Yard) confrontations. Thus, the impacts of CAFO's are not just limited to health hazards but have also extended to property economic losses in regions around the operations.

Another growing global concern is the extensive use of antibiotics in animal feeds which contributes to increasing antibiotic resistance being transmitted to humans. Estimates depict that approximately 20 million pounds of antibiotics are given annually to the animals to prevent them from infections due to confined and stressful conditions and approximately 65% of these antibiotics are identical to those used in human medicines (Osterberg, 2004). These antibiotics have been detected in surface waters at elevated levels.

The environmental and health impacts of animal agriculture are not limited to the local or regional aspects. Current waste treatment methods release large amounts of methane to the atmosphere. Methane is a major constituent of natural gas and a potent greenhouse gas when released to the atmosphere. Methane is about 21 times more powerful at warming the atmosphere than carbon dioxide (CO_2) by weight and has a chemical lifetime in the atmosphere of approximately 12 years (EPA, 2001). Long atmospheric lifetime potency as a green house gas and potential use as an energy source makes methane ideal for mitigating global warming in near-term. In 2005, agricultural activities were responsible for emissions of 536.3 Tg (Terra grams) CO_2 Eq. or 7.4 % of total US green house gases (GHG) emissions. Of the various agricultural activities, methane emissions from manure waste were 41.3 Tg CO_2 equivalent or 8% of total US methane emissions in 2005 (EPA, 2007). As this methane is from a concentrated source, it can provide an excellent energy source, and is easily destroyed by combustion. Thus, attenuating this GHG source is quite logical in an approach to reducing GHG's.

Given the range and magnitude of environmental issues from animal agriculture waste streams, advanced treatment approaches are needed. Several technologies have been introduced to abate the impacts from the increasing CAFO operations, but high implementation costs have discouraged wide spread use. Several existing technologies can generate revenue streams and are becoming increasingly attractive. Some of the practices used in the industry include composting and pelletizing which involve transformation of manure into value added products and other technologies like combustion (gasification and co-firing), Chemical conversion (Methanol Production) and biological conversion (Anaerobic Digestion) involve transformation and use as an energy source, but most include conversion using an external energy source (EPA, 2000), and given the energy pricing projections, such processes are looking less attractive. Anaerobic digesters (AD) have received attention in the last decade (Table 1.1, Paper) addressing some of the environmental impacts of manure waste while providing farmers with economic benefits. Economic evaluations of some case studies have confirmed that the AD technology is "a commercially available bioconversion technology with considerable potential for providing profitable co-products, along with a cost-effective renewable fuel" (Lusk, 1998).

1.2 GOALS AND OBJECTIVES

The goal of this study was to determine how recent changes in available revenue streams, subsidies and improved anaerobic digestion (AD) technology have impacted the financial feasibility of AD projects specifically for Missouri livestock producers, in potentially aiding its deployment. To reach this goal, several hypothesis driven objectives were set.

Objective 1: To evaluate recent research related to the project which is interdisciplinary in nature. Varying fields that needs investigation include environment, green economics and finance. One important area of relevant progress is the new carbon markets, which involve costs and mechanisms for farmers to utilize carbon credits.

Hypothesis: The existing research in related fields can provide necessary insight to the diverse costs and revenue streams needed to develop the model and to better understand their interrelations.

Objective 2: To develop an economic model that identifies and quantifies the financial benefits that a typical swine farm could gain from the integration of an anaerobic digester and electricity generation system. The benefits that were considered include subsidies, sale of carbon credits and sale of electricity. The model will also quantify the sensitivity to the operational assumpti1ons and financial variables.

Hypothesis: As a function of the type of farm and other specific economic variables the model will facilitate justification of investments as well as identify the economic conditions that justify these investments.

Objective 3: To develop specific contacts with active practitioners in this field for attaining current valuable inputs necessary for accurate model development in this dynamic field.

Hypothesis: The experience will also be of assistance in understanding the certification systems, various methodologies involved under the clean development mechanism (CDM) and other involved processes in a better way.

Objective 4: In coordination with the Missouri Department of Agriculture develop a list of potential farms that may be viable and interested in implementing AD technology to produce energy and thereafter evaluating these specific case studies using the economic model. Another goal was to gather case specific data regarding farm specifications, existing manure management system and on farm electricity consumption.

Hypothesis: This information will be used for biogas and power generation estimates from the AD technology provider and incorporating those along with the other information into the model will lead to development of separate models for different case studies.

Completing these objectives will lead to conclusive knowledge of the recent economic benefits and mechanical changes in AD technology which may make this technology viable. Previous research has looked into various cash flows separately and no study has found this technology feasible in terms of economic returns. This research aims at combining all the possible current revenue streams and performing net present value (NPV) and internal rate of return (IRR) analysis for three case studies in central MO to support decision makers that are accustomed to using either one of these popular metrics. This research will apply the study to real world projects and gain specific knowledge needed for technology transfer and development. In the long-term, the findings and model produced through this work will help individuals to further delve into AD technology development and economics so that widespread application can be facilitated.

2. LITERATURE REVIEW

2.1 ANAEROBIC DIGESTION

Anaerobic Digestion (AD) is a two stage process to decompose organic molecules and volatile solids (VS) in the absence of oxygen. In the process a biogas, composed primarily of methane, is produced as a product of digestion. In the first stage, the VS present in the manure are converted into fatty acids by anaerobic bacteria known as acidogens and in the second stage these acids are converted into biogas by more specialized bacteria known as methanogens. Proper design and management of Anaerobic Digesters can help in transforming the animal waste into a money-making asset as the BTU value of the biogas is approximately 70% of pure natural gas. Currently U.S. livestock operations primarily use four types of anaerobic digester technology: slurry, plug-flow, complete-mix, and covered lagoons (Lusk, 1998). Both the covered lagoons and heated tank digester have certain advantages and disadvantages over each other. For example, the covered lagoons cost much less than the heated tank digesters are trouble free and require lower maintenance. On the other hand covered lagoons are less efficient and require much more time for the digestion process to complete. Thus, the technology to be used depends on various factors such as the farm size, financial condition of the owner and requirements of the farm (M. Saele, 1998). A number of early animal waste digestion systems failed due to various factors such as improper design and management, excessive operating costs, over stated benefits, unreliable markets for biogas, lack of financial support from government and lack of incentive or cooperation regarding electricity buy back. Past research has revealed the failure rates for complete mix and plug flow types of AD systems to be 70% and 63%

respectively, which are very high. Covered lagoons had lower failure rate of 22% (Lusk, 1998). Although these numbers are similar to the failure rates of many other energy technologies ranging from synthetic fuels to other renewables, still they are high enough to discourage the widespread implementation.

In recent years there has been a renewed interest in the technology, as well as in almost any renewable- or alternative-energy process. Increasing awareness and research has demonstrated that properly designed and operated anaerobic digester can fully treat animal waste for traditional constituents (solids and BOD) as well as odor and other environmental concerns like pathogens and nutrients.

Energy economics are also making AD more attractive. The rising prices of the liquid fuels and natural gas that can be displaced with renewable sources like biogas is a major motivating factor for implementing the technology. Total electricity generation potential from diary and swine farms in US is approx. 6,332,000 megawatt hour per year (EPA, 2005). The energy generated can be used to offset farm energy requirements and any excess energy can be sold to the local utilities. Harvesting the hot water and steam from the engine generator’s exhaust and cooling systems can further increase the efficiency of the engine. The biogas can also be burned to produce hot water and steam that can be used for heating and sanitary washing and thus offsetting the cost of using liquefied petroleum gas (LPG) for these purposes. Another encouraging addition to the directory of the motivating factors is the “Net metering law” (explained in the next section) which is being employed by the many state government’s to encourage the use of renewable energy practices.

2.2 UTILITY PRICING

State governments in the U.S. are adopting a number of policies to encourage the production of electricity from renewable sources. Some of the rules that are being implemented are; renewable portfolio standards (RPS), net metering laws, public benefit funds, generation disclosure rules, equipment certification and contractor licensing (Vachon, 2006). Out of these policies, net metering laws directly add to the list of economic incentives which are encouraging the individuals to adopt renewable energy practices. Net metering has been defined as “a technique for calculating the household’s net electric bill, which can boost the financial appeal of renewable energy technologies” (Starrs, 1996). Net metering allows the customers to use the energy generated to offset their own consumption over an entire billing period by enabling their meters to essentially turn backwards when they generate electricity exceeding their current demands. Thus, the customers effectively receive the retail prices for the electricity they are generating. It also gives customers the option of banking the energy so that it can be used during peak periods, thus maximizing the value of their productions and moreover benefiting the local utilities by reducing the load on the systems during these periods. Currently net metering is offered in at least 35 states including Missouri (DSIRE, 2007).

In most of the states, any residential or small commercial electricity customer who generates any amount of electricity is eligible for net metering. The technical requirements include; net metering systems should be at customer’s expense, and all the equipment should meet the requirements established by the national electrical code (DSIRE, 2007). Since the energy generated is considered renewable energy, the credit for generating the energy can be sold as renewable energy credits (REC’s) to companies, states or industries building their own renewable portfolio standards (RPS). Currently 31 states have RPS goals or mandates and many more municipalities have set their own goals. The goals range from sourcing 20% of their power from renewables by 2010 (California) and 0.5-2.2% by 2011 (Wisconsin) to 15 states that do not have any goals (Petersik, 2004).

2.3 CARBON CREDITS

Evolution of green house gas markets is a major milestone in providing financial feasibility for AD technology. Methane is about 21 times more powerful at warming the atmosphere than carbon dioxide (CO_2) by weight and has a chemical lifetime in the atmosphere of approximately 12 years (EPA, 2001).The reductions in the methane emissions are quantified into tradable commodities noted as “carbon credits”. One carbon credit is equal to one ton of carbon dioxide. The sale of carbon credits can be carried out in a variety of methods, including: open markets like Chicago Climate Exchange (CCX) through various brokerage houses like Environmental Credit Corporation (ECC), direct purchase by companies, states or industries looking to build a carbon credit portfolio, or sale to organizations like EcoSecurities that look to help develop projects and offer guaranteed purchase agreements and build as agglomerated portfolio that could be marketed later. A diverse variety of business plans are offered by brokerage firms, companies and organizations, and the decision lies in the hands of the individual to choose among the various options. Brokerage firms like ECC operate as an aggregator on the CCX. They provide services to the clients with ongoing GHG mitigation or sequestration projects, finance new projects, operate a carbon credit mutual fund, and also provide market liquidity both as a trader and broker of carbon credits. The services include consulting, project documentation, verification (through a CCX approved, third-party verifier), registration, transaction, and brokerage services to the clients.

In particular ECC operates two distinct program types. In the first case they provide carbon credit services to farms which have existing digester equipment on their farm or plan to purchase the system themselves. For these clients, they do not provide any financing and are only in charge of the carbon credit flow. ECC undertakes all of the required paperwork for the client, hires a verifier, advocates the project at the CCX, manages their carbon credits and the client doesn't incur any direct costs. The second type of project is one where no methane capture/digester system exists. In these cases, ECC can pay for digester cover for the farm and own the project. ECC also undertakes all of the services listed above as well. In the above two cases the company pays all of the costs in exchange for a share of the carbon credit value each year. In these types of models, the farmer receives a percentage of carbon credits revenue, thus receiving an opportunity to benefit from potential price appreciation (Six, 2007).

Another type of model that is possible is an up-front model, where ECC pays a flat-fee amount to purchase the carbon credit stream from the farm for a fixed period of time. For example, they might offer a farmer $100,000 in cash today for all the credits produced for the next ten years. Yet another model that is conceivable is one in which an aggregator simply facilitates trading of the credits for a fee or commission, while the farmer undertakes all the costs, paperwork, and other duties (Six, 2007).

In any of these models, the actual CCX process will be substantially the same. Initially, project documents are prepared. These documents explain the project, offer site information, and detail the changes from the base case to the current practice which the project owner believes entitle him to carbon reduction credits. After these are created, an independent verifier examines the project and certifies the truth of the claims, including a quantification of the GHG emission reductions. Then the request for project registration and credit issuance is submitted to the CCX committee for approval. If approved, the NASD (National Association of Securities Dealers) also must approve the credits and validate their issuance as financial instruments. Finally, the credits (packaged as Carbon Financial Instruments, or CFI, each representing 100 metric tons of Certified Emissions Reduction) are issued into the account of the aggregator or other CCX member claiming them. At this time, they are eligible to be held or traded on or off the exchange for payment. ECC in particular offers clients the opportunity to turn them into shares in their pool, thus creating an investment for the clients (ECC, 2004).

With the increasing interest in using marketable carbon credits there is considerable speculation in the US market over future prices of CC. Some individuals expect the prices to be fixed, or provided as a subsidy, or charged as a tax where as others anticipate that the prices would emulate the European market. Although currently subsidies and carbon taxes are a part of GHG emission policies, the value of CC will be determined by the interaction of supply and demand in the market. Prices for credits in US ranged from $2.10 to $3.10/CC in 2005 at CCX. On the other hand the European market prices in 2005 were around $19/CC (Williams, 2005).

Many factors affect the supply and demand of carbon credits and the combination of these factors determines the prices of CC. One of the major factors which would enhance the demand and hence the price of the credits is the implementation of policies that will facilitate green house gas reduction. The difference in prices of credits in the European and American markets is a result of difference in policy. Europe has ratified the Kyoto, thus the reduction is mandatory where as the US market is still voluntary thus the demand is much smaller. Another factor which will affect the demand is the price of alternative energies like wind and solar energy. Cheaper prices as compared to the conventional fossil fuels would result in reduction in the demand of the credits (Williams, 2005). Technology advancement which will enable the use of conventional fuels more efficiently would also reduce the demand for CC and thus decrease the price. This phenomenon was observed in the European market crash following the release of the verified 2005 emissions data which showed that companies emitted less CO_2 in 2005 than they were allowed (Capoor, 2007).

