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Turning Chesapeake Bay Watershed Poultry Manure and Litter into Energy:

An Analysis of the Impediments and the Feasibility of Implementing Energy Technologies in the Chesapeake Bay Watershed in Order to Improve Water Quality




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Cover photos (from left to right)
- Chickens: University of Warwick http://www2.warwick.ac.uk/fac/sci/bio/research/ee/ee/research/modelling/avian_flu/
- Gasification system in Coeur d'Alene, Idaho: Farm Pilot Project Coordination Inc. http://www.fppcinc.org/poultry.htm
- Model of a typical biomass gasification plant: USC Times, February 2005 article by Chris Horn http://www.sc.edu/usctimes/articles/2005-02/biomass_gasification.html
- Power lines: Article on electricity distribution, photograph provided by Matteo Mode http://gis.vsb.cz/webcastle/scripts/picturebook.php?KB_Code=win1250&PF=PB&ID_System=&Vmod=Single&ID=7&Pressed=_view_one_

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Executive Summary

Introduction

In its 2005 Manure Strategy, the Chesapeake Bay Program recognized the significance of controlling nutrient loads from manure in order to restore the Chesapeake Bay. An important component of an overall nutrient management strategy for agricultural lands, therefore, involves finding alternative uses for excess manure. This is particularly important because as animal operations become more concentrated and the acreage of cropland available for manure application is lost to development, the challenge of manure management is only expected to intensify. Additionally, regulations that limit land application and require phosphorus-based nutrient management plans will likely result in an increase in the amount of excess manure that is available.

One potential use for the region's excess manure is energy generation. Using excess manure to feed energy generation systems could potentially result in a reduced nutrient load to the Bay, thus improving water quality. This report explores this option by analyzing the feasibility of using poultry litter for energy in the Chesapeake Bay watershed. Poultry litter, rather than manure from other livestock types, was chosen for this report because the Chesapeake Bay watershed is known to be a major national producer of poultry and poultry litter is often concentrated in particular regions and is easier to transport. In order to better assess the feasibility of this option, this report looks at technologies that could potentially be used to convert poultry litter into energy and identifies impediments and incentives that a litter-to-energy project may encounter in this region.

This report provides the following:

- **Technology Analysis** that summarizes:
  - Poultry litter-to-energy technologies, including their effectiveness, their challenges, and their applicability in the Chesapeake Bay watershed.
  - List of ongoing poultry litter-to-energy projects in the United States and United Kingdom, including information on scale, litter requirements, energy outputs, operation and maintenance requirements, emissions, ash byproducts, and cost.
- **Policy Analysis** that summarizes federal policies, state policies, and air quality regulations that relate to poultry litter-to-energy projects.
- **Economic Analysis** of incentives and impediments to implementing poultry litter-to-energy projects in the Chesapeake Bay watershed, including discussions on tax credits, funding sources, and profit options.
- **Findings and Recommendations** that look at whether litter-to-energy systems should be promoted in the Chesapeake Bay watershed, including information on commercial-scale vs. farm-scale systems and a list of issues that still need to be better addressed.

Findings

- The current political climate supports the use of renewable and alternative energy sources to some extent. Federal and state governments are showing increased interest in alternative energy and have implemented a number of programs that encourage the development and use of alternative energy technologies, although often not specifically manure-to-energy technologies.

- The thermal processing of poultry waste is generally feasible from a technological standpoint. Instead, barriers often tend to be economical, political, or based on litter availability. For example, it may be difficult to acquire air quality permits for litter-to-energy systems in some regions due to already poor air quality.
- Financial assistance is needed to make litter-to-energy systems economically feasible. There are a number of financial assistance options already in existence that may be able to provide support for these systems, although high cost will likely be an impediment for the foreseeable future.
- There are a number of ways that a farm-scale litter-to-energy system could potentially earn a profit or lead to savings in operation costs. These options include net metering, green pricing programs, renewable energy certificates, trading programs, ash sales, and heat generation. Not all of these options are currently available in the Chesapeake Bay watershed, although they could one day be offered in this region.
- Deciding which type of system, either farm-scale or commercial-scale, is the most viable in the Chesapeake Bay watershed and best meets the needs of the region is not necessarily a clear-cut decision due to a number of factors. There are pros and cons to each system type (see the following text boxes).

