A review of energy production systems through the utilization of poultry litter as a fuel source and determination of feasibility for North Carolina farming operations

by
Kyle W. Crawford

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Masters of

Environmental Assessment

Raleigh, North Carolina

2013

Committee Chair:
Linda Taylor

ABSTRACT

Crawford, Kyle. A review of Energy Production Systems through the utilization of poultry litter as a fuel source and determination of feasibility for North Carolina's poultry farming operations (Under the direction of Linda Taylor)

There is both a growing demand for clean energy consumption and an increase in agricultural production in order to both feed the world and continue to keep our global environment as clean as possible. The following dissertation aims to determine if clean and sustainable biofuel energy, utilization of poultry litter a fuel source, could be utilized to power the operation of a poultry farm, the same farm in which the litter was derived. Three techniques will be assessed: combustion, gasification, and digestion. In addition, a determination of feasibility associated with an average North Carolina poultry operation will be assessed for long term feasibility and applicability.

BIOGRAPHY

I was born and raised in Southern Wake County, with ties to the farming Community of Clinton, North Carolina. Over the years I have gained an ever increasing respect for our North Carolina farming community. The outdoors of our State has become my passion and as such, I was led to North Carolina State University for my undergraduate degree from the College of Natural Resources, in Environmental Technology. Following completion, I began work as an Environmental Scientist for a Raleigh based engineering firm. As life changes, so did my career path and I have since left the engineering field and now manage the central and northeastern North Carolina territory for an industrial tools distribution company. My passion for North Carolina farmers is still ever present and as such I felt farthing my knowledge associated with the interconnectedness of humans, chemicals, and the environment would be a great benefit, especially if I could cater towards how such events influence the eastern NC farming community.

ACKNOWLEDGMENTS

I would like to thank my wife, Casey, for supporting me through this three year graduate school process. She did an incredible job of holding down the fort through my job change, house moves, and yes….our new Baby Girl!

A special thanks to my parents for "pushing" me in the right direction. Thank you Mom and Dad.

A big thanks to Crane Creek farms and allowing me to utilize your farm as the test facility for some of these applications and theories. I will continue to purchase your chickens!

Lastly, thank you Ms. Linda Taylor! You have been extremely wonderful to work with, bounce ideas off of, and accommodating to my schedule. I appreciate all of your support, motivation, and knowledge.

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Introduction

There is an estimated 65,000 broiler (chicken) and turkey production houses located within the United States (6) accounting for over 9 billion chickens that are born, raised, and sold for food (3) each year within the United States. Of these 65,000 production houses, over 75% utilize propane as a major contributing fuel source (6). The growing of chickens and turkeys is very labor intensive and calls for a strict management, within this plan are a tolerant temperature range in which the production houses must maintain for the proper growing of birds and reduction in mortality. This maintaining of temperature, via heaters, fans, and air movers, creates a financial burden associated with paying the energy and power bill at the end of the month. In addition, energy is utilized to light the houses, automatically fill feed bins, and provided power to the necessary system controls. These energy needs add up and the average yearly expenditures for a four house operation can range from $10,000-$20,000 per year (6). So, how can this large expenditure be combated and/or reduced. One potential solution, involves the utilization of new technology that enables the burning, gasification, or digestion of biomass to provide energy. Excess biomass is readily available on a poultry operation; on average a four house poultry operation can produce 65 tons of litter per year (6). This poultry litter, is a viable and renewable energy (2) source. Jim Potter, president of Homeland Renewable Energy, stated "The combustion of poultry litter provides far superior value versus any other renewable energy technology" (9). In many cases, poultry litter is a by-product, potentially deemed a waste of the animal operation. With the rise and growing

need for finding alternative energy and reducing our overall energy footprint, poultry litter as a biofuel is an excellent solution.

North Carolina Ranks #3 nationally in total poultry production and is an excellent region in order to utilize such innovate systems. Poultry production in North Carolina is ranked as the #1 agricultural industry within our state, and has a yearly economic impact of 12.8 billion dollars and accounts for over 37% of all cash farm receipts throughout North Carolina. In other words, North Carolina has a lot of chickens and a lot chickens produces a lot of waste. So what do we do with this waste? Currently, most farmers land apply the litter waste as a form of fertilizer. However, if over applied the excess nutrients located in poultry waste can lead to some more serious North Carolina environmental issues, including eutrophication. So, how can North Carolina utilize its poultry waste in a sustainable manner? As the growing world population needs a more efficient means of producing poultry on a larger and more sustainable scale, could North Carolina poultry producers become the ground floor for a more self-sustaining production? Could local North Carolina farmers utilize excess waste from the poultry farm as a biomass fuel to produce energy for the houses in which the poultry is produced?