Thus the uncertainty, complexity and volatility of the carbon market add considerable risk. Companies like EcoSecurities adopt a different approach to reduce the amount of risk taken by the customer by giving approximately $3-5 dollars net based on different methods involved for a period of 1- 5 years (futures contract) and option to buy the credits for the same number of years as the contract (Devorcek, 2007). Another growing concern due to rapid growth of the voluntary carbon market in US is the quality of credits generated since there is no regulatory body overseeing these activities. At present the companies are inclined to push as many projects as they can to increase the volumes. In the voluntary setup this would work fine, but when the policy changes and compliance comes in, the standards would become more stringent and the quality of the credits will be very important to maintain sustainable prices. EcoSecurities targets stringent verification processes by working with the International Emissions Trading

Association and the Climate Group to establish a high level verification process (www.v-c-s.org) that allows the highest value per ton. This value is granted as the project is proven to be "additional". A project activity is considered to be additional if anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the project activity (EcoSecurities, 2005).

As a whole, carbon credits are an emerging source of income to the farmers which adds to the economic returns from the project. The decision to choose among the above described plans is entirely in the hands of the customer. Overall, there are diverse varieties of agricultural projects that can help in reduction of GHG such as: methane capture at livestock waste treatment facilities; soil carbon sequestration activities; forest carbon sequestration; and other GHG reductions strategies. All such projects could be new revenue streams for certain agriculture projects.

2.4 SUBSIDIES

With increasing environmental awareness, a clear gap exists in technology and implementation of GHG mitigation and renewable energy projects. To help initiate such projects and speed technology development various subsidies are available to help make more of the initial projects financially viable. Some of the grants that were considered for this particular Missouri-based study include Missouri Agricultural & Small Business Development Authority's (MASBDA) Managed Environment Livestock Operation (MELO) Tax Credit program, Missouri Environmental Quality Incentive Program (EQIP) provided by National Resource Conservation Service (NRCS) and Farm Bill 9006. MELO program considers the actual cost to a producer of implementing odor abatement as best management practices, and costs necessary to achieve MELO accreditation from the Missouri Department of Agriculture as eligible expenses. The maximum cumulative tax credit shall be an amount equal to the lesser of 50% of the eligible expenses, or $50,000 (Spieler, 2007). The Environmental Quality Incentives Program (EQIP) is a voluntary conservation program from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). Missouri's EQIP program is developed using locally led conservation through soil and water conservation districts and the Missouri State Technical Committee. Any producer or entity engaged in livestock or crop production on eligible land which includes cropland, rangeland, pasture and other farm or ranch lands, as determined by the Secretary of Agriculture can apply for EQIP. The cost sharing for AD technology would be 50% of the total amount, or $100,000 which ever is lesser (NRCS, 2006).

Farm Bill section 9006 refers to the renewable energy systems and energy efficiency improvements program, which was created as part of the energy title in the 2002 Farm Bill. The USDA anticipates that this program will help farmers, ranchers and small businesses in rural areas to reduce the energy costs and consumption and also help the nation to meet its energy needs. Grant requests are limited to 25 percent of the eligible project costs. Energy efficiency grants can range from $1,500 to $250,000 (USDA, 2006). These subsidies are approved year by year and they might go away any year.

To sum up increasing world populations, increase use of energy in developing countries, decreasing source of hydrocarbons, increasing concern for environmental issues, and increasing value for CCs make it very likely that these AD systems will be financially viable in the future reducing the environmental impacts and concurrently generating revenue streams, but the revenue potential is still not fully understood and certainly the concepts of greenhouse gas reduction, net metering laws, carbon credit marketing, renewable portfolio standards (RPS) and renewable energy credits (REC's) are not in the common vocabulary of today's livestock farmers. It is difficult for the farmers to visualize the costs and benefits associated with an AD system for their farms. Therefore, this work will serve to look at swine waste treatment using anaerobic digestion and the associated revenue streams and investments in capital and annual operating expenses, and then to generate the internal rate of return and the net present values of such projects for three case studies in Missouri as presented in the following article.

PAPER

1. Carbon Credits and Energy Subsidies in Economic Decision Making for CAFO Waste Treatment

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1.1 ABSTRACT

Released waste into the environment has always had a societal cost. Current issues with swine waste suggest that improved treatment is needed as agricultural production has become more industry-like and also as we now globally value the mitigation of global warming. The current need for and the economic support of advanced waste treatment has converged for animal agriculture, and now improved waste treatment is possible with concurrent economic benefit through alternative energy and carbon emissions. Recent changes have resulted in renewal of interest in anaerobic digestion (AD) technology with methane capture and energy production. An economic model was constructed to evaluate the financial potential of anaerobic digestion for swine waste considering initial investments, the associated costs and new revenue streams of carbon credits, renewable energy credits and electricity sales. Current available subsidies were also taken into consideration. The model was formulated based on case specific inputs and was applied to three case studies in central Missouri. The model inputs were also evaluated by experienced vendors (who have developed similar projects) for validity. The results revealed that the present prices of carbon credits and electricity are not

enough to prove the financial feasibility of applying AD technology in all cases without the availability of current subsidies. The endeavor also showed that electricity prices have modest impacts on the corresponding NPV of the project. On the other hand, the carbon credit market projections affect the NPV to a greater degree. Clearly, carbon credit markets may play a pivotal role in widespread development and implementation of the technology. In all the three scenarios the projects were profitable with the presence of the current state and federal subsidies. However, since the subsidies may not be available for many years, high CC and electricity prices are probably needed for future profitability of the technology.

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1.2 INTRODUCTION

An estimated 376,000 livestock operations that confine animals in the U.S. generate approximately 128 billion pounds of manure each year (EPA, 2000). This waste currently contributes to local air pollution, local/regional water pollution and global carbon emissions. This waste can also represent a renewable energy source and a potential carbon market revenue stream. Using novel waste treatment approaches, the economic and environmental benefits can be tapped concurrently. Manure and wastewater from confined animal feeding operations (CAFO's) contribute water borne pollutants such as nutrients, organic matter, sediments, pathogens, heavy metals and antibiotics to the environment (Lusk, 1998). The projected Gulf of Mexico hypoxia is growing to an all-time high, and is largely attributed to animal pollution sources (Osterberg, 2004). Impacts from these wastes on surface and groundwater are well documented. Waste storage and/or treatment processes have slowly evolved to minimize these impacts, yet the problems persist and have grown in recent years with greater production and more intense methods, such as more CAFOs.

Air borne pollutants odors, dust, methane and ammonia are also an issue from animal waste treatment. In recent years, odors in rural areas have become problematic causing direct impacts on the property values that have been quantified (Herriges, 2005). Nuisance and property value concerns have lead to local and state-wide moratoriums on new facilities or expansions and many NIMBY (Not In My Back Yard) confrontations. Odors are considered to be a primary waste issue in many agricultural areas, including Missouri where a series of county health ordinances essentially established bans on new CAFO's or expansions of existing facilities. In discussions on the ordinances, odors were often listed as a primary concern relating to health.

The environmental and health impacts of animal agriculture waste are not limited to the local or regional aspects. Methane is a potent greenhouse gas when released to the atmosphere and is the primary gas emitted from anaerobic lagoons, the most prevalent waste treatment technology. Methane is about 21 times more powerful at warming the atmosphere than carbon dioxide (CO_2) by weight and has a chemical lifetime in the atmosphere of approximately 12 years (EPA, 2001). In 2005, agricultural activities were responsible for emissions of 536.3 Tg (Terra grams) CO_2 Eq. or 7.4 % of total US green house gases (GHG) emissions. Out of the various agricultural activities, methane emissions from manure management were 41.3 Tg CO_2 equivalent or 8% of total US methane emissions in 2005 (EPA, 2007). Internationally, the US has been documented to be the lead contributor of methane from animal agriculture, (Figure 1.1)

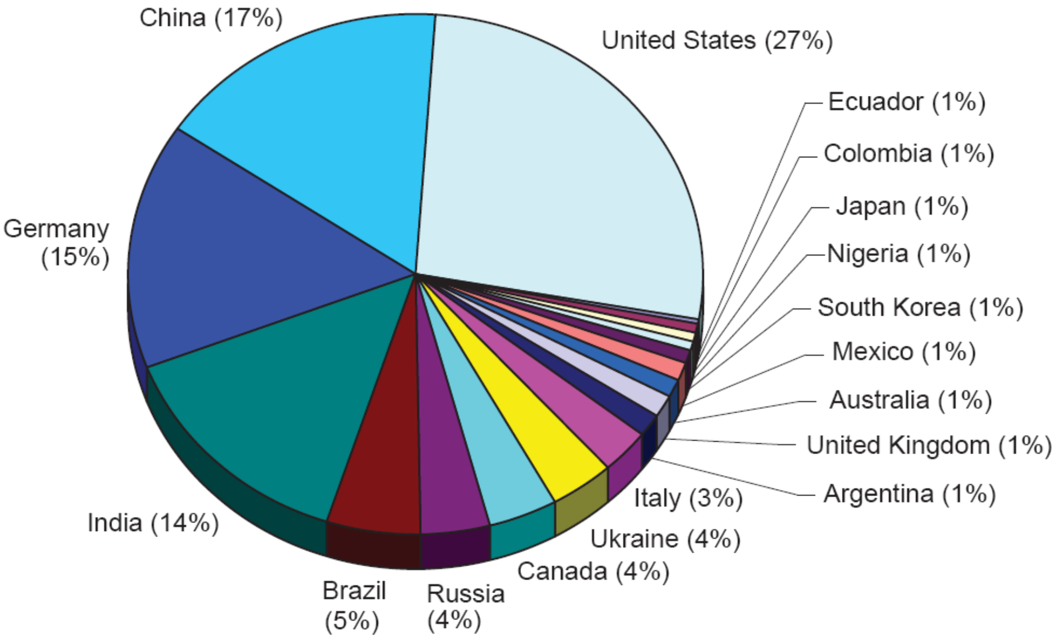


Figure 1.1: Livestock methane emissions from major livestock producing countries world wide (markets, 2006)

Given the range and magnitude of environmental issues from animal agriculture waste streams, advanced treatment approaches are needed that make financial sense to the farmers. Several existing technologies can generate revenue streams and are becoming increasingly attractive. Some of the practices used in the industry include composting and pelletizing involving transformation of manure into value added products. Technologies like combustion (gasification and co firing), chemical conversion (methanol production) and biological conversion (anaerobic digestion) involve transformation and production of an energy source. Most include conversion using an external energy source (EPA, 2000), and given the energy pricing projections, such processes are looking less attractive. Anaerobic digesters (AD) have received increased attention in the last decade since it addresses some of the environmental impacts of manure management while providing farmers with economic benefits. The major changes that have lead to renewed interest in AD technology are listed in table 1.1. AD is the bacterial breakdown of organic materials in the absence of oxygen. In the process, a biogas composed primarily of methane is produced, and the gas is then combusted in an engine, boiler or flare. Research has shown that a number of early animal waste digestion systems failed due to various factors such as improper design and management, excessive operating costs, unreliable markets for biogas and lack of incentive or cooperation regarding electricity production and buy back (Nelson, 2002). In recent years there has been a renewed interest in the technology, as well as other renewable- or alternative-energy process.

Table 1.1: Recent changes that have lead to the renewed interest in AD technology:

Topic	Changes	Citation
Anaerobic digestion technology	• Improved Design, • Experienced vendors, • Low failure rate(Most farmers are satisfied with their investments)	(EPA, 2002a)
Utility pricing	• Net metering law • Increasing liquid fuel and natural gas prices.	(DSIRE, 2007)
Evolution of carbon markets	• CCX (Market established) • Supreme Court ruling on CO2 as a pollutant	(CCX, 2003) (Daley, 2007)
Subsidies	• Farm Bill section-9006 • NRCS- EQIP • MELO	(USDA, 2006) (NRCS, 2006) (Spieler, 2007)
Tax incentive bill	• Legislation to promote biogas development from animal waste	(Craig, 2007)

Increasing awareness and research have demonstrated that properly designed and operated anaerobic digesters can fully treat animal waste for traditional constituents like solids and biochemical oxygen demand (BOD), as well as odor and other environmental concerns like pathogens and nutrients.

Energy economics are also making AD more attractive. The rising prices for the liquid fuels and natural gas that can be displaced with renewable sources is a major motivating factor for implementing the technology. Total electricity generation potential from diary and swine farms in the U.S. is approximately 6,332,000 megawatt hour per year (EPA, 2005). Thus energy generated can be used to offset on-farm energy requirements, and/or excess energy can be sold to the local utilities. To encourage the use of renewable energy practices states are implementing "Net metering laws". Net metering allows individual, grid-tied customers who generate electricity to receive credit from their utility for any excess power they generate beyond what they consume. Under most state rules, residential, commercial, and industrial customers are eligible for net metering (DSIRE, 2007). Since the energy generated is also renewable energy, the credit for generating the energy can be sold to companies, states or industries building their own renewable portfolio standards (RPS). Currently 31 states have RPS goals or mandates and many more municipalities have set their own goals. These goals range from sourcing 20% of their power from renewables by 2010 (California) and 0.5-2.2% by 2011 (Wisconsin) to 15 states that do not have any goals (Petersik, 2004).

Evolution of GHG markets is major contributor to the potential financial feasibility for AD technology. The reductions in the methane emissions are quantified into tradable commodities noted as "carbon credits". The sale of carbon credits can be carried out in a variety of methods, including: open markets like Chicago Climate Exchange (CCX) through various brokerage houses like Environmental Credit Corporation (ECC), or direct purchase by companies, states or industries looking to build a carbon credit portfolio. The credits can also be sold to organizations like EcoSecurities Such organizations develop projects and offer guaranteed purchase agreements and build as agglomerated portfolio that could be marketed later. As a whole, carbon credits are an emerging source of income to the farmers which adds to the economic returns from the project. Overall, a variety of agricultural projects can help reduce GHG such as: methane capture at livestock waste treatment facilities; soil carbon sequestration activities, forest carbon sequestration, and other GHG reductions strategies. All such projects could generate new revenue streams.