Small Farm-Scale

Pros

- Avoids high transportation costs
- Avoids road damage and air emissions caused by litter transporting vehicles
- Does not require a large, constant litter supply
- Provides energy benefits to the farmer and helps promote farm viability through energy cost savings (propane, electricity)
- Provides income generation for the farmer through value-added by-products (ash, electricity, renewable energy credits, nutrient trading, carbon trading)
- Provides an efficient alternative for on-site disposal of poultry carcasses
- Biosecurity of facilities maintained due to on-site litter processing
- Potentially improves bird health and bird quality by reducing the levels of introduced water vapor and ammonia emissions within the poultry houses (compared to heating with propane)

Cons

- Limited number of experimental-level farm-scale litter-fueled systems in existence
- On-farm storage of litter needed for extended periods of time
- Higher system capital cost per unit of energy produced
- Higher operational and maintenance costs (financial and labor) for the farmer

Large Commercial-Scale

Pros

- Several large commercial-scale litter-fueled energy plants are already successfully operating
- On-farm storage of litter is reduced or eliminated
- Lower system capital cost per unit of energy produced
- Lower operational and maintenance system costs (financial and labor) for the farmer compared to farm-scale systems located on-site
- Energy and employment benefits provided to the community

Cons

- Requires a large, consistent litter supply
- High transportation costs
- Litter transporting vehicles may negatively impact roads and air quality
- Biosecurity measures must be taken into account due to off-site litter transportation
- Higher system capital costs which typically require government subsidies for sustainable economics
- Does not provide direct energy benefits to the farmer and continues reliance on purchased energy sources (propane, electricity) for farm operations
- Does not replace the use of propane heat in the poultry houses, thus it does not provide the benefit to bird health that may result from using the litter-generated heat rather than propane heat
- Does not necessarily provide the farmer with income generation through value-added by-products (ash, electricity, renewable energy credits, nutrient trading, carbon trading); the appropriate programs would need to be in place in order for the farmer to benefit from these options
- Does not provide the farmer with an alternative for on-site disposal of poultry carcasses, which can be a benefit of small farm-scale systems

Conclusions

Both farm-scale and commercial-scale litter-to-energy systems may be a potential way to use the excess litter found in the Chesapeake Bay watershed. The findings of this report suggest that litter-to-energy systems are, for the most part, technologically feasible; however, there are other challenges that must be overcome to make these systems a viable option in the Chesapeake Bay watershed, including high system cost and the issue of litter availability. In addition, there are still a number of variables that need to be better understood in order to determine whether litter-to-energy systems are truly feasible in the Chesapeake Bay watershed and whether or not they should be promoted by organizations such as the Chesapeake Bay Program. Following is a list of questions and issues that still need to be better addressed.

If current and future research studies and demonstration projects explore these issues and their findings indicate that projects like this should be pursued in the Chesapeake Bay watershed, then steps that could be taken to increase the feasibility and promote the adoption of litter-to-energy systems in this region include:

- Educating farmers on the feasibility and benefits of litter-to-energy projects
- Increasing the number of renewable energy programs that litter-to-energy projects qualify for (both for financial assistance and profit options)
- Working with EPA and USDA to incorporate litter-to-energy technologies into their grant program priorities

- Talking with states to assess how their existing programs could be used to promote litter-to-energy systems

Recommendations for Further Research

Environmental Impacts

- What level of nutrient load reduction can be achieved through the use of a litter-to-energy system? A more in-depth analysis is needed to quantify the reduction resulting from the use of litter-to-energy systems versus the status quo (e.g. land application).
- What sort of air emissions do these systems release (type and amount)? Although there is already some information on this, additional information would be useful.
- What impact do the air emissions from these systems have on water quality?
- Are there potential toxic air pollution concerns that need to be better addressed (such as those resulting from the release of airborne arsenic)?
- Are state and federal air permitting programs set up to allow for these types of operations?