Due to the large volume of poultry production and waste located within North Carolina, large scale power generation through the combustion of poultry litter has been recognized and pursued by commercial companies. Fibrowatt, LLC has pursued North Carolina for the establishment of three poultry fired plants in Surry, Montgomery, and Sampson Counties (7). Large scale production of energy via the combustion of poultry litter is not uncommon for Fibrowatt, LLC. In 2007, Fibrowatt built its first facility in the United States with a 55-

megawatt poultry fired plant in Minnesota that will utilize and combust nearly 600,000 tons per year of poultry litter and agricultural biomass (7). However, this study aims to review existing energy production systems via the utilization of poultry litter and determine if the use of poultry litter as a biofuel from a North Carolina family owned poultry operation is a feasible means to reduce operation costs associated with high energy consumptions of such operations. Fuel necessary to heat the poultry houses is the single greatest operating expense for poultry producers in the United States (6).

What is Poultry Litter?

Poultry litter consists of various materials including: wood shavings, saw dust, peanut or rice hulls, grass, and chopped corn cobs (13). In addition, poultry litter contains 13 plant nutrients including: nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, manganese, copper, zinc, chlorine, boron, iron, and molybdenum (4). Thus, poultry litter makes an excellent fertilizer when properly land applied.

The amount of litter within a poultry house is dependent upon the moisture content and litter depth at the time the house is cleaned (4), in addition, the number of flocks in which were grown on that litter layer prior to house cleanout and removal is a necessary component to determine the litter layer depth.

The calorific value is a way in which to measure the quantity of heat that can be produced from a single unit of material. According to Webster's dictionary the calorific value is "the quantity of heat produced by the complete combustion of a given mass of a fuel, usually expressed in joules per kilogram". The calorific value of coal is 15,000-27,000 KJ/kg which

is equal to 8,000 to 14,000 Btu/lb. The heating value of poultry litter averages around 4,100 Btu/lb (2), thus half as effective as coal, but higher than others, such as when compared to natural gas (950 – 1,150 Btu/lb) (14).

Litter can be considered moist to quite dry, but averages approximately 25% moisture content (2). Poultry litter as a potential thermal energy source is possible, and when combusted can result in a adiabatic flame temperature of approximately 2000 degrees Fahrenheit (2).

Section 1 - **Review of Poultry Litter to Energy Systems**

1.1 – **Gasification**

Gasification is considered the cleanest and most efficient form of energy production (11) and is a two stage process. First, a minimal amount of propane is used to heat the primary and secondary chambers (1), this is necessary to allow the chambers to reach proper operating temperatures. The poultry litter is then loaded into feed hoppers which move the litter into the gasification system. These hoppers are feed and load the system when necessary (dependent upon operating needs). Since the primary chamber has already been heated, the poultry litter begins to cook as it is added into the system (1). This cooking creates off-gases, which is forced through a chimney into a secondary chamber, where ignition occurs in a high heat environment (1). The heat passes around a heat exchanger which heats water up to 220 degrees Fahrenheit (1). This heated water boils a refrigerant, driving a turbine, and creating power (1). Gasification is a very efficient form of poultry litter to energy solution and when

compared to other methods, such as combustion, Gasification has twice the energy production (12).

The installation of a gasification system can provide a number of benefits according to Marc Marsh, a South Carolina Poultry Farmer, who has installed a 30 kilowatt system. These benefits include: on-farm disposal of litter, production of energy, potential sale of power, and a by-product called "bio-char" which is an excellent fertilizer, especially in the turf grass industry (1). These type gasification systems can theoretically provide and sustain energy all year long (1). According to Mike Williams, NCSU Collage of Agriculture and Life Sciences Professor, the gasification process is more efficient and has a higher energy ratio than other potential systems.

However, with all systems, they are some hurdles that must be addressed. According to Marsh, poultry litter is not a consistent fuel source and can entail moisture problems (1). Another issue is the storage of litter, approximately 10,000 square feet of dry storage space was necessary in order to store the litter necessary to handle Marsh's gasification system (1). In addition, these systems can be labor intensive. The litter hoppers that feed the system have to be loaded by farm operators when necessary. Marsh's system has to be loaded by a farm employee twice a day (1). Lastly, gasification units may not be economically feasible. Preston Burnette, United States Farm Pilot Project Engineer, is still not sure if these type systems will work out as being economical and stated "the system components themselves are a bit expensive because so few are commercially available" (1).