With increasing environmental awareness, a clear gap exists in technology and implementation of GHG mitigation and renewable energy projects. To help initiate such projects and speed technology development various subsidies are available to provide assistance making initial projects financially viable. Some of the grants that were considered for this particular Missouri-based study include Missouri Agricultural & Small Business Development Authority's (MASBDA) Managed Environment Livestock Operation (MELO) Tax Credit program, Missouri Environmental Quality Incentive Program (EQIP) provided by National Resource Conservation Service (NRCS) and Farm Bill section 9006. MELO program considers the actual cost to a producer of implementing odor abatement as best management practices and costs necessary to achieve MELO accreditation from the Missouri Department of Agriculture as eligible expenses. The maximum cumulative tax credit shall be an amount equal to the lesser of

50% of the eligible expenses, or $50,000 (Spieler, 2007). The EQIP is a voluntary conservation program from the NRCS. The cost sharing for AD technology under EQIP would be 50% of the total amount, or $100,000 which ever is lesser (NRCS, 2006). Farm Bill section 9006 refers to the renewable energy systems and energy efficiency improvements program, which was created as part of the energy title in the 2002 Farm Bill. Grant requests are limited to 25 percent of the eligible project costs. Energy efficiency grants can range from $1,500 to $250,000 (USDA, 2006). As a whole these incentives can subsidize a considerable portion of the initial investment.

Considering all the above factors the anaerobic digestion (AD) technology has become increasingly viable as summarized in table 1.1. However, the revenue potential is still not fully understood and certainly the concepts of greenhouse gas reduction, net metering laws, carbon credit marketing, renewable portfolio standards and renewable energy credits are not in the common vocabulary of today's livestock farmers and the details of their implementation have not been worked out. This work will look at swine waste treatment using anaerobic digestion and the associated revenue streams and investments in capital and annual operating expenses and then to generate results including internal rate of return (IRR) and the net present values (NPV) of such projects for three case studies in Missouri.

1.3 ANAEROBIC DIGESTER FINANCIAL FEASIBILITY MODEL:

GENERATION:

The economic model identifies and quantifies the tangible benefits that a typical swine farm might gain from the integration of an anaerobic digester system. The model also quantifies the impact of changes to the operational assumptions. This facilitates justification of investments as a function of the type of farm and other economic variables as well as what conditions may be modified to justify these investments. Currently available subsidies and tax incentives for Missouri farmers were considered in the three case studies, and were also eliminated under some scenarios.

METHOD:

An economic model was constructed and carried out as an Excel® spreadsheet making it easy to distribute and modify the inputs for specific users and also to print and generate graphs. This approach also allows users to understand the mechanisms that generate these costs and benefits. Transparency in generation and operation of the model helps in building confidence in the users. The model was populated with inputs based upon a set of case studies which included three swine farms in central Missouri referenced as farms A, B, and C.

REVENUE AND COST STREAMS CONSIDERED:

Model inputs and parameters were based on readily available statistics and information from Agstar which is a program encouraging the use of methane recovery technologies at CAFOs. The Agstar program is a voluntary effort jointly sponsored by USEPA, USDA and USDOE. Other specific costs and inputs were taken from companies like EcoSecurities, Environmental Fabrics Incorporation (EFI), RCM Digesters and

Environmental Credit Corporation (ECC) which are vendors and active practitioners in development of AD technology.

Using data or assumptions regarding the farm size and operations the model can calculate:

1) revenues which include sale of green house gas reduction credits as available in the Chicago Climate Exchange or EcoSecurities,
2) reduced farm costs from the generation of electricity to offset use based on the methane produced in the anaerobic digester,
3) cash flow from sale of excess electricity generated, to the local utilities and
4) any other farmer benefits that might apply at certain locations and certain times, such as accelerated depreciation, renewable energy credits and tax credits
5) the subsidies were also taken into consideration while considering the funding for the project like MELO for Tax benefits, NRCS MO for EQIP and Farm Bill 9006

The noted subsidies are all current and available but the future availability is uncertain. The user of the model can easily extrapolate operational and other maintenance costs. The model can also utilize case specific information or assumptions regarding initial cost of the equipments like the generator and digester and their respective salvage values, which is important as many facilities have assets and resources that are available and valuable.

1.4 MODEL EQUATIONS AND ASSUMPTIONS:

Based on the model specifications the engine requirements and other costs were obtained from RCM digesters and EFI. The volatile solids rate and the methane conversion rate (Table 1.2) were obtained from Missouri waste generation data available from the USDA and the potential methane generated was calculated based on these values. The equation used was:

$$Y = Fs \times V.S.R \times M.C.R \times \eta d \times 1000 \times 365 \qquad (1)$$

Where Y= Methane generated in liters/year.

Fs= No. of heads (animals)

V.S.R= Volatile Solid Rate (kg/head/ day)

M.C.R= Methane Conversion Rate (L/g Volatile solid)

ηd = Efficiency of the digester(%).

The data for other farm and operational inputs like farm size, type of animals, running time, efficiency and maintenance cost of the digester (Table 1.2) was collected from the farm owners and RCM digesters.

Conservative input and assumptions were used. The salvage value of the generator and the digester were taken to be 70% and 10% respectively (Fischer, 1981) and straight line depreciation was used for the analysis. The amount of electricity available for sale was assumed to be 30% of the total electricity generated, though this factor varies among different livestock operations.

Table 1.2: Operational inputs and assumptions for all the case studies.

ASSUMPTIONS/INPUTS	INITIAL INPUT VALUES
Volatile solids generation rate	0.5 kg/head/day
Methane conversion efficiency	0.7 liter/g VS
Type of animals considered	Sows, Teaser Boars, Weaners and Finishers (depends on specific case study) (Table 1.5)
Farm size	(Table 1.5)
Combined generation and capture efficiency of the covered lagoon digester	65%
Operation and maintenance cost of the digester	$ 0.015 / kWh (as $/ kWh of Power generated)
Running time of the generator	80%
VER price (Carbon credits)	(US$/ ton-CO2) (Figure 1.3) Considered 3 different scenarios
Cost of the generator	$1/watt, variable on existing equipment

Financial assumptions (Table 1.3) were made based upon the inputs from RCM digesters, ECC, EFI and EcoSecurities.

Table 1.3: Economic assumptions for the model, based upon the inputs from RCM digesters, ECC, EFI and EcoSecurities.

ASSUMPTIONS/INPUTS	ESTIMATES/INPUTS
Depreciation	Period: 10 years (straight line)
Percent of power used onsite.	70%
Percentage of electricity available for sale	30%
Discount rate	15%
Inflation rate	3%
Corporate tax rate (federal & state)	28%

1.5 MODEL STRUCTURE:

The model structure is shown in Figure 1.2. The inputs to the model consist of the farm specifications, necessary assumptions, cost of the equipments, trading and registration costs for sale of carbon credits. The revenue streams from each source and the total cost would be calculated within the model and the final result of the model consists of the net present value and internal rate of return for the project. Although the result of the model gives an indication of the amount of revenue that can be generated from the project, there are several other factors which can affect the farmer's decision to go ahead with the venture. These factors include; risks involved in the investments, concerns about additional maintenance of the equipment such as the digester and generator, and diversion from the main mission of raising animals. There are also other factors that could positively impact farmer's decision. These include; improved waste treatment, waste heat generation and recovery, potential improved fertilizer value of the waste stream and also reduction in the odors emanating from the waste treatment processes. All these external factors in decision making are represented by the question mark in "Invest in farms?" (Figure 1.2); but such human factors issues are not taken into consideration in this financial modeling exercise.

The model allows for easy modification of any of the assumptions, and since they are calculated in an iterative fashion, it allows for sanity checks at any level of the calculation process. Each of the major cost and revenue items are handled in separate rows so that different rates of change can be utilized. This approach also facilitates the addition or elimination of factors to the model, as well as displaying annual changes of the total revenues and costs during the years of modeling. The model can utilize more complex changes, as is expected for carbon credit prices. In selecting assumptions, the objective is to generate useful, conservative, reasonable and realistic results.

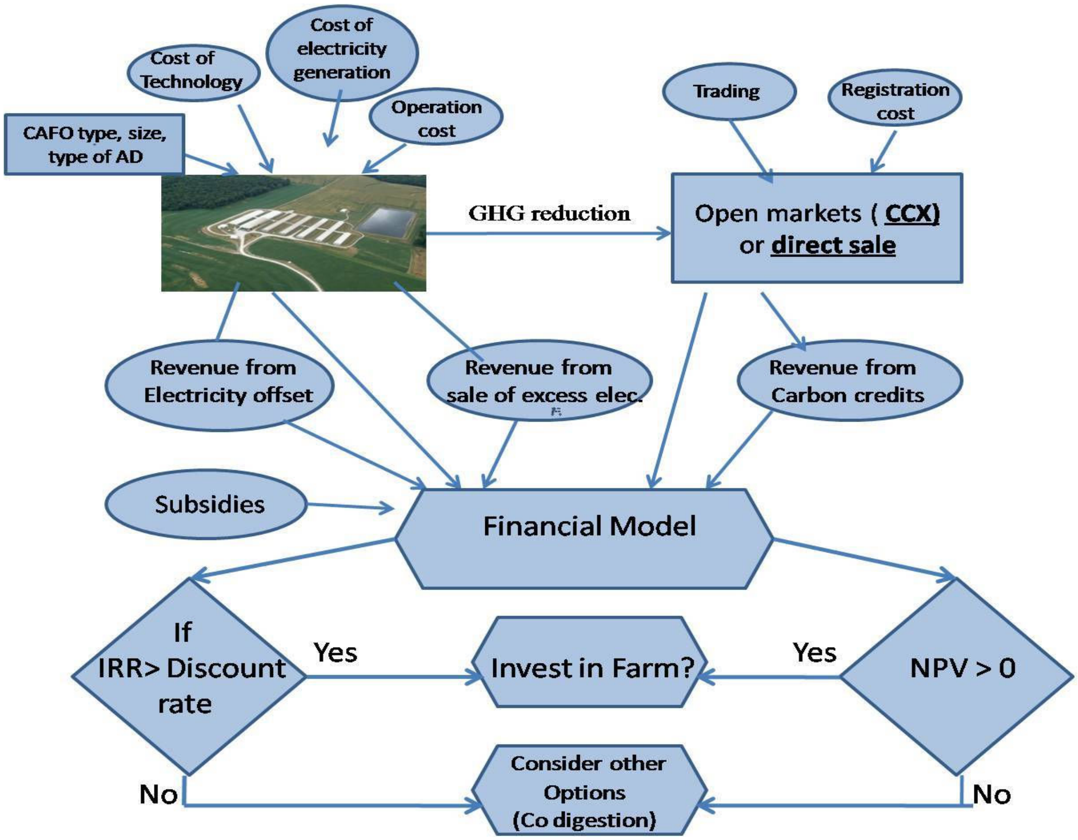


Figure 1.2: Structure of the financial model showing how revenue streams, subsidies, investments and type of facilities enter into decision making.

1.6 SENSTIVITY ANALYSIS:

To evaluate which factors have the greatest impact on the projects' NPV a sensitivity analysis on variable inputs was conducted. The input variables: carbon credit prices, electricity offset and buy back rates, number of carbon credits per head, discount rate used, cost of the equipments and the inflation rate were considered. A conservative and an optimistic case were considered using values obtained from literature or experienced professionals and NPV was calculated for both the cases considering all variables separately. Then the difference (Δ) between the NPV of both the cases was calculated for all the variables. The results showed that the major cash flow is based upon the sale CC's and electricity, so any changes in their prices will have a significant impact on the economics for each case study A, B and C.

Price forecasts for carbon credit which were taken from previous market analysis presented by Iowa Farm Bureau (Miller, 2007) show that a significant increase in the value of carbon credits is expected which would help in increase the NPV for these projects. Thus, the assessments were based on these forecasts by considering three different scenarios with varying price ranges. Figure 1.3 shows the different prices of carbon credits under different forecast scenarios. The value of electricity generated was varied in the sensitivity analysis, with the recent passage of the net metering law used to predict future buy back rates for additional power generated, ranging from $ 0.02/kWh to $ 0.06/kWh. Accordingly, the IRR and NPV were also calculated based on the electricity purchase rates from $0.06/kWh to $ 0.12/kWh to attain a value of electricity generated and used directly thereby offsetting farm requirements.

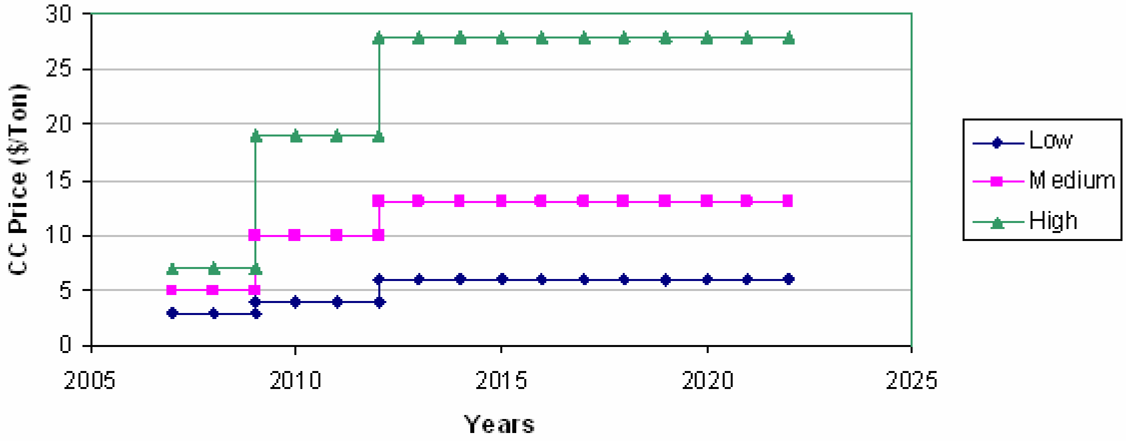


Figure 1.3:Varying Carbon Credit Prices to mimic previous projections based upon market analysis (Miller, 2007)

Subsidies are also known to be a major factor in the economic evaluation of proposed AD projects. Thus two different cases were considered; in the first case the funds from the grants were included in the model whereas in the second case the farmer had to make the full investment thus showing the benefits of the current subsidies.

Economic scenario 1 to 3 had carbon credit prices ranging between low and high forecasts (Table 1.4) with electricity purchase rate of $0.08/kWh and buy back rate of $0.02/kWh. The electricity rate represents the price the case study farms would otherwise pay to the local utility for electricity, and thus it is an avoided cost when electricity generated is used to quench the on-farm requirements. The buy back rate represents the rate at which the excess electricity can be sold to the utilities. With the net metering programs serving as an important incentive for investments in renewable energy generation the project owner can receive the retail price for the electricity used and production price for the excess power generated.