Poultry Litter Supply

- How much excess litter is available in different regions of the Chesapeake Bay watershed? What other factors affect litter supply (e.g. price of energy and other market forces)? Is there enough excess litter to support a large commercial-scale litter-to-energy plant?

Co-Firing / Blending Potential

- What is the combustion performance of poultry litter when co-firing with conventional fuels (e.g. coal or natural gas) and unconventional fuels (e.g. waste coal)?
- If there is an insufficient amount of litter for an energy generation system, could the litter be blended with other biomass feedstock, agricultural waste, or sewage sludge?
- What are the optimal blending ratios, the required combustion/gasification conditions, and the necessary pollutant emission controls when co-firing or blending the litter?
- Do the ammonia and urea-based compounds found in poultry litter have a NO_x reducing effect? Several studies have indicated that they may. This issue should be further investigated.

Cost

- How much does an on-farm litter-to-energy system cost? On-farm systems are still relatively new and many of the current systems have been constructed as part of demonstration or research projects, making it difficult to determine the cost of future systems.
- How much money would a farmer need to put up to get a system installed and operating on his farm?
- What is the potential payback timeframe for a litter-to-energy system? Several ongoing studies are expected to quantify this. Understanding this component is critical in determining the marketability of these systems.

Ash / Bio-Char

- Is there a viable market for the ash and bio-char byproducts? A number of projects have already shown that these byproducts can be used as fertilizer.

- What price could these byproducts be sold for?
- Are there other potential uses for these byproducts (e.g. construction, activated carbon production)?
- How do the ash characteristics vary under different combustion/gasification conditions?

Farmer Willingness

- Are farmers in the Chesapeake Bay watershed willing to participate in litter-to-energy projects? If it is determined that litter-to-energy systems are viable and should be promoted in the watershed, then education and outreach efforts will be needed to encourage farmer adoption of these systems.
- How much time must a farmer devote to operating and maintaining an on-farm litter-to-energy system?

I. Introduction

In its 2005 Manure Strategy, the Chesapeake Bay Program recognized the significance of controlling nutrient loads from manure in order to restore the Chesapeake Bay.[1] An important component of an overall nutrient management strategy for agricultural lands, therefore, involves finding alternative uses for excess manure. This is particularly important because as animal operations become more concentrated and the acreage of cropland available for manure application is lost to development, the challenge of manure management is only expected to intensify. Additionally, regulations that limit land application and require phosphorus-based nutrient management plans will likely result in an increase in the amount of excess manure that is available.

In order to help address this issue, the Chesapeake Executive Council signed Directive No. 04-3: *Building New Partnerships and New Markets for Agricultural Animal Manure and Poultry Litter in the Chesapeake Bay Watershed*. This directive was based on recommendations that were developed at the Chesapeake Bay Program's 2004 Agricultural Summit by a wide range of stakeholders. In this directive, the Chesapeake Executive Council committed to six objectives that were intended to help develop sustainable solutions for reducing nutrient pollution from animal manure and poultry litter in the Bay watershed, including demonstrating the feasibility of using manure as an energy source.[2] In order to determine how to follow through with these objectives, the Chesapeake Bay Program developed their Manure Strategy. This strategy was formally called the *Strategy for Managing Surplus Nutrients from Agricultural Animal Manure and Poultry Litter in the Chesapeake Bay Watershed* and it was endorsed by the Chesapeake Executive Council, the headwater states, and the U.S. Department of Agriculture in November 2005.[3]

One of the goals of the Manure Strategy was "to identify and promote a range of economically viable and environmentally sustainable alternatives to applying raw manure and litter nutrients to agricultural lands". According to the Strategy, this goal will be achieved by focusing on developing technologies and building markets for litter and manure products for use as compost, soil amendments, fertilizers, and energy throughout the Chesapeake Bay watershed, particularly in those regions with significant manure and litter nutrient surpluses. The Strategy called for the creation of a Regional Manure and Litter Use Technology Task Force. The purpose of this group was to identify and promote promising technologies for producing manure and litter products. This task force met for the first time in March 2006 and identified a list of promising technologies to explore. During this meeting, the Chesapeake Bay Program was tasked with further researching these potential technologies. This report is an outcome of that charge.