1.1A - **Gasification – Currently Utilized Systems:**

In 2012 the United States Farm Pilot Project partnered with Marc Marsh, a South Carolina poultry farmer, and installed a nearly one million dollar gasification system that will harness approximately 30 kilowatts of power (1). Marsh's farm generates 1,200 tons of litter annually (1). All manure is stored onsite and moved to the 'gasifier' when fuel is needed. The aforementioned project has proven that the gasification of poultry litter to produce fuel is possible (1). Marsh's system burns approximately 200 lbs of litter per hour, allowing for a consistent 20-30 kilowatts of power (1) to be produced. The Marsh farm project demonstrated that a gasification system could not only be utilized to create energy but also heat (1).

1.2 – **Combustion**

Direct combustion, in its simplest form, is one of the oldest ways in which to produce energy from biomass (12). The combustion process is much simpler than gasification and has been utilized to burn municipal wastewater sludge for over a century (2). Litter is placed inside a furnace, where it is heated, mixed and "plowed" (2), until complete combustion has been achieved. This heat is collected in waste-heat-boilers (WHB) which generate steam. This process steam is then used for electric generation (2) as it drives a turbine.

One of the newest and most innovative combustion systems is a Multiple Hearth Furnace. The Multiple hearth Furnace stacks several hearth furnaces vertically, with alternating holes to allow for air (oxygen) to enter the system and complete the combustion process of the

litter. A rotating shaft with blades, “plow”, pushes, the litter into each hearth, enabling the complete combustion of product (2).

The resulting ash, following MHF combustion of poultry litter, is an excellent and ‘concentrated’ fertilizer (2). This ash is high in phosphorous, potassium, and calcium and is much more concentrated than bulk litter (2), thus, allowing for easier transport (2) and application. When a MHF system is utilized properly, all exhaust gas emissions meet EPA requirements (2) and if poultry litter replaced natural gas, fuel oil, and coal to generate steam and electricity, then a cleaner environment (2) could potentially be argued.

Litter burns easily, however, due to the high volume of potassium phosphorous, magnesium, calcium, manganese, and additional materials problems arise with both the exhaust by-product and left over ash (2) associated with these systems. Over time these materials build up on the heat exchanger, reducing effectiveness and increasing labor inputs associated with the cleaning of the exchangers (2). At best direct combustion of litter is only 20% efficient (12), so any reduction in efficiency is not warranted. However, if the litter is burned hot enough to allow for a complete combustion, such as utilizing a Multiple Hearth Furnace (MHF) the aforementioned problems may not be as significant and/or present (2). In addition, when burning chicken litter, odor is always going to be a potential factor. However, if kept in storage, odors should not be a contributing factor.

1.2A - **Combustion – Currently Utilized Systems:**

This technology is not uncommon and has been utilized on some larger poultry operations in Europe. A 36.5 kW (270 million kilowatt hours of electricity per year) facility is located

within The Netherlands and is anticipated to convert one third of the nations poultry waste into power (10). In order to achieve the necessary energy output the facility will combust 440,000 tons of poultry waste per year; producing enough energy to power approximately 90,000 houses (10).

Two of the largest family owned, poultry producers in England, have employed combustion systems in order to reduce waste and promote a sustainable energy (8) source. Currently, England does not allow the combustion of poultry litter, due to the classification of litter as waste, so the family owned systems currently operate on the combustion of wood chips. However, both farms implementing this equipment are optimistic that the emissions laws will change (8) and as a result have invested 1.8 million in order to implement the necessary poultry litter combustion systems (8). Wood chips burners, which will also double as a poultry litter furnace, consists of two 500KW burners which are feed at a rate of 5 tons to 10 tons of chips per day (8). It is estimated that these systems will allow a 50% cost savings and return when compared to gas cost on heating the 12 broiler sites (up to 840,000 birds). As a result, a seven year ROI (return on investment) (8) has been established for these systems.

Locally, a Virginia farmer is heating its poultry house through the combustion of litter gathered onsite and the Farm Pilot Project coordination, Inc. also located in Virginia, is utilizing 2,200 tons of poultry litter per year to produce both heat and power (9).