Thus the buy back rates are varied between $0.02/kWh to $0.06/kWh (Table 1.4) in scenarios 13 to 18 keeping the retail electricity price constant at $0.08/kWh. In scenarios 4 to 12 the retail electricity prices are varied from $0.06 to $0.12 /kWh for different ranges of carbon credit prices and buy back rate is kept constant at $0.02/kWh. Scenarios 1 to 18 considered a project life of 10 years and also included the subsidies. Scenarios 19 to 36 mimic the scenarios 1 to 18 except that the owner had to make his own investments without any subsidies available for the project.

Table 1.4: Different scenarios considered for sensitivity analysis with project life of 10 years. Subsidies were taken into consideration as noted and carbon credit prices were varied as shown in Fig 1.3

Scenarios, with Sub 1-18 and without Sub 19-36	**Carbon Credit Price $/CC (fig. 1.3)**	**Offset Electricity Price$/kWh**	**Electricity Buy back rate $/kWh**
1, 19	LOW	0.08	0.02
2, 20	MEDIUM	0.08	0.02
3, 21	HIGH	0.08	0.02
4, 22	LOW	0.06	0.02
5, 23	MEDIUM	0.06	0.02
6, 24	HIGH	0.06	0.02
7, 25	LOW	0.10	0.02
8, 26	MEDIUM	0.10	0.02
9, 27	HIGH	0.10	0.02
10, 28	LOW	0.12	0.02
11, 29	MEDIUM	0.12	0.02
12, 30	HIGH	0.12	0.02
13, 31	LOW	0.08	0.04
14, 32	MEDIUM	0.08	0.04
15, 33	HIGH	0.08	0.04
16, 34	LOW	0.08	0.06
17, 35	MEDIUM	0.08	0.06
18, 36	HIGH	0.08	0.06

1.7 CASE STUDY DESCRIPTIONS:

Three farms were considered for the study. The three farms are in east central Missouri, in close proximity, and referred to as farms A, B, C. Table 1.5 shows the existing manure management facilities in the three farms. Farm A operates 2,980 sows, 20 Teaser Boars, 5,000 weaners to finisher facility. The barns are pull-plug gutter flushed and are flushed with recycled lagoon water. The waste flows to the open lagoon by a buried underground pipeline. The farmer is interested in producing electricity on site rather than simply flaring the captured biogas. Thus methane from the digester will be burned in an internal combustion engine to drive a 70 KW generator. The farmer already owns a generator set which would serve the purpose and hence the cost of the generator can be avoided, and was not included in the model analysis.

Table 1.5: Existing manure management systems at case studies in central Missouri.

FARMS	A	B	C
Type of Animals	2980 Sows, 20 Teaser Boars and 5000 Weaners to finisher	2900 Weaners, 2900 Finishers	425 Sows, 620 Replacement Gilts and 2000 Gestation Sows
Existing Animal Waste Management system	Open Lagoon	Open Lagoon	Open Lagoon
Existing Manure Collection System	Pull Plug	Pull Plug	Pull Plug
Suggested New Technology	Covered Lagoon	Covered Lagoon	Covered Lagoon
Number of Deep Pits	1	1	3
Dimensions of the Pits	Depth =18-24 inches	Depth= 2ft	pit 1: 200×80×12 ft pit 2: 160×40×8 ft pit 3: 124× 24×4 ft
Dimensions of the Lagoon	856×352×15 ft	494×225×5 ft	333×333×15 ft

Farm B operates a facility with 2,900 weaners and 2,900 finishers also has a plug flow system, which finally drains to an anaerobic lagoon. In this case the farm doesn’t have an existing generator thus a new set of 60 KW would have to be bought, adding to the initial investment.

Farm C operates a facility of 425 sows, 625 replacement gilts and 2,000 gestation sows facility. The waste handling system consists of a plug recharge system, with 3 deep pit operations, which drains into a lagoon. The lagoon system includes an adjacent emergency secondary containment basin. This facility will use a 50 KW generator.

1.8 RESULTS:

The cost, benefit estimates and all the financial assumptions were incorporated in the model and a number of parameters like NPV of revenue from electricity and carbon credits and the NPV and IRR of the project under different scenarios were calculated for the three farms A, B and C (Table 1.6, 1.7, 1.8).

For farm A the methane produced was calculated to be 1820 cubic meter/ day which was validated by estimates from EFI professionals (1800 cubic meter/day) based upon their experience. The power generated by 70 KW engine generators was projected to be 490,560 kWh/year, which far exceeds the facilities needs.

Table 1.6: Output of the economic model for Farm A under different financial scenarios (Table- 1.4)

Scenarios #	NPV of Revenue (electricity)	NPV of Revenue (Carbon Credits)	Project NPV W/ subs	IRR (%) W/Subs	Project NPV W/o Subs	IRR (%) W/o Subs
1,19	$169,259	$121,983	$100,181	29.06	($19,592)	12.9
2,20	$169,259	$263,530	$202,096	39.34	$82,322	22.77
3,21	$169,259	$508,747	$378,651	51.53	$258,878	35.06
4,22	$131,039	$121,983	$72,663	25.52	($47,110)	9.82
5,23	$131,039	$263,530	$174,577	36.4	$54,804	20.24
6,24	$131,039	$508,747	$351,133	49.09	$231,360	33
7,25	$207,479	$121,983	$127,699	32.44	$7,926	15.83
8,26	$207,479	$263,530	$229,614	42.22	$109,841	25.24
9,27	$207,479	$508,747	$406,170	53.96	$286,397	37.12
10,28	$245,699	$121,983	$155,218	35.69	$35,445	18.65
11,29	$245,699	$263,530	$257,132	45.04	$137,359	27.67
12,30	$245,699	$508,747	$433,688	56.37	$313,915	39.16
13,31	$185,639	$121,983	$111,975	30.53	($7,798)	14.17
14,32	$185,639	$263,530	$213,889	40.59	$94,116	23.84
15,33	$185,639	$508,747	$394,445	52.57	$270,672	35.94
16,34	$202,019	$121,983	$123,768	31.97	$3,995	15.42
17,35	$202,019	$263,530	$225,683	41.81	$105,910	24.89
18,36	$202,019	$508,747	$402,238	53.61	$282,465	36.82

For this farm if the subsidies are accounted in the analysis the project yields high IRR (25%- 56%) in all the scenarios and if we calculate the NPV without taking the subsidies into consideration then: with low CC projections although the project NPV is positive with electricity prices above $0.10/kWh and buy back rates above $0.04/kWh but financial gains are not significant, with medium and high CC projections NPV is positive and lies in the range of $54,000- $137,000 for medium and $231,000- $313,000 for high scenario respectively. The sensitivity to the electricity offset price is shown in Fig. 1.4 keeping the electricity buyback rate at $0.02/kWh. The sensitivity to the electricity buyback rate is shown in Fig. 1.5 keeping the electricity offset price at $0.08/kWh.

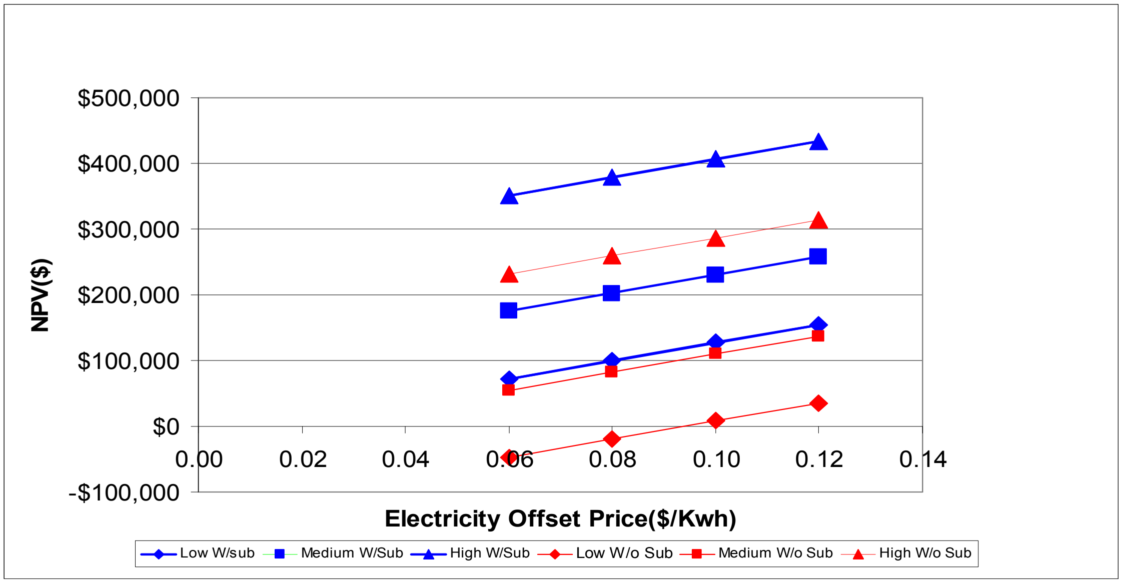


Fig 1.4) Sensitivity analysis based on electricity offset prices and CC projections for farm A

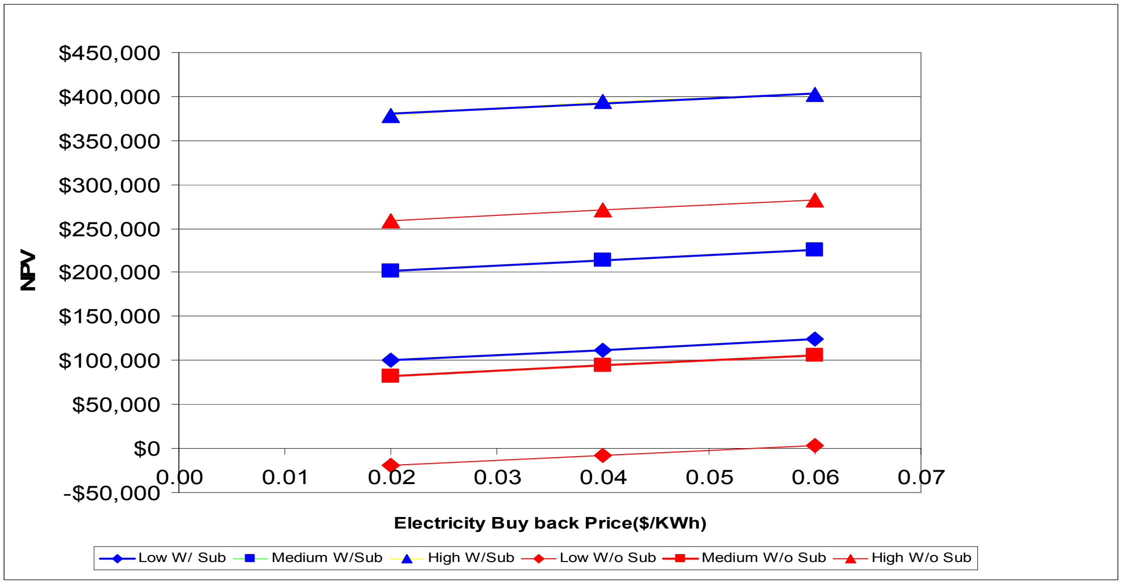


Fig 1.5) Sensitivity analyses based on electricity buy back rates and CC projections for farm A

For Farm B the methane produced was calculated to be 1,000 cubic meter/ day which was slightly higher than what was estimated by EFI (740 cubic meter/day). While the projections are fairly close, in an effort to maintain conservative assumptions in this model lower value (740 cubic meter/day) was utilized. The power generation rate was projected to be 420,480 kWh/year.

Without the subsidies the project at farm B does not yield positive NPV with low CC prices and with medium CC projections NPV is positive only with electricity price of above $0.10/kWh. High CC prices yield soaring NPV ranging between $45,000 and $92,000 if retail electricity prices above $0.08 /kWh. Again, increasing the buy back rates from 2 cents to 6 cents/kWh, keeping the offset price constant at $0.08 /kWh does not yield significant increase in NPV with low and medium CC prices (Figure 1.6, 1.7).