The purpose of this report is to analyze the feasibility of using poultry litter for energy in the Chesapeake Bay watershed. Using excess manure to feed energy generation systems in this region could potentially result in a reduced nutrient load to the Bay, thus improving water quality. Poultry litter, rather than manure from other livestock types, was chosen for this report because the Chesapeake Bay watershed is known to be a major national producer of poultry and poultry litter is often concentrated in particular regions and is easier to transport. In order to better assess the feasibility of this option, this report explores technologies that could potentially be used to convert poultry litter into energy and identifies impediments and incentives that a litter-to-energy project may encounter in this region.

II. Litter Availability

A region or a farm operation has excess poultry litter if more nutrients are available from the litter than can be used for local land application. A number of factors affect whether or not a farm has excess manure, including concentration of the livestock, nutrient levels in the soil, crop rotation and crop choice, acreage of crop and pasture land, and nutrient content of the manure.

If excess litter is present, then the excess will either need to be transported to an area in need of nutrients or an alternative use will need to be found for it. According to the Chesapeake Bay Program's Manure Strategy, "after feed management, the best long-term sustainable solution to dealing with manure and poultry litter nutrient surpluses is to develop alternative uses for litter and manure nutrients".[4] Energy generation is one potential use for excess poultry litter. Other potential uses include compost, soil amendments, and fertilizers. When discussing the feasibility of a litter-to-energy project, an important question that needs to be addressed is whether or not there is enough excess poultry litter available in a particular area to make the construction and operation of such a project feasible.

The amount of litter required by a litter-to-energy system varies depending on the technology being used and the amount of energy being generated. For example, a 60 kW (0.06 MW) farm-scale gasifier system in the Netherlands that was developed by Biomass Technology Group in cooperation with poultry farmer Duis v.o.f. requires 900 tons of poultry litter per year,[5] whereas the 55 MW Fibrominn plant that was recently constructed in Benson, Minnesota requires 700,000 tons of poultry litter and other agricultural biomass per year.[6] To put this into perspective, 720 thousand birds per year generate approximately 900 tons of litter annually and 560 million birds per year generate approximately 700,000 tons of litter annually.[7]

Since manure can be applied to cropland as an alternative to commercial fertilizer, the price of fertilizer tends to impact the demand for and thus the availability of excess manure and litter. If fertilizer prices are high, then litter will be more in demand and the available supply will likely be limited. The amount of poultry manure and litter available for use is also dependent on the frequency of poultry house clean-outs. Many poultry growers line the floor of their houses with bedding material that consists primarily of wood shavings and sawdust. When a house undergoes a total clean-out, all of this bedding material is removed along with the accumulated manure. Today, bedding material is relatively expensive, thus many poultry growers use the same material for several flocks. Poultry houses on the Delmarva Peninsula typically undergo a complete cleanout every 2-

4 years,[8] although some poultry companies have gone to yearly cleanouts. [9] If a poultry house is not undergoing a complete cleanout after a flock, only the cake is removed. Cake is the term used to describe clumps of surface manure. Cake typically accumulates around water lines and feed stations where the birds spend a disproportionate amount of their time. Because of this, it is important to take cleanout frequency into consideration when calculating the amount of litter available for use.