A MHF system is currently being utilized for the power generation via the combustion of municipal sewage sludge, but offers insight should these systems be implemented within a poultry operation. In 2006, a MHF system was installed at a wastewater treatment plant, and burns approximately 14 tons of dried sewage sludge per day (2) proving the validity and

application of the MHF within the poultry biofuel to energy arena. It is estimated that an average pound of poultry litter could produce 3,,800 to 5,000 of Btu (6) when combusted within a MHF. If you anticipate the aforementioned combustion system to be 70% efficient (6) and utilize the average 65 tons of litter produced per year by a four house operation, the surplus yearly litter could provide 86% of the overall energy needs (6).

1.3 – **Digestion**

Within a digestion system, Chicken litter and manure, is fed into a digester, which is similar to a silo (3) or large vat. The manure is then heated and mixed with bacteria. The by-product is methane gas, which is captured (3). Once captured methane burned (11) which produces the necessary energy. Not only do these systems produce energy, but they also capture the excess methane, thus, reducing emissions and assisting with such global environmental challenges such as global warming (11).

The Environmental Protection Agency promotes the use of manure digester and has been since 1993 (3). According to Chris Voell, EPA Program Manager, the number of digesters around the country could be in the thousands if some changes were made to current energy policy rules and all the 'red tape' (3) that must be managed. Energy cost savings is the biggest advantage in the utilization of a manure digester. According to John Logan, owner of Eagle Green Digesters and poultry farmer, his power bills were approximately $8,000 a month before implementation, after the addition of a digester they aforementioned power bills were reduced to approximately $200.00. In addition, Logan stated that some months he

can sell his power back to the grid and receives a check back from the power company (3) for his energy production. Based on the aforementioned numbers, provided by Logan associated with his farm, the Eagle Green digester will pay for itself within 5 years and will save on average $96,000 each additional year of operation.

Many people are discouraged to pursue any such type of operation as the legal 'red tape' is complicated and consists of a patchwork of local, state, and federal energy policy rules (3). In addition, the intimal start-up of such systems are costly. The Eagle Green Company sells digesters starting at $500,000 each (3), however, many operations would require at minimum two digesters resulting in a start-up cost over one million dollars.

1.3A - **Digestion – Currently Utilized Systems:**

The first successful and patented chicken litter/poop digester was installed in Prentiss, Mississippi (3). John Logan, receives 275,000 chickens at one week of age which he raises for an additional 38 days before his houses are turned and the chickens are sold to market (3). His digestion system has reduced his monthly energy expenditures from $8,000 a month to below $200 a month. In addition, some months his farm operation receives a check from the power company for energy that has been sold back into the grid. Currently, there are approximately 130 digesters in use around the country (3), however, according to the EPA the number of digesters around the country could be in the thousands if permitting and 'red tape' constraints could be resolved.