Table 1.7: Output of the economic model for Farm B under different financial scenarios (Table- 1.4)

Scenarios #	NPV of Revenue (electricity)	NPV of Revenue (Carbon Credits)	Project NPV W/ subs	IRR (%) W/Subs	Project NPV W/o Subs	IRR (%) W/o Subs
1,19	$145,079	$51,407	$45,166	21.81	($71,736)	6.85
2,20	$145,079	$111,059	$88,115	27.21	($28,786)	11.94
3,21	$145,079	$214,400	$162,521	34.49	$45,619	19.28
4,22	$112,319	$51,407	$21,579	18.36	($95,323)	3.90
5,23	$112,319	$111,059	$64,528	24.16	($52,373)	9.34
6,24	$112,319	$214,400	$138,934	31.89	$22,032	17.09
7,25	$177,839	$51,407	$68,753	25.07	($48,149)	9.64
8,26	$177,839	$111,059	$111,702	30.14	($5,199)	14.46
9,27	$177,839	$214,400	$186,108	37.03	$69,206	21.43
10,28	$210,599	$51,407	$92,340	28.19	($24,562)	12.32
11,29	$210,599	$111,059	$135,289	32.99	$18,388	16.89
12,30	$210,599	$214,400	$209,695	39.52	$92,794	23.55
13,31	$159,119	$51,407	$55,274	23.23	($61,627)	8.06
14,32	$159,119	$111,059	$98,224	28.48	($18,678)	13.03
15,33	$159,119	$214,400	$172,630	35.58	$55,728	20.21
16,34	$173,159	$51,407	$65,383	24.62	($51,518)	9.25
17,35	$173,159	$111,059	$108,333	29.73	($8,569)	14.10
18,36	$173,159	$214,400	$182,738	36.67	$65,837	21.13

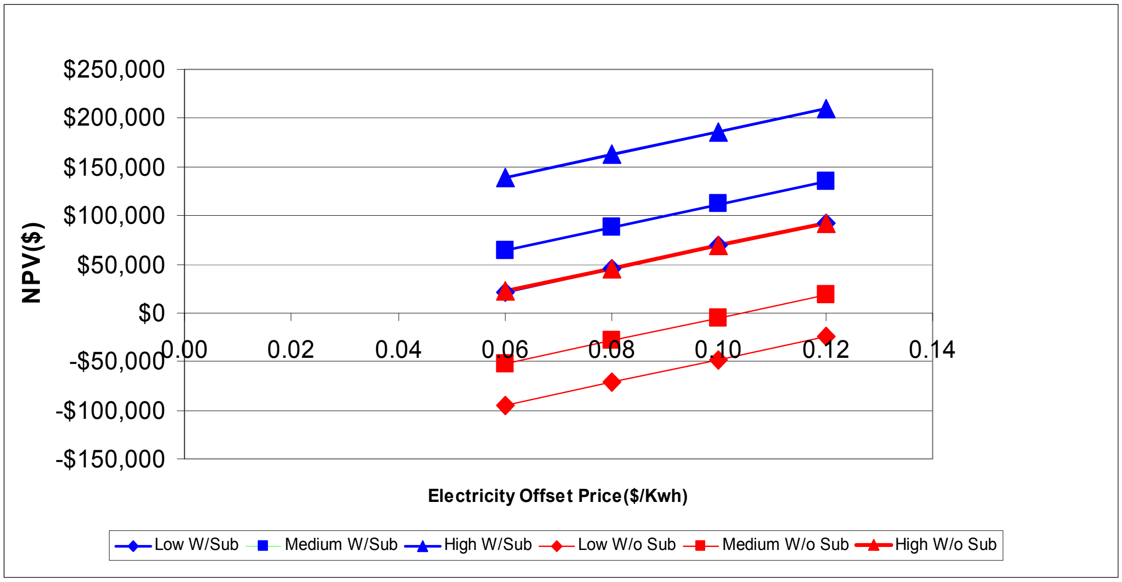


Fig 1.6) Sensitivity analysis based on electricity offset prices and CC projections for farm B

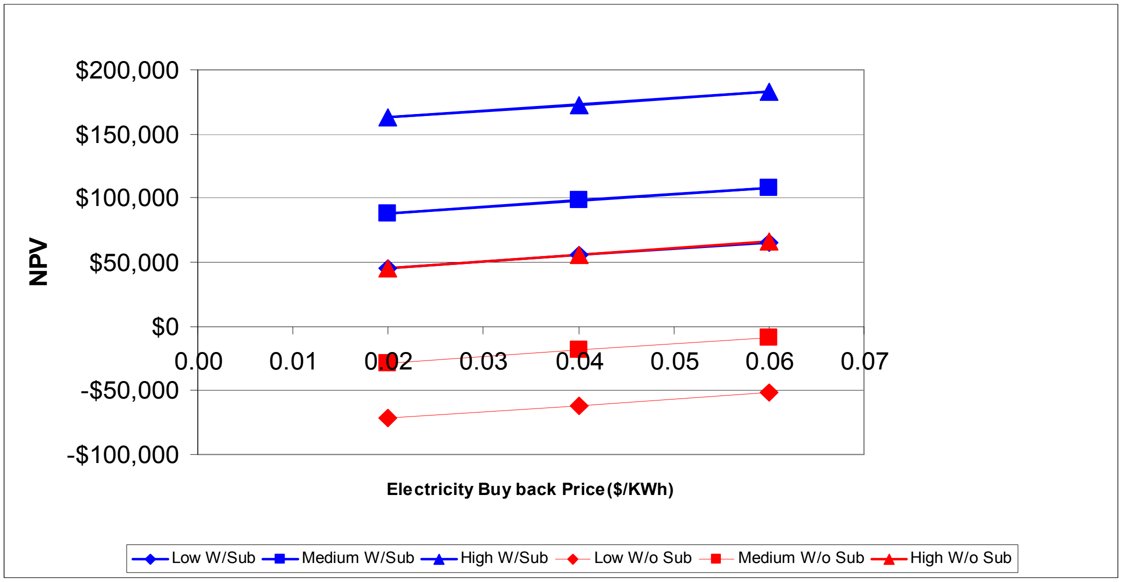


Fig 1.7) Sensitivity analyses based on electricity buy back rates and CC projections for farm B.

Similarly for Farm C the methane was estimated to be 683 cubic meter/day and the power generated was projected to be 350,400 kWh/year. Farm C follows the same trends as farm A except that the project seems to be yielding considerably lower NPV with medium CC projections (Figure 1.8, 1.9). For this farm the subsidies again make the project profitable under all scenarios.

While the case studies were specific and tailored to the individual farms, generalization can be drawn for a typical farm in Missouri. Therefore, farm A can be generalized for many swine facilities as the average practice in Missouri is 7500 head operation. The models for all three farms reveal that the availability of current subsidies is the key to economic feasibility under all other scenarios. Clearly, current subsidies are very important for increasing application of methane capture and utilization technologies.

Table 1.8: Output of the economic model for Farm C under different financial scenarios (Table- 1.4)

Scenarios #	NPV of Revenue (electricity)	NPV of Revenue (Carbon Credits)	Project NPV W/ subs	IRR (%) W/Subs	Project NPV W/o Subs	IRR (%) W/o Subs
1,19	$120,899	$55,546	$60,950	27.07	($39,258)	9.36
2,20	$120,899	$120,000	$107,357	34.10	$7,149	15.95
3,21	$120,899	$231,661	$187,753	43.07	$87,545	24.99
4,22	$93,599	$55,546	$41,294	23.44	($58,914)	6.34
5,23	$93,599	$120,000	$87,701	30.95	($12,507)	13.32
6,24	$93,599	$231,661	$168,097	40.41	$67,889	22.81
7,25	$148,199	$55,546	$80,606	30.52	($19,602)	12.24
8,26	$148,199	$120,000	$127,013	37.15	$26,805	18.50
9,27	$148,199	$231,661	$207,409	45.69	$107,201	27.16
10,28	$175,499	$55,546	$100,262	33.83	$54	15.01
11,29	$175,499	$120,000	$146,669	40.12	$46,461	20.99
12,30	$175,499	$231,661	$227,065	48.27	$126,857	29.30
13,31	$132,599	$55,546	$69,374	28.57	($30,834)	10.60
14,32	$132,599	$120,000	$115,781	35.42	$15,573	17.05
15,33	$132,599	$231,661	$196,177	44.19	$95,969	25.92
16,34	$144,299	$55,546	$77,798	30.04	($22,410)	11.83
17,35	$144,299	$120,000	$124,205	36.72	$23,997	18.14
18,36	$144,299	$231,661	$204,601	45.31	$104,393	26.85

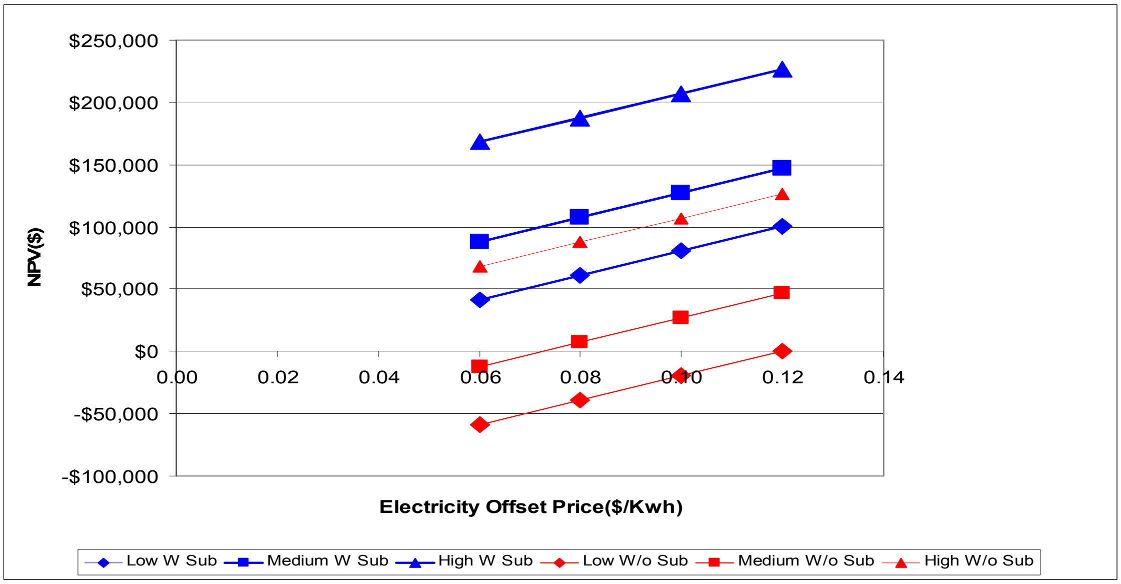


Fig 1.8) Sensitivity analysis based on electricity offset prices and CC projections for farm C

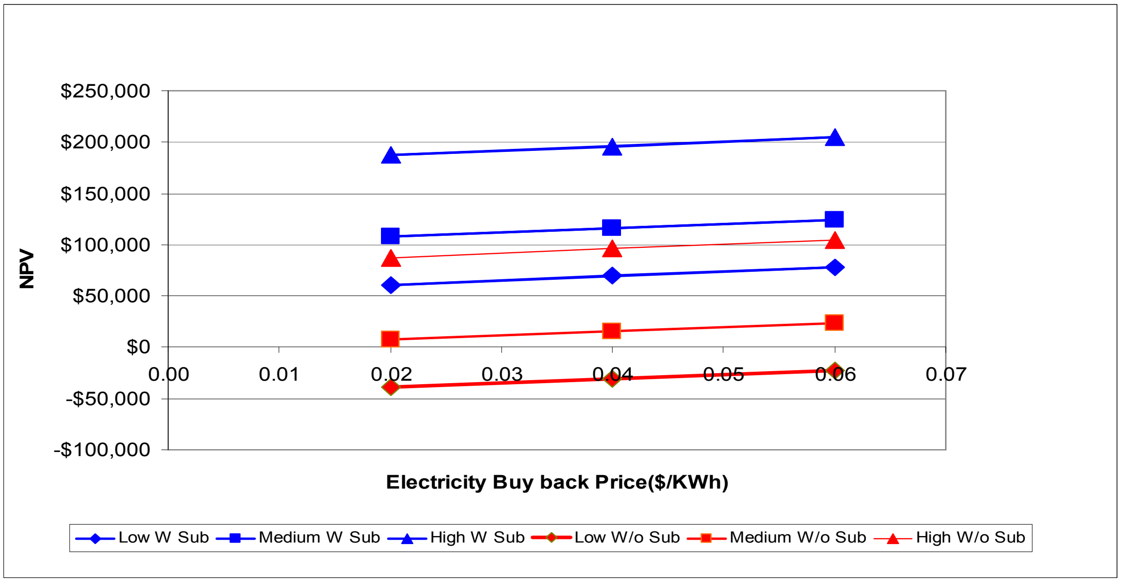


Fig 1.9) Sensitivity analyses based on electricity buy back rates and CC projections for farm C

1.9 CONCLUSIONS:

The results show that the present prices of carbon credits and electricity would not be enough to provide financial justification for the AD technology in all cases without the availability of current subsidies. However, when high CC and electricity prices were considered the results yielded significant positive NPV, but the uncertainty, risk and novelty of the CC markets makes the high CC projections impractical and thus current subsidies are critical to make the technology viable for farmers at this time. The sensitivity analysis found the change in electricity prices has a modest impact on the NPV of the project. However, the alteration in the CC projections affects the NPV even more dramatically. Thus it can be inferred that the value of carbon credits will play a pivotal role in widespread application of the technology. Results also show that with current subsidies the technology seems to be financially viable for all the three farms. Thus, the subsidies can do their part to help the farmers to purchase these renewable energy systems, but considering that the subsidies are not guaranteed to be available for future high CC and electricity prices would be needed for the technology to be profitable. The rising energy prices and the government's effort to encourage the production of electricity from renewable sources by implementing rules such as; net metering law, public benefit funds and generation disclosure rules make high electricity prices in future more likely. Even though, the ambiguity in the present carbon markets wouldn't confirm high CC rates but various hedging strategies such as entering into a long term contract would confirm the cash flow for a longer period. Also, there are many indirect revenues which have not been taken into account in this analysis. Better nutrient value from the manure will improve the productivity of the crops. The prices of land in the surrounding area would increase as a result of odor reduction as odor impacts have been reported to decrease surrounding values by 10%(Herriges, 2005). Heat produced from the digester during summer can be used to offset the cost of heating by external sources like natural gas and LPG for fulfilling the, on farm heat requirements in winter. In the future sale of renewable energy credits (REC's) can also be an additional source of revenue. Considering the results of the study, indirect revenues, and reduction in water and air pollution and more importantly reduction in green house gases anaerobic digestion (AD) technology seems to be highly viable mitigating the environmental impacts and concurrently generating profits for the farmers.

1.10 ACKNOWLEDGEMENTS:

This work was supported by the Department of Engineering Management, University of Missouri Rolla. The authors would like to thank the three participating farmers for providing the necessary details about the farms. They would also like to thank the Missouri Department of Agriculture for providing communication with farms in the state of Missouri. Authors also thank Dennis Shanklin from Environmental Fabrics Incorporation (EFI) for providing the methane production rates and cost estimates for the digesters, Andy Dvoracek (EcoSecurities) for verifying the inputs and assumptions in the financial model and sharing their business plan for carbon credits, Derek Six (Environmental Credit Corporation) for explaining the inner working of the carbon markets and sharing their business plans and Angie McEliece (RCM Digesters) for providing the necessary financial and operational inputs to be considered in the model. The input and collaborations with these experts was invaluable in developing this model, and ensuring its validity.

1.11 References:

CCX. (2003). "History of Chicago Climate Exchange" url: http://www.chicagoclimatex.com/content.jsf?id=1.

Craig, L. (2007). "A biogas production incentive act of 2007" 110th Congress 1st session April 18th, 2007. Bill in House of Representatives (H.R. 2038) url: http://craig.senate.gov/releases/biogas_bill_2007.pdf

Daley, B. (2007). "Supreme Court rules greenhouse gases a pollutant." a news paper article issue date April 2, 2007 url: http://www.boston.com/news/science/articles/2007/04/02/epa/

DSIRE(2007). "Net metering rules for renewable energy, published by, North Carolina Solar Center and the Interstate Renewable Energy Council (IREC). (DSIRE) Database for state incentives for renewables and efficiency url: http://www.dsireusa.org/library/includes/seeallincentivetype.cfm?type=Net&currentpageid=7&back=regtab

EPA (2000). "Alternative technologies/uses of Manure." Report on Confined animal feedlot operations.url: www.epa.gov/npdes/pubs/cafo_report.pdf

EPA (2001). "green house gas properties." U.S. EPA Methane: Science, url: http://www.epa.gov/methane/scientific.html#greenhouse.