Animal production operations are widespread throughout the Chesapeake Bay watershed; however, not all areas have high concentrations of livestock. The three regions that have the highest concentrations of livestock, including poultry, are the Lower Susquehanna River basin in Pennsylvania; the Shenandoah Valley in Virginia and West Virginia; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.[10] Although the New York portion of the watershed has a large number of dairy and beef operations, they have essentially no poultry operations. According to one analysis, the amount of excess manure produced in each of the concentrated regions listed above by all livestock types (not just poultry) ranges from approximately 250,000 to 600,000 tons.[11]

Regions with concentrated poultry production operations may be the most appropriate for large, off-site litter-to-energy facilities. These facilities would need to be supplied with a substantial amount of litter. Due to the cost and logistics of litter transport, obtaining litter from nearby poultry operations would be more feasible than obtaining litter from more distant, less concentrated poultry operations. Maryland's Manure Transportation Project estimates that it costs 15 cents per ton-mile to transport manure,[12] while American Heat and Power LLC estimates that it is even more expensive, with a cost of approximately 35 cents per ton-mile. Using American Heat and Power's estimate, hauling a 20 ton load 25 miles (which is equivalent to 500 ton-miles) would cost approximately $175 or $8.75 per ton. In addition, American Heat and Power suggests that $5 per ton should be added to cover clean-out costs, thus making the total cost in this example roughly $13.75 per ton.[13] Smaller, on-site litter-to-energy systems may be suitable for a wider range of locations than larger off-site facilities since these systems could potentially be constructed on farms both inside and outside of concentrated poultry regions. In addition, an on-site facility would not need to deal with the biosecurity issues that an off-site project would encounter since the litter is not being transported off of the farm.

There are several manure transport programs and manure matching programs in the Chesapeake Bay watershed that may be able to assist litter-to-energy facilities in acquiring poultry litter. If a litter-to-energy facility is designed to accept litter from off-site farms, transportation cost is often an issue. Manure transport programs are in place in some areas that can lessen the cost of transport by providing financial assistance for the transportation of manure from the farm to the facility. For example, Maryland's manure transport program, which is administered by the Maryland Agricultural Water Quality Cost-Share Program, and Delaware's nutrient management relocation program, which is administered by the Delaware Nutrient Management Program, both provide animal producers with cost-share assistance of up to $20 or $18 per ton, respectively, to transport their excess manure to other farms or alternative use facilities.[14,15] Pennsylvania also has a manure transportation assistance program that provides funding to farmers or industries to help offset the transportation costs incurred from transporting manure to alternative use facilities, but not for transport from farm to farm. This program is relatively new and is expected to provide cost-share assistance equivalent to 5 cents per pound of nutrients (nitrogen and phosphorus).[16]

There are also several manure transport programs in the region that litter-to-energy facilities may not be able to benefit from at this time. West Virginia's program is administered by USDA's Natural Resources Conservation Service (NRCS), which considers litter transfer to be an eligible practice under their Agricultural Management Assistance (AMA) program. The purpose of this practice, however, is to transfer excess poultry litter from the Chesapeake Bay watershed portion of WV to eligible areas of WV outside of the Chesapeake Bay drainage area.[17] Therefore, since a litter-to-energy facility would most likely be located close to the farms in the Chesapeake Bay watershed portion of WV, and not outside of the drainage area, poultry producers may not be eligible to receive cost-share assistance for transferring their litter to these facilities at this time, although this could change in the future.

A similar circumstance arises with Virginia's poultry litter transport incentive program, which is administered by Virginia's Department of Conservation and Recreation and the Virginia Poultry Federation. This program offers $5-$12 per ton of litter transported, but in order to be eligible for this payment, the litter must be transported to an area far from where it is generated, which will most likely not be practical for many litter-to-energy projects. In order to receive payment, this program requires that the poultry litter must be transported from farms in Page and Rockingham counties to a final destination that is not within Accomack, Augusta, Northampton, Page, Rockingham, or Shenandoah County.[18]