Section 2 - **North Carolina – Farm Operation Feasibility Study**

2.1 - **Project Test Farm**

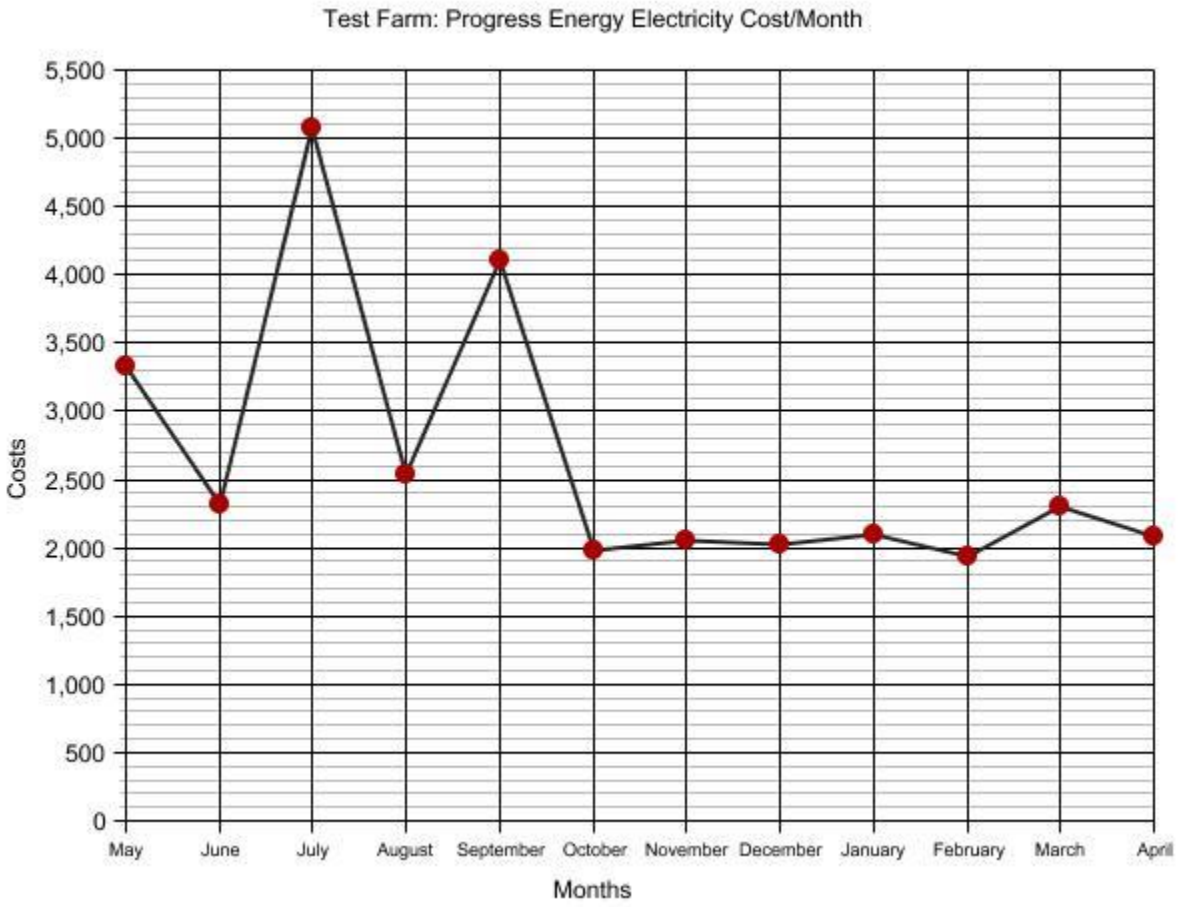
The test farm for this study consists of a family owned and operated poultry operation in the heart of North Carolina poultry country, Sampson County. This farm consists of six chicken houses, with each house containing approximately 30,900 birds or 185,400 birds per turn. All chickens are received when they are one day old and are grown out to approximately 6 lbs. and sold to market 49 days later. There are approximately 5 turns per year, resulting in 927,000 chickens in and out of the farm each year. Once chickens have been turned, an approximately 2 week "gap" is observed between flocks to ensure the houses are working properly, complete any necessary repairs, and provide adequate time for house clean out.

Currently, there are two forms of energy utilized to power the aforementioned poultry operation. The test farm utilizes both Progress Energy for electricity and Parker Gas as a propane source. Propane is necessary for winter heat. Electricity is utilized year round to power the house fans, lights, and water pumps. Each house contains 14 fans to assist with air flow and cooling. During the summer all 14 fans are in operation per house, however, during the winter months fan usage drops to only 4 fans per house, in order to assist with air circulation. Propane is utilized to supply heat to the houses during these winter months of November, December, January, February, and March.

Total Energy Costs for 2012:

Progress Energy	- $29,398.61
Parker Gas	- $25,123.32
Total Energy Expenditures:	- $54,521.93

Monthly Energy Usages:



The above referenced information denotes the yearly expenditure broken down per month for operation related energy costs. During the winter months (Oct. through February) heat is subsidized via propane, thus a decrease in electricity costs, however, an increase in propane

costs is observed. In addition, peaks and valleys are observed within the heat of summer months. This is in relation to the chicken time in which chickens are turned. Once a flock has been turned the house is empty for approximately 2 weeks for house cleanout. In addition, once hatchlings are placed back into the houses, due to chicken size upon receipt, they are only opened to half of each house. Thus, electricity usage is ramped up throughout the growth period of chickens. As they grow, they require more space, thus more electricity is needed to maintain adequate living conditions within a larger environment. Energy usage peaks were observed in July ($5,079.00 dollars), September ($4,109.00 dollars), and May ($3,325.00 dollars).