EPA (2002a). "Managing Manure with Biogas Recovery Systems Improved Performance at Competitive Costs." Agstar Program ,Report # 430-F-02-004, url: http://www.epa.gov/agstar/pdf/manage.pdf.

EPA (2005). "Market Opportunities for Biogas Recovery Systems A Guide to Identifying Candidates for On-Farm and Centralized Systems." Agstar Program, Report # 430-8-06-004 url: http://www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf.

EPA (2007). "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005." url: http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf.

Fischer, J. R., D. D Osburn, N. F. Meader, and C. D. Fulhage. (1981). "Economics of a swine manure anaerobic digester." Transactions of the ASAE **24**: 1306–1310.

Herriges, J. A., Secchi, S., Babcock, B. A. (2005). "Living with hogs in Iowa: The impact of livestock facilities on rural residential property values." Land Economics **81**(4): 530-545.

Lusk, P. (1998). Methane recovery from animal manures the current opportunities casebook. National Renewable Energy Laboratory/SR-580-24145.url: http://www.nrel.gov/docs/fy99osti/25145.pdf

Methane to markets (2006). “Managing animal waste to recover methane: International opportunities for Project Development". (Methane to market partnership) url: http://www.methanetomarkets.org/resources/factsheets/agriculture_eng.pdf

Miller, D (2007). "Price forecasts for US carbon credits. Iowa Farm Bureau Carbon Credit Aggregation" url: http://www.iowafarmbureau.com/biogas/ccb.pdf

Nelson, C. (2002). "Final Report: Haubenschild Farms Anaerobic Digester" The Minnesota project, University of Minnesota url: http://www.mnproject.org/pdf/Haubyrptupdated.pdf

NRCS (2006). "More Information about EQIP" by U. S. Department of Agriculture, National Resources Conservation Services url: http://www.mo.nrcs.usda.gov/programs/eqip/moreinfoeqip.html

Osterberg, D. W. (2004). "Addressing Externalities From Swine Production to Reduce Public Health and Environmental Impacts." American Journal of Public Health **94**: 1703–1708.

Petersik, T. (2004). "State Renewable Energy Requirements and Goals: Status Through 2003 ", by Department of Energy url: http://www.eia.doe.gov/oiaf/analysispaper/rps/.

Spieler, T. L. (2007). Senate Bill No.643 94th General Assembly, first regular session for "Missouri agricultural and small business development authority" url: http://www.senate.mo.gov/07info/pdf-bill/intro/SB643.pdf

USDA (2006). "What is the Section 9006 Program?" by USDA rural development. url: http://www.rurdev.usda.gov/rbs/farmbill/what_is.html.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1. CONCLUSIONS:

This study resulted in development of a financial model that predicts the viability of the AD projects as a function of different economic scenarios for three specific case studies in central Missouri. The main conclusions of the study are:

- When current federal and state subsidies are included in the analysis, technology appears to be economically viable for all the three farms irrespective of the CC and electricity prices.
- At present prices of carbon credits and electricity the financial feasibility of the AD technology is questionable in all cases in the absence of current subsidies.
- The value of carbon credits may play a pivotal role in widespread application of the technology, as they show a greater impact in NPV over the anticipated ranges of values.
- High CC values and electricity prices would be needed for AD projects to be profitable in the future, considering that the subsidies may not be available in future.
- This financial model can facilitate the justification of investments as well as identify the economic conditions that justify these investments.
- Case specific information like existing manure management system and on-farm electricity consumption is also important, as can be observed from this study where farm B is bigger in size than farm C but the results show that farm C yield significantly higher NPV.

The results show that the present prices of carbon credits and electricity would not be enough to prove the financial feasibility of the AD technology in all cases without the availability of current subsidies. Although, when high CC and electricity prices were considered the results yielded significant NPV, but the uncertainty, risk and novelty of the CC markets makes the high CC projections questionable and thus current subsidies are indispensable to make the technology viable. From evaluating Figures 4, 5 and 6 it is found that the change in electricity prices has a modest impact on the corresponding NPV of the project. Conversely the alteration in the CC projections affects the NPV more dramatically. Thus, it can be inferred that the value of carbon credits may play a pivotal role in widespread application of the technology. The results show that the subsidies serve the intended purpose by helping the farmers to purchase renewable energy systems and make energy efficiency improvements cheaper. However, considering that the subsidies are not guaranteed to be available in future years, high CC and electricity prices would be needed for AD projects to be profitable. The rising energy prices and the government's effort to encourage the production of electricity from renewable sources by implementing rules such as; net metering law, public benefit funds and generation disclosure rules ensure high electricity prices in future. Even though, the ambiguity in the present carbon markets would not confirm high CC rates but various hedging strategies such as entering into a long term contract would confirm the cash flow for a longer period. Also, many indirect revenues, which have not been taken into account in this analysis may exist such as better nutrient value from the manure that will improve the productivity of the crops and the prices of land in the surrounding area would increase as a result of odor reduction (Herriges, 2005) Heat produced from the digester could also be used in the winter to offset the cost of heating by external sources like natural gas and LPG for fulfilling the on farm requirements. In the future, sale of Renewable energy credits (REC's) could also be an additional source of revenue. Thus, these sources could offer additional financial benefits from the project but quantification if these benefits are beyond the current scope of our study. Previous research has evaluated various cash flows separately and none of them have proven this technology feasible in terms of economic returns. Garrison's research showed that swine finishing operations needed more than 5,000 head and electricity price of $0.12/kWh to be economically feasible and his results also indicated that increased energy prices and financial assistance was needed to encourage significant numbers of facilities to recover energy from manure (Garrison, 2005). Ghafoori found that the price of carbon credits required to cover the cost of AD plant processing of manure was greater than $125/ ton of CO_2 and his results showed that the current value of CC's is not enough to prove the economic feasibility of AD treatment of manure from mixed farming areas (Ghafoori, 2007). In this study three revenue sources including subsidies, electricity and CC have been taken into account and results show that the project is feasible under a number of scenarios.

Considering the results of the study which involved combination of all the revenue streams together, indirect revenues, reduction in water and air pollution and more importantly reduction in green house gases anaerobic digestion (AD) technology seems to be highly viable diminishing the environmental impacts and concurrently generating profits for the farmers.

3.2. RECOMMENDATIONS:

On a broad aspect anaerobic digestion (AD) technology is not novel; however the process is highly underutilized particularly at the time of growing environmental concerns, increasing need of inexpensive energy, agricultural waste issues and most importantly ever-increasing need to avoid green house gases due to rising global warming. Some of the animal producers are already aware of the latent benefits of the AD technology and have taken the initiative to get some projects going such as Haubenschild farms anaerobic digester project (Nelson, 2002), but still there is a serious lack of knowledge and market understanding exists in this area. Many producers are reluctant to take the leap of faith needed to make the projects happen. Thus, there is a need to spread the knowledge so that widespread application of this technology could be made possible. State wide workshops should be organized and people from all spheres including animal producers, leaders in biogas generation, local utilities and the technology vendors should be invited to increase the awareness among the concerned people. Understanding the mechanisms and potential of the upcoming carbon credit markets is another major challenge which needs to be dealt with. Seminars should be held to educate people about the intricacies of carbon finance and processes involved in trading of these credits. One such talk on “Introduction to carbon market trading and finance” was given by Peter C. Fusaro chairman, Global Change Associates in New York in May 2007. Many utilities, investment banks, research universities and commodity trading firms attended the talk and the seminar was enlightening to most of the attendees. More seminars of these kinds are recommended at regular intervals.

More research is recommended into evaluating the biogas potential and seasonal variability of electricity generation. Research is also suggested in technological advancements in the AD technology to improve the efficiency of the digester so that more biogas can be produced and the economic returns can be increased. Increasing the efficiency of the generator is another factor which can be targeted in the future to aid economic returns.

The economic model used for the study identifies and quantifies the tangible benefits that a typical swine farm might gain from the integration of an anaerobic digester system. Almost all the model inputs and parameters including electricity offset and buyback price were based on readily available statistics and information, which can be referenced, but the future price of the carbon credits is a variable which is based upon mere speculations. The CC market is highly unpredictable at the moment and the rates of CC entirely depend upon the interaction between the supply and demand of these credits, in a 100% voluntary market. Many factors could affect the demand and hence the prices of the credits. One of the most important factors is the public opinion, currently going green (reducing emissions by buying these credits) is considered to be stylish and is used as a marketing strategy by large companies. Once the emission reduction becomes mandatory the demand of these credits would increase considerably. Another factor which will affect the demand is the price of alternative energies like wind and solar energy. Cheaper prices as compared to the conventional fossil fuels would result in reduction in the demand of the credits. Technology advancement which will enable the use of conventional fuels more efficiently would also reduce the demand for CC and thus decreasing the price. This phenomenon was observed in the European market crash following the release of the verified 2005 emissions data which showed that companies emitted less CO_2 in 2005 than they were allowed. Considering the uncertainty and risk involved in these markets future contracts with fixed prices and for longer periods have clear benefits.

The model uses the cost estimates for the digester from the technology vendor as an input and doesn't have any relationship to calculate the cost based on the number of heads and type of animals. Future work can be done to improve some of the characteristics of model so that it can be made more user friendly and can be used to run the analysis for any swine farm. Small alterations in the calculations can also facilitate the use of the model for other livestock like dairy or even other industries like food processing.

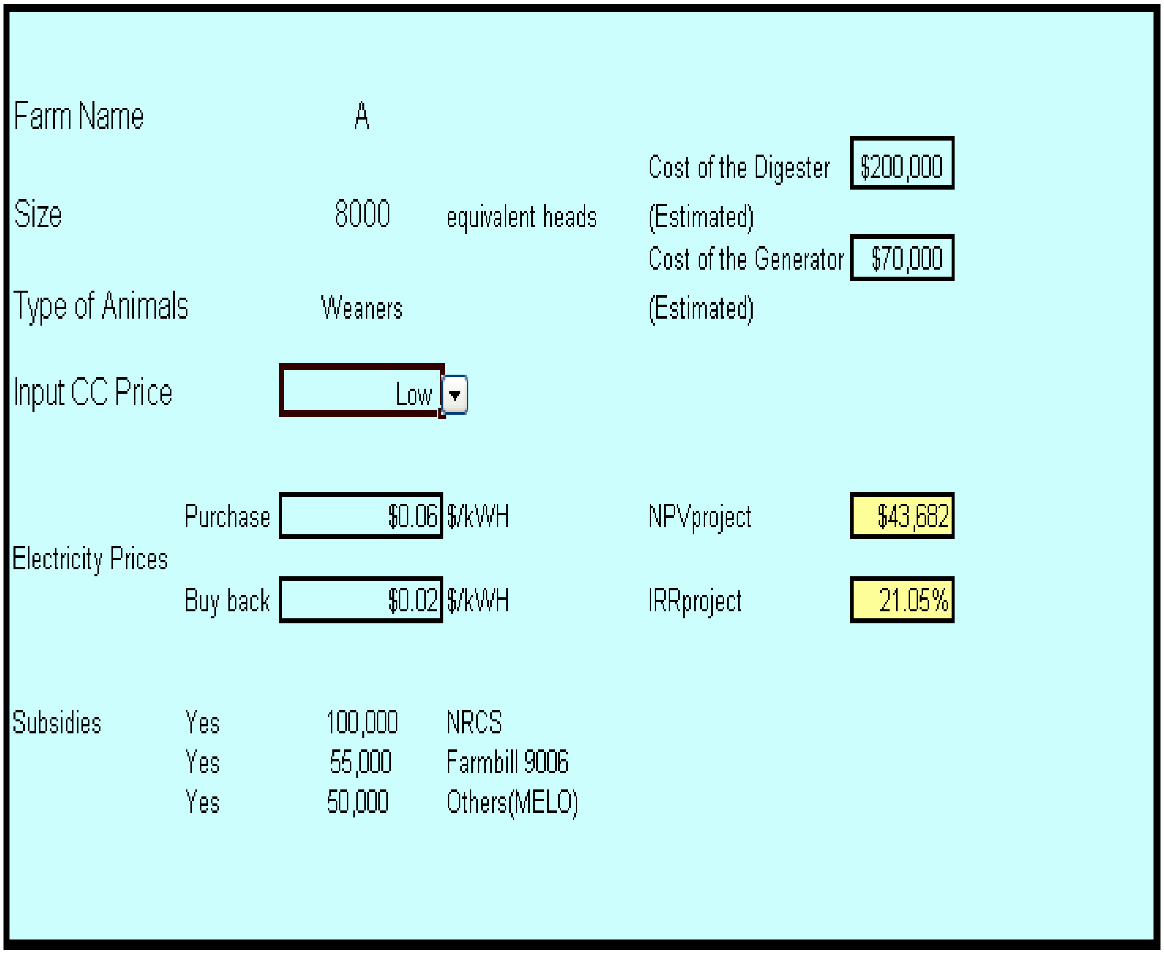
It is further recommended to perform similar analysis including other quantifiable revenue sources like offsetting heat requirements, selling renewable energy credits, improved crop production due to better fertilizers and increase in the property prices due to odor reduction which could further increase the economic returns.

APPENDIX A:

Sample financial model for farm A.