Manure Transport Programs

Maryland	MD Department of Agriculture Website: http://www.mda.state.md.us/resource_conservation/financial_assistance/manure_management/index.php Phone: Contact the local soil conservation district or call MDA's toll free hotline at 1-877-7MANURE
Delaware	DE Nutrient Management Program Website: http://dda.delaware.gov/nutrients/nm_reloc.shtml Phone: (302) 698-4500
Pennsylvania	PA State Conservation Commission Website: http://www.agriculture.state.pa.us/agriculture/cwp/view.asp?a=3&q=127144
West Virginia	USDA Natural Resources Conservation Service Website: http://www.wv.nrcs.usda.gov/programs/ama/07_AMA/ama.html Phone: Contact Herbert Andrick at (304)284-7560
Virginia	VA Department of Conservation and Recreation and the Virginia Poultry Federation Website: http://www.dcr.virginia.gov/soil_&_water/nmlitter.shtml

Manure matching programs are another type of program that litter-to-energy facilities may be able to benefit from. These programs link farmers who have excess animal manure with nearby farms or alternative use projects that can use the manure. This service is typically free and available to both sending and receiving operations. Maryland, Delaware, and Pennsylvania all have manure matching programs.[19, 20,21] A similar program, called the Virginia Poultry Litter Hotline, is also operated in Virginia by the Virginia Poultry Federation and the Shenandoah Resource Conservation and Development Council. This hotline was created to help connect poultry farmers with excess manure in the Shenandoah Valley to litter buyers and haulers throughout Virginia.[22] Manure matching programs such as these could be used to help those developing litter-to-energy products locate available litter sources.

Manure Matching Programs

Maryland	MD Department of Agriculture Website: http://www.mda.state.md.us/resource_conservation/financial_assistance/manure_management/index.php Phone: Contact Norman Astle at 410-841-5874
Delaware	DE Department of Agriculture Website: http://dda.delaware.gov/nutrients/DMmatch.shtml Phone: (302)698-4500
Pennsylvania	PA Small Business Development Centers and PA State Conservation Commission Website: http://www.manuretrader.org
Virginia	Shenandoah Resource Conservation and Development Council and the Virginia Poultry Federation Phone: Contact Becky Barlow at 1-800-418-0768

Other poultry litter uses that a litter-to-energy project may need to compete with for an adequate litter supply include land application, pelletization, and compost. These uses should be taken into account when determining whether or not there is enough poultry litter available to fuel a litter-to-energy system. If more poultry litter exists than can be applied to local cropland, then the litter can potentially be transported to a nearby area that is in need of nutrients. The feasibility of this will depend on the cost of transportation and the cost of commercial fertilizer.

In addition to land application, litter-to-energy projects may also need to compete with pelletization and compost operations for a consistent litter supply. The Delmarva Peninsula is home to a large-scale litter-pelletizing operation called Perdue AgriRecycle. Perdue AgriRecycle contracts for approximately 60,000 tons of poultry litter annually, which is equivalent to about one-eighth of the Peninsula's poultry litter.[23] In exchange for their excess litter, Perdue AgriRecycle provides participating growers with professional cleanouts and hauling.[24] Composting operations also typically use up a portion of a region's excess litter. On the Delmarva Peninsula, typically 10-15,000 tons of poultry litter, which is equivalent to 1-2 percent of the region's total poultry litter supply, is used for compost.[25] In addition, a significant portion of the poultry litter in Pennsylvania and its surrounding states is used to generate compost specifically for Pennsylvania's mushroom industry.[26] In order to gain a better understanding of the location and amount of excess litter in the watershed, it is recommended that these attributes be better assessed.

III. Technologies

Overview of Poultry Litter-to-Energy Technologies

In poultry production, the three wastes of primary concern are the bedding material used to line the floor of the poultry houses, the manure resulting from poultry production, and the dead birds. Throughout this report, the term "litter" is used to refer to a combination of poultry manure and bedding material (woodchips and sawdust). Litter composition is predominantly made up of water and carbon with smaller amounts of nitrogen and phosphorous and trace levels of chlorine, calcium, magnesium, sodium, manganese, iron, copper, zinc, and arsenic.[27]

Land application, which currently is the major disposal method for litter and manure, is under pressure due to its ability to pollute water resources through leaching and runoff.[28] Once manure application rates exceed a crop's ability to uptake the nitrogen and phosphorus found in the manure and surpass the land's ability to assimilate the remaining phosphorus, repeated applications can lead to a buildup of nutrients in the soil, thus increasing the potential for leaching and runoff to ground and surface water sources.[29] In order to help restore and protect water quality, cost-effective alternative technologies need to be employed to remove the excess litter from concentrated areas.[30] This section provides an overview of possible poultry litter-to-energy technologies, which are a potential alternative use for the Chesapeake Bay watershed's excess litter.