Litter Availability:

1.25 tons of litter per 1,000 birds sold

30,900 chickens per house x 6 chicken houses = 185,400 chickens

185,400 chickens x 5 turns per year x 1.25 tons/1,000 birds = 1,158.75 tons/farm/year

Bird Type	Litter Production per 1,000 Birds Sold (tons/1,000 Birds)	Litter Production per Animal Unit Sold (tons/AU sold)
Broiler • Whole litter	1.25	0.56

(5)(NRAES, 1999)

2.2 - **Energy Usage and Potential Solutions:**

The aforementioned test farm utilized 337,520 kilowatt hours of electricity (kWh) for the year of 2012. One potential solution in reduction of energy cost would be through the utilization of a gasification system. Our test farm is very similar to that of Marsh's in South Carolina, however our test farm produces approximately 42 tons less of excess litter per year. Similar to Marsh's the test farm system would cost approximately 1 million dollars and could potentially harness 30 kilowatts of power, or 262,950 kwh per year. This would not completely satisfy the energy consumption needs of the farm, but could reduce operating energy cost by 75%. In theory, our yearly energy consumption would be one-third, thus reducing the $54,521.93 of yearly energy expenditures to $17,991.93. A yearly savings of $36,530, however this only allows for a 27 year return on investment (ROI). Even though this solution is feasible the longevity in recovery of initial up front expenses does not make this solution desirable.

If combustion was to be used, there are multiple potential solutions. A system similar to that described within the Netherlands, needs at least 12,054 tons of litter per kW. Our test farm only accumulates 1,158 tons per year, thus this system is not desired. When compared to the European family owned combustion systems, these may be more viable for our test farm. These combustion systems require at least 1,825 tons of litter per year, but can potentially reduce energy cost by 50%, saving the test farm approximately $27,260 dollars per year. However, these systems can cost in excess of 1 million dollars and the aforementioned European combustion system cost 1.8 million dollars, resulting in a 66 year return on

investment, thus making it not a feasible solution. Therefore, an MHF combustion system would be the only viable small scale combustion option. These systems can be up to 70% efficient (6), however, no initial investment costs have been determined, thus more research within this equipment needs to be administered.

Lastly, a digestion system could be utilized to reduce and or eliminate energy operating cost. Per initial investigation, these systems appear to be the most promising for small scale energy production. The Eagle Green Company sells digesters starting at $500,000 each (3), however, many operations would require at minimum two digesters resulting in a start-up cost over one million dollars. However, according to Jeff Breeden, Eagle Green Engineer, 1 lb. of chicken litter can produce 8 cubic feet of methane gas. The Eagle Green Systems then turn the methane gas into energy and are 80% effective. Therefore, if we assume the aforementioned digester to be 80% effective, the yearly operating energy costs would be reduced to $10,915. This would allow for a 23 year ROI, however, there is the potential for the Eagle Green digestion system to completely eliminate energy cost, such as the example provided by owner and operator, John Logan. If all energy operating costs could be eliminate then the Eagle Green digestion systems, resulting in an 18 year ROI.

Conclusion:

All systems described have many properties and attributes that are advantages for a small scale poultry litter to energy production system. All appear to be viable and feasible to produce an adequate amount of energy necessary to substantially reduce and/or eliminate

energy operating costs on the test farm. However, due to very large up-front costs for the purchase and installation of such systems the return on investment ranges from 18 to 66 years. Especially, when looking at combustion systems, which were the least efficient and had the longest ROI of 66 years. One major drawback associated with any feasible system is upfront costs. Some poultry producers may feel a 3-5 year return on investment (ROI) is worth the investment, whereas, others are skeptical due to the large sum of initial money and investment of time into the necessary systems. However, according to this review there is not currently an energy producing system that could provide enough adequate energy to support the test farm that would entail a 3 to 5 year ROI. In addition, Mike Williams, North Carolina State Poultry Science Professor, stated that the operational feasibility of a small scale system would be complicated and currently the capital cost out weight any long turn benefits, which was confirmed by this research.

Additional research needs to be conducted within this field in order to lower capital costs associated with these systems. Currently, the limiting factor for implementation of systems is the necessary capital expenses, which can be in excess of 1 million dollars. As technology continues to expand, so should research into cost reductions associated with sustainable poultry litter to energy systems. In addition, I feel more information needs to be obtained within the validated of poultry litter/manure digestions systems. This equipment appears to currently be the most cost effective when compared to savings and according to the EPA could be utilized nationwide.

Poultry production is a growing industry that needs to utilize innovate technology. As technology grows so will the ability to power poultry houses with excess chicken litter.

According to Jim Potter, president of Homeland Renewable Energy, Inc. parent company of Fibrowatt stated "The development of Poultry litter-based renewables is an opportunity for the world" (9). With a growing need for a more sustainable future the need to continue looking is evident and should start with….. poultry power.

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