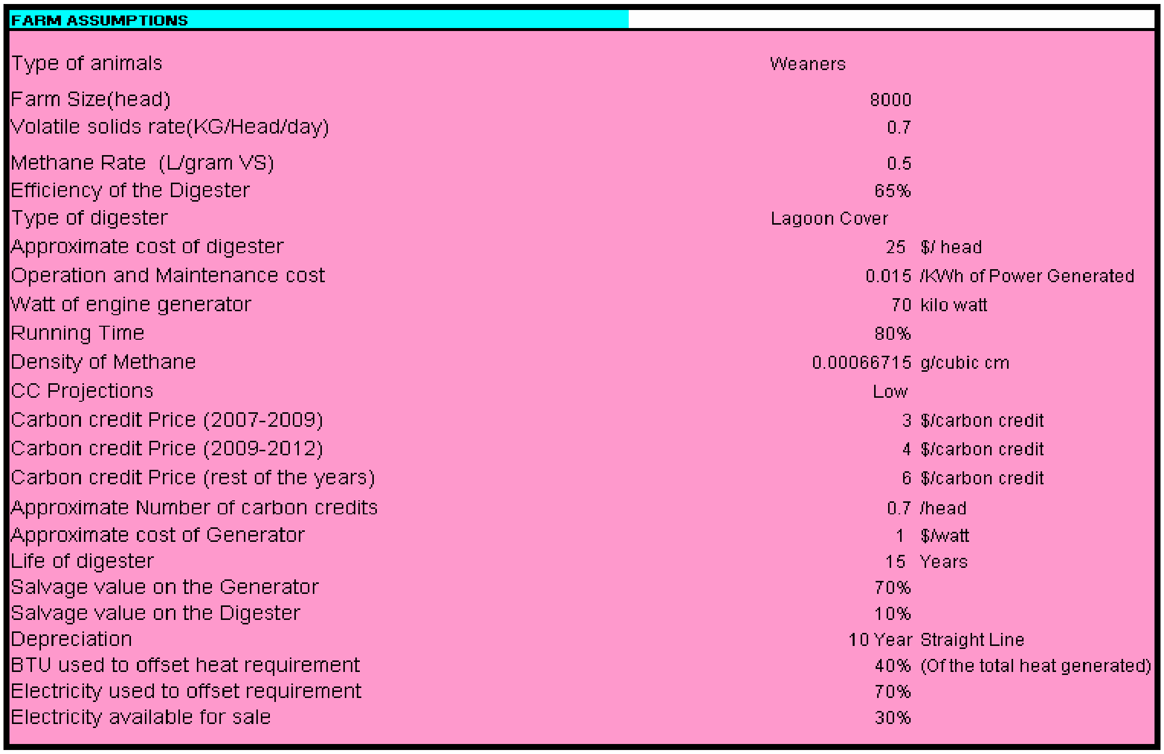
Sample financial model for farm A:

<u>Figure A1: Excel spreadsheet- Interface of the model:</u>



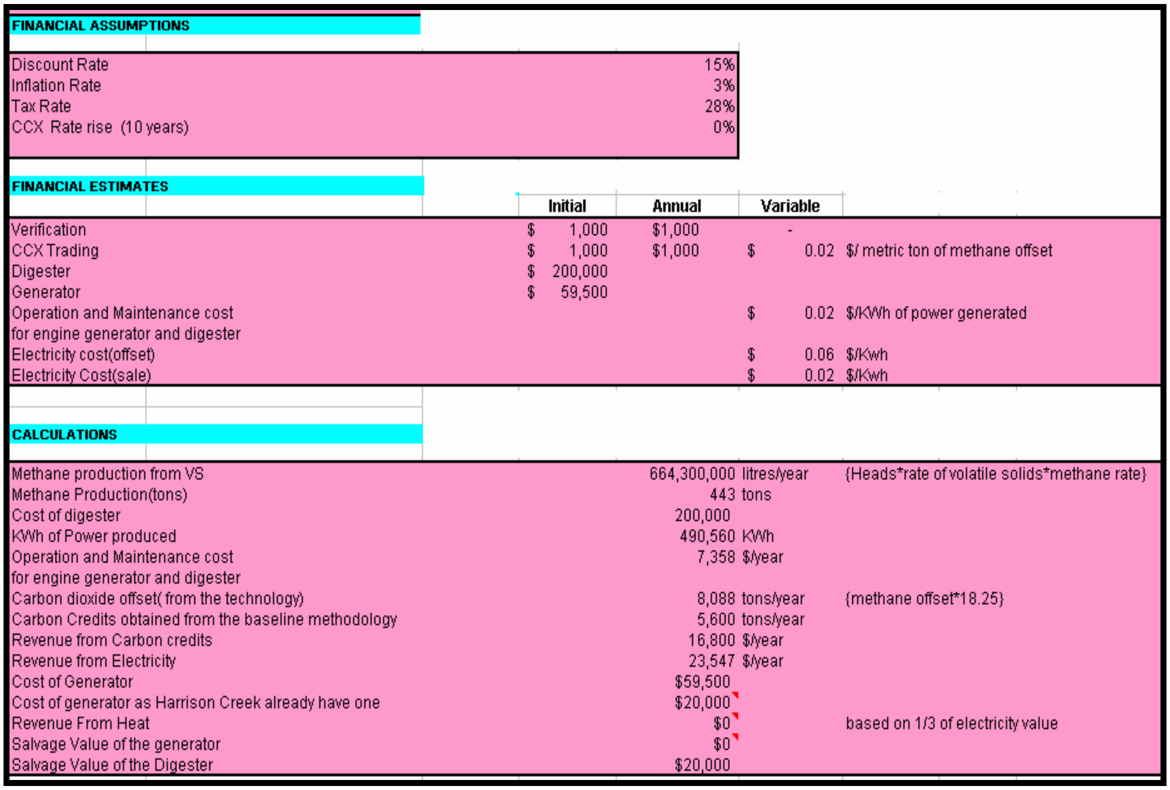
Farm Name		A			
				Cost of the Digester (Estimated)	$200,000
Size		8000	equivalent heads		
				Cost of the Generator (Estimated)	$70,000
Type of Animals		Weaners			
Input CC Price		Low			
Electricity Prices	Purchase	$0.06	$/kWH	NPVproject	$43,682
	Buy back	$0.02	$/kWH	IRRproject	21.05%
Subsidies	Yes	100,000	NRCS		
	Yes	55,000	Farmbill 9006		
	Yes	50,000	Others(MELO)		

Figure A2: Spreadsheet considering model assumptions and calculations:



FARM ASSUMPTIONS

Type of animals	Weaners	
Farm Size(head)	8000	
Volatile solids rate(KG/Head/day)	0.7	
Methane Rate (L/gram VS)	0.5	
Efficiency of the Digester	65%	
Type of digester	Lagoon Cover	
Approximate cost of digester	25	$/ head
Operation and Maintenance cost	0.015	/KWh of Power Generated
Watt of engine generator	70	kilo watt
Running Time	80%	
Density of Methane	0.00066715	g/cubic cm
CC Projections	Low	
Carbon credit Price (2007-2009)	3	$/carbon credit
Carbon credit Price (2009-2012)	4	$/carbon credit
Carbon credit Price (rest of the years)	6	$/carbon credit
Approximate Number of carbon credits	0.7	/head
Approximate cost of Generator	1	$/watt
Life of digester	15	Years
Salvage value on the Generator	70%	
Salvage value on the Digester	10%	
Depreciation	10 Year	Straight Line
BTU used to offset heat requirement	40%	(Of the total heat generated)
Electricity used to offset requirement	70%	
Electricity available for sale	30%	



FINANCIAL ASSUMPTIONS

Discount Rate	15%
Inflation Rate	3%
Tax Rate	28%
CCX Rate rise (10 years)	0%

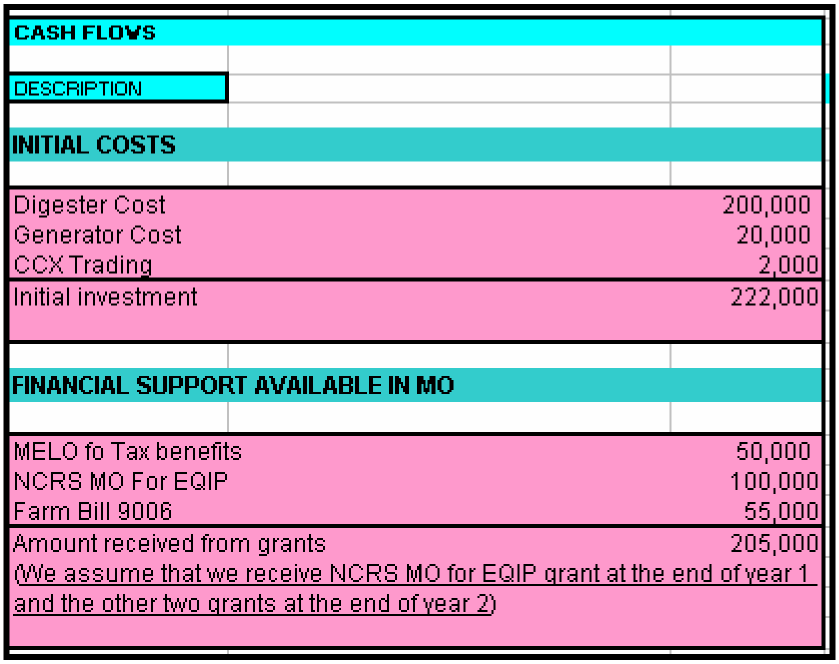
FINANCIAL ESTIMATES

	Initial	Annual	Variable	
Verification	$ 1,000	$1,000	-	
CCX Trading	$ 1,000	$1,000	$ 0.02	$/ metric ton of methane offset
Digester	$ 200,000			
Generator	$ 59,500			
Operation and Maintenance cost for engine generator and digester			$ 0.02	$/KWh of power generated
Electricity cost(offset)			$ 0.06	$/Kwh
Electricity Cost(sale)			$ 0.02	$/Kwh

CALCULATIONS

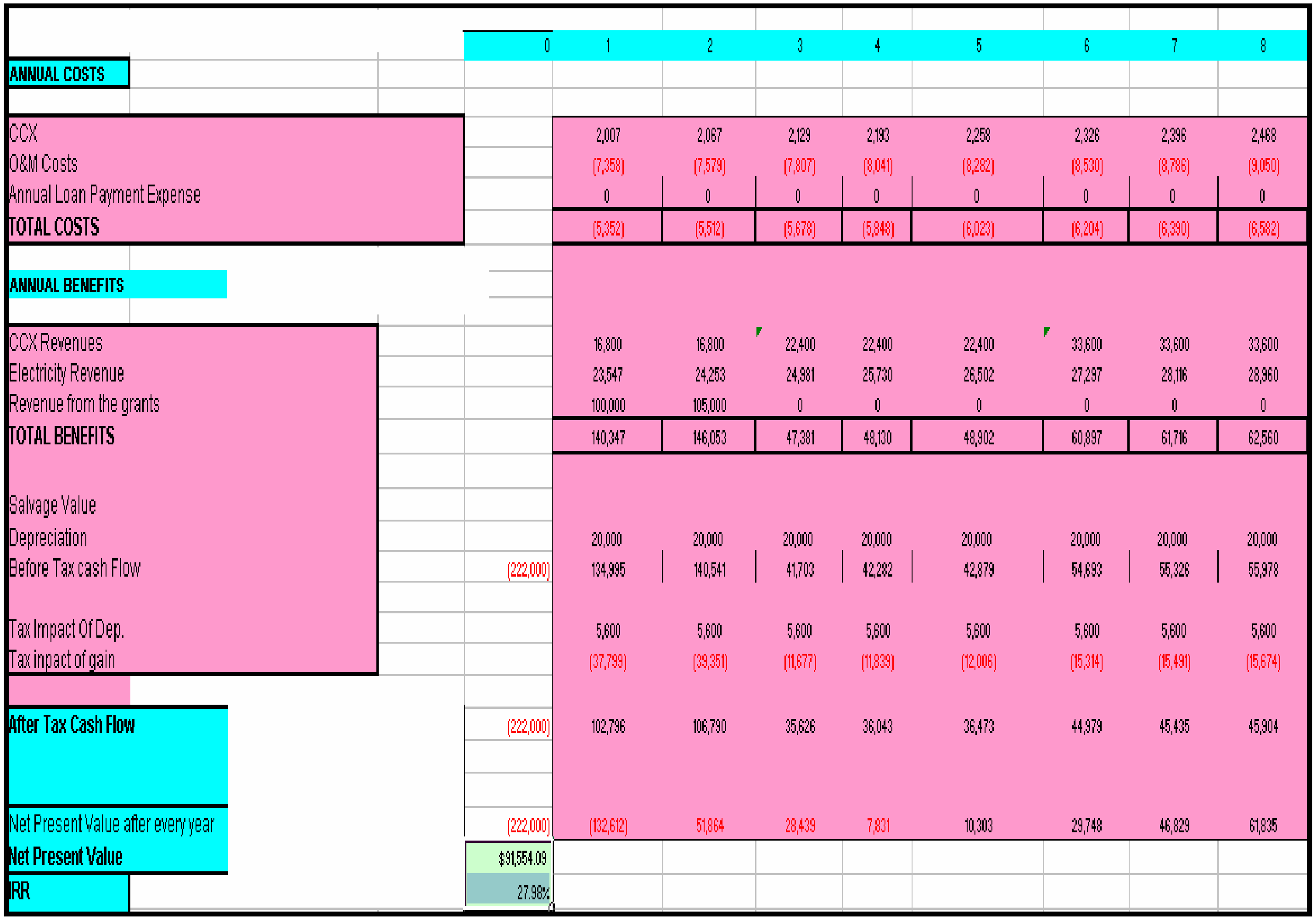
Methane production from VS	664,300,000	litres/year	{Heads*rate of volatile solids*methane rate}
Methane Production(tons)	443	tons	
Cost of digester	200,000		
KWh of Power produced	490,560	KWh	
Operation and Maintenance cost for engine generator and digester	7,358	$/year	
Carbon dioxide offset(from the technology)	8,088	tons/year	{methane offset*18.25}
Carbon Credits obtained from the baseline methodology	5,600	tons/year	
Revenue from Carbon credits	16,800	$/year	
Revenue from Electricity	23,547	$/year	
Cost of Generator	$59,500		
Cost of generator as Harrison Creek already have one	$20,000		
Revenue From Heat	$0		based on 1/3 of electricity value
Salvage Value of the generator	$0		
Salvage Value of the Digester	$20,000		

Figure A3: Spreadsheet showing initial costs and current subsidies:



CASH FLOWS	
DESCRIPTION	
INITIAL COSTS	
Digester Cost	200,000
Generator Cost	20,000
CCX Trading	2,000
Initial investment	222,000
FINANCIAL SUPPORT AVAILABLE IN MO	
MELO fo Tax benefits	50,000
NCRS MO For EQIP	100,000
Farm Bill 9006	55,000
Amount received from grants	205,000
(We assume that we receive NCRS MO for EQIP grant at the end of year 1 and the other two grants at the end of year 2)	

Figure A4: Body of the model:



	0	1	2	3	4	5	6	7	8
ANNUAL COSTS									
CCX		2,007	2,067	2,129	2,193	2,258	2,326	2,396	2,468
O&M Costs		(7,358)	(7,579)	(7,807)	(8,041)	(8,282)	(8,530)	(8,786)	(9,050)
Annual Loan Payment Expense		0	0	0	0	0	0	0	0
TOTAL COSTS		(5,352)	(5,512)	(5,678)	(5,848)	(6,023)	(6,204)	(6,390)	(6,582)
ANNUAL BENEFITS									
CCX Revenues		16,800	16,800	22,400	22,400	22,400	33,600	33,600	33,600
Electricity Revenue		23,547	24,253	24,981	25,730	26,502	27,297	28,116	28,960
Revenue from the grants		100,000	105,000	0	0	0	0	0	0
TOTAL BENEFITS		140,347	146,053	47,381	48,130	48,902	60,897	61,716	62,560
Salvage Value									
Depreciation		20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Before Tax cash Flow	(222,000)	134,995	140,541	41,703	42,282	42,879	54,693	55,326	55,978
Tax Impact Of Dep.		5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600
Tax inpact of gain		(37,799)	(39,351)	(11,677)	(11,839)	(12,006)	(15,314)	(15,491)	(15,674)
After Tax Cash Flow	(222,000)	102,796	106,790	35,626	36,043	36,473	44,979	45,435	45,904
Net Present Value after every year	(222,000)	(132,612)	51,864	28,439	7,831	10,303	29,748	46,829	61,835
Net Present Value	$91,554.09								
IRR	27.98%								

APPENDIX B:

List of potential CAFO’s developed with the help of Missouri Department of Agriculture.