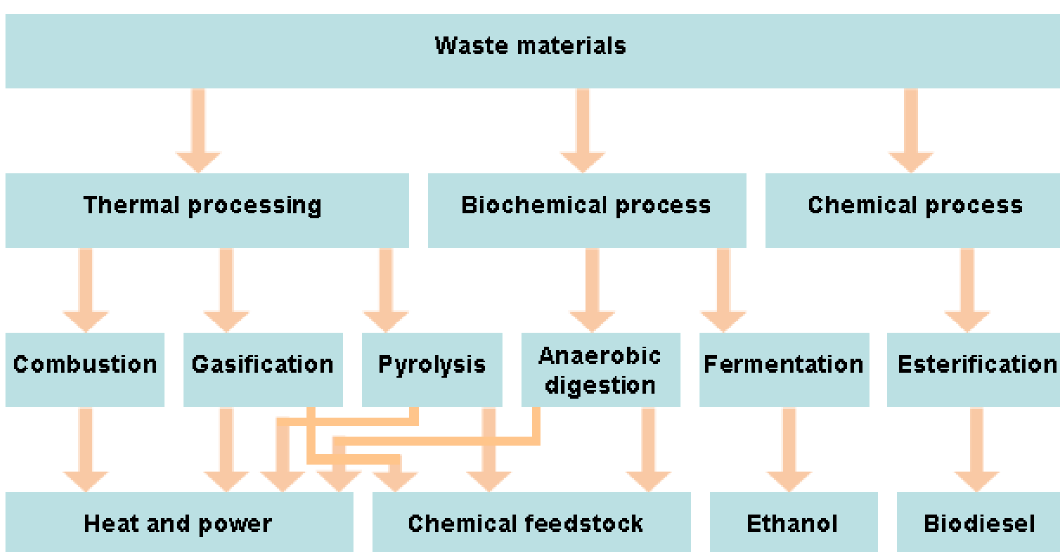

Figure 1. Pathways to convert waste materials to energy or energy related product.[31]

As can be seen in Figure 1, combustion, gasification, and pyrolysis are three types of thermal processing methods that can be used to convert waste material into energy. The main difference between these three methods is the ratio of oxygen present. The combustion process takes place at a very high temperature and requires either stoichiometric conditions (consuming reagents in the exact proportions required for a given reaction) or excess oxygen, whereas pyrolysis takes place at a relatively low temperature with almost no oxygen present. Gasification falls into the middle range, requiring a temperature between that of combustion and pyrolysis and a limited air or oxygen supply (see Table 1). Appendix A provides an overview of the poultry litter-to-energy technology examples that are explored in this report, as well as several others that are not mentioned in the text.

Table 1. Characteristics of the different thermal processing methods.[32]

	Combustion	**Gasification**	**Pyrolysis**
Temperature (F)	3600	1100-1800	390-1100
O_2 supplied	> stoichiometric	Limited, < stoichiometric	None
Products	CO_2, H_2O, ash	CO, H_2, ash	Oils, tars

Combustion

The different combustion technologies can be classified based on a variety of criteria, such as the system used (stoker boilers, fluidized bed boilers); however, a broad classification can be made between mass burn incineration and other types.[33] Mass-burn combustion is large scale incineration in a single stage chamber unit in which complete combustion or oxidation takes place. Typical volumes of waste are between 10 and 50 tons per hour. Other types of combustion involve small-scale volumes typically between 1 and 2 tons per hour. The systems used in small-scale incineration include fluidized bed, cyclonic, rotary kiln, and liquid and gaseous incinerators.[34]

In this report, the two most commonly used boiler types, stoker and fluidized bed boilers, are discussed. Stoker boilers are boilers that burn solid fuel in a bed on a stationary or moving grate that is located at the bottom of the furnace. Fluidized bed incinerators can burn wastes with difficult combustion properties, including municipal solid waste, sewage sludge, and biomass. Fluidized beds consist of a bed of sand particles contained in a vertical refractory-lined chamber through which the combustion air is blown from below.[35] This air keeps the bed in a floating or fluidized state, which contributes to more efficient contact between the fuel and the combustion air.