List of potential CAFOs for the study:

FISHER HOG FARMS
MO-G010660, Pike Co., Middletown
Owner: Jim Fisher, Tel: 573-549-2468

Summary: A swine sow operation consisting of eleven production barns serving 3430 swine over 55 lbs. The operation holds 496 sows and litters, 2,294 gestation sows, 400 replacement gilts, and 240 grower pigs. Manure from barns 1, 5, 6, 7, 8 and 9 is flushed to a single anaerobic lagoon from pull plug pit systems located under slotted floors using recycled flush water. Manure from barns 2, 3, 4, and 10 utilize deep concrete pits under the floor for manure storage. Manure from barn 11 is flushed via a pull plug pit system to the deep concrete pit beneath barn 10. The lagoon system includes an adjacent emergency secondary containment basin. Swine mortalities are composted on site.

ALLAN BARNES FINSIHING FARM
MO-G010568, Audrain Co., MIDDLETOWN
Owner: Alan Barnes, Tel: (573) 549-2455

Summary: This hog finishing operation consists of three sites on one parcel of land with a total on farm capacity of 13,000 swine over 55 pounds. The east site contains four confinement houses with 4,000 finishing hogs an anaerobic lagoon. The west site contains four confinement houses with 4,000 finishing hogs an anaerobic lagoon. The central site which is currently under construction has one confinement building with 5,000 finishing hogs an anaerobic lagoon. Lagoon effluent nutrients are utilized on about 186 spreadable acres on-site or on 149 acres available nearby. Effluent is transported through temporary irrigation pipelines and land applied with a traveling gun.

PORK MASTER, INC.
MOG010018, Callaway Co., FULTON
Owner: Gary Horstmeier, Tel: (573) 642-8635

Summary: A swine feeding operation consisting of eight production buildings, one solids separation basin, one swine composter and land application area serving a total of 5,600 finishing hogs. Manure is removed from the buildings with recycled lagoon water by a gutter flush system under slotted floors and transported to the solids separation basin with PVC pipes. Overflow from the basin goes to the aerated lagoon where manure and wastewater is stored. Manure solids in the settling basin are removed two times per year and applied to cropland using a tank wagon and tractor mounted injection system. Processed manure is removed one time per year from the lagoon and applied to cropland using a center pivot irrigation system.

HARRISON CREEK FARMS
MOG010223, Callaway Co., AUXVASSE
Owner: Kenny Brinker, Tel: (573) 386-5585

Summary: This is a farrow to finish swine confinement operation containing approximately 13,077 total swine. It has 216 sows and litters, 1,165 gestation sows, 7,000 finishing hogs and 4,696 nursery pigs. The barns are pull-plug gutter flushed and are flushed with recycled lagoon water. The barns are connected to the anaerobic lagoon by a buried underground pipeline.

JEFF BROWNING FARM
Southern Pike County
Owner: Jeff Browning, P.E. Tel: (573) 324-6557

Summary: Four 1,024 head finishing barns with two separate anaerobic lagoons in southern Pike County. All four barns are relatively close together and could be taken to a single treatment point.

WILBURN HOG FARMS, LLC
MOG010544, AUDRAIN Co., LADDONIA
Owner: Jay Wilburn Tel: (573) 373-5626

Summary: A swine feeding operation consisting of six production buildings serving 5,600 finishing hogs. Manure is flushed to the anaerobic lagoon via pull plug pits system under slotted floors.

List of farms that are willing to participate:

Steven Troesser, Vandalia/Mexico
Deep pit, new construction
110-138 miles from Rolla
573-721-1061

Scott Hayes, Monroe City
2-5000 head finishers
Lagoon and deep pit
167 miles from Rolla
573-406-2476

Marcus Belshe, Eugene
3200 head nursery
Lagoon storage
76 miles from Rolla
573-498-3795, 573-690-6678

Rick Rehmeier, Augusta
Lagoon storage
Innovator has equipment set up there
78 miles from Rolla
636-357-8078, 636-228-4373

David Stephens, Zeysing Farms, Marshall
155 miles from Rolla
660-631-2309

Dennis Zerr, Kingdom City
6000 head operation
Lagoon storage
93 miles from Rolla
573-220-5171, 573-254-3358

Larry Hendricks, Auxvasse
100 miles from Rolla
573-386-5155

BIBLIOGRAPHY

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P. S., Wichman, M. (2007). "Impacts of waste from concentrated animal feeding operations on water quality." Environmental Health Perspectives **115**(2): 308-312.

Capoor, K. (2007). State and Trends of Carbon Market 2007. Washington D.C., The World Bank. url: http://carbonfinance.org/docs/Carbon_Trends_2007-_FINAL_-_May_2.pdf

CCX. (2003). "History of Chicago Climate Exchange" url: http://www.chicagoclimatex.com/content.jsf?id=1.

Craig, L. (2007). "A biogas production incentive act of 2007" 110th Congress 1st session April 18th, 2007. Bill in House of Representatives (H.R. 2038) url: http://craig.senate.gov/releases/biogas_bill_2007.pdf

Daley, B. (2007). "Supreme Court rules greenhouse gases a pollutant." a news paper article issue date April 2, 2007 url: http://www.boston.com/news/science/articles/2007/04/02/epa/

Dvoracek, A. (2007). EcoSecurities (Personal Communication) with T. Grover, June 2, 2007

Donham, K. J. (2000). "The concentration of swine production - Effects on swine health, productivity, human health, and the environment." Veterinary Clinics of North America-Food Animal Practice **16**(3): 559-+.

DSIRE(2007). "Net metering rules for renewable energy, published by, North Carolina Solar Center and the Interstate Renewable Energy Council (IREC). (DSIRE) Database for state incentives for renewables and efficiency url: http://www.dsireusa.org/library/includes/seeallincentivetype.cfm?type=Net&currentpageid=7&back=regtab

ECC (2004). "Environmental Credit Corp. Supplying Environmental Credits to Global Financial Markets." url: http://www.envcc.com/downloads/ECC_Brochure_(12-05).pdf.

EcoSecurities. (2005). "Delivering high quality emission reductions to the voluntary market" url: http://www.ecosecurities.com/Assets/3438/ecosecurities%20ver%20brochure.pdf.

EPA (2000). "Alternative technologies/uses of Manure." Report on Confined animal feedlot operations.url: www.epa.gov/npdes/pubs/cafo_report.pdf

EPA (2001). "green house gas properties." U.S. EPA Methane: Science, url: http://www.epa.gov/methane/scientific.html#greenhouse.

EPA (2002a). "Managing Manure with Biogas Recovery Systems Improved Performance at Competitive Costs." Agstar Program ,Report # 430-F-02-004, url: http://www.epa.gov/agstar/pdf/manage.pdf.

EPA (2002b). "The Benefits of Reducing Nitrate Contamination in Private Domestic Wells Under CAFO Regulatory Options." Report # 821-R-03-008. url: http://www.epa.gov/npdes/pubs/cafo_benefit_nitrate.pdf.

EPA (2005). "Market Opportunities for Biogas Recovery Systems A Guide to Identifying Candidates for On-Farm and Centralized Systems." Agstar Program, Report # 430-8-06-004 url: http://www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf.

EPA (2007). "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2005." url: http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf.

Fischer, J. R., D. D Osburn, N. F. Meader, and C. D. Fulhage. (1981). "Economics of a swine manure anaerobic digester." Transactions of the ASAE **24**: 1306–1310.

Garrison, A. V., Richard, T. L. (2005). "Methane and manure: Feasibility analysis of price and policy alternatives." Transactions of the ASAE **48**(3): 1287-1294.

Ghafoori, E., Flynn, P. C., Checkel, M. D. (2007). "Carbon credits required to make manure biogas plants economic." International Journal of Green Energy **4**(3): 339-349.

Herriges, J. A., Secchi, S., Babcock, B. A. (2005). "Living with hogs in Iowa: The impact of livestock facilities on rural residential property values." Land Economics **81**(4): 530-545.

Lusk, P. (1998). Methane recovery from animal manures the current opportunities casebook. National Renewable Energy Laboratory/SR-580-24145.url: http://www.nrel.gov/docs/fy99osti/25145.pdf

M. Saele (1998) "Anaerobic Digester Lagoon with Methane Gas Recovery: First year Management and Economics" by USDA-NRCS. url: http://www.p2pays.org/ref/21/20969.htm

Methane to markets (2006). “Managing animal waste to recover methane: International opportunities for Project Development". (Methane to market partnership) url: http://www.methanetomarkets.org/resources/factsheets/agriculture_eng.pdf

Miller, D (2007). "Price forecasts for US carbon credits. Iowa Farm Bureau Carbon Credit Aggregation" url: http://www.iowafarmbureau.com/biogas/ccb.pdf

Nelson, C. (2002). "Final Report: Haubenschild Farms Anaerobic Digester" The Minnesota project, University of Minnesota url: http://www.mnproject.org/pdf/Haubyrptupdated.pdf

NRCS (2006). "More Information about EQIP" by U. S. Department of Agriculture, National Resources Conservation Services url: http://www.mo.nrcs.usda.gov/programs/eqip/moreinfoeqip.html

NRDC. "America's Animal Factories: How States Fail to Prevent Pollution from Livestock Waste", National Resources Defense Council url:http://www.nrdc.org/water/pollution/factor/gloss.asp.

Osterberg, D. W. (2004). "Addressing Externalities From Swine Production to Reduce Public Health and Environmental Impacts." American Journal of Public Health **94**: 1703–1708.

Petersik, T. (2004). "State Renewable Energy Requirements and Goals: Status Through 2003 ", by Department of Energy url: http://www.eia.doe.gov/oiaf/analysispaper/rps/.

Six, D. (2007). Environmental Credit Corporation. (Personal Communication)with T.Grover on April 15, 2007

Spieler, T. L. (2007). Senate Bill No.643 94th General Assembly, first regular session for "Missouri agricultural and small business development authority" url: http://www.senate.mo.gov/07info/pdf-bill/intro/SB643.pdf

Starrs, T. J. (1996). "Net Metering: New Opportunities For Home Power" by Center of Renewable Energy and Sustainable Technology, url: http://www.crest.org/repp_pubs/articles/issuebr2/issuebr2.pdf.

Sullivan, W. G. (2001). Engineering Economy, Addison Wesley Longman (Singapore) Pt. Ltd., Indian Branch. Page number 148, 158

USDA. (2006). "What is the Section 9006 Program?" by USDA rural development. url: http://www.rurdev.usda.gov/rbs/farmbill/what_is.html.

Vachon, S. (2006). "The role of social, political, and economic interests in promoting state green electricity policies" Environmental Science & Policy **9**(7-8): 652-662

Williams, J. R., Peterson, J. M., Mooney, S. (2005). "The value of carbon credits - Is there a final answer." Journal of Soil and Water Conservation **60**(2): 36A-40A.

World Bank. "Carbon Finance: Glossary of terms" url: http://carbonfinance.org/Router.cfm?Page=Glossary.

VITA

I was born on September 20th, 1984, to my loving parents. I grew up in the town of Faridabad and had a great childhood playing with friends, especially cricket and football, a true Indian child of the 80s.

As I grew into a young man my interests changed with the passage of time and I moved from games to real world scenarios. My interest always stayed around relating my studies to my immediate surroundings. I participated in a number of project works and team events throughout my school career and was famous for my versatility.

In high school I still had plenty of time to pursue other interests in academics, sports, drama and relationships. I did well in school and never had to work very hard even though I took a variety of classes of various levels of difficulty. I was not a standout but was a consistent student and managed to score in the top few.

Giving a tough fight with the entrance exams back in India, I managed to seek admission in one of the best technical institutes in the country where I pursued my bachelors in chemical engineering. After graduating as chemical engineer, I decided to get exposed to the global scenario of my field as a result of which I moved to Rolla, Missouri to start my graduate school in the field of engineering management. The University of Missouri, Rolla was a great fit for me and I found a great research program, good friends and beautiful weather.

I decided to enter the engineering management program and was glad to receive an opportunity to work with such professional and experienced advisors. Thanks to the combined financial and technical support of Dr. Nystrom and Dr. Joel Burken under whose guidance; I successfully completed my thesis graduating as a master of science in May 2008.