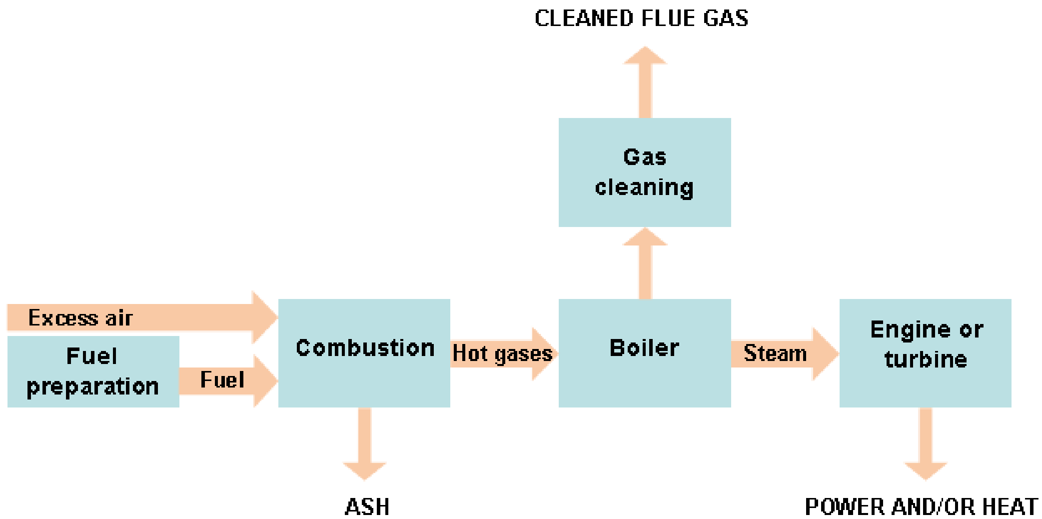

Figure 2. Flow chart of conventional waste combustion.[36]

The direct combustion of poultry litter is a promising alternative to land application due to the litters' relatively high energy content. However, burning chicken waste is technologically challenging; unlike fossil fuels or wood, poultry litter is a more complex material without a consistent composition and moisture content. The relative percentage of carbon, hydrogen, and oxygen in the poultry litter is similar to typical wood waste, but the ash content is significantly higher in the poultry litter due to the contaminants originating from the handling operations and dirt mixing into the bedding material (see Table 2).[37]

The moisture content of poultry litter is also relatively high, which can cause difficulties in feeding the combustor and maintaining sustainable combustion. In addition, a higher moisture content results in fuel with a lower caloric value.[38] The moisture content of the poultry litter varies depending on the type of operation. Broilers typically result in litter with a moisture content of about 20-35%, whereas layers result in litter with a higher moisture content (around 50%). One way that the moisture content of layer litter could be reduced, perhaps even bringing it on par with broiler litter, is through the installation of belt drying systems within the layer houses.[39]

Table 2. Characteristics of different fuels and poultry litter.[40]

	Poultry litter	Coal	Wood
Carbon, dry wt%	39.5	74	49.7
Hydrogen, dry wt%	4.3	5.1	5.4
Nitrogen, dry wt%	3.9	1.6	0.2
Sulfur, dry wt%	0.8	2.3	0.1
Ash, dry wt%	22.9	9.1	5.3
Chlorine, dry wt%	1.28	0	0
Oxygen, dry wt%	27.3	7.9	39.3
Moisture, %	20-35	5.2	50
Dry HHV*, Btu/lb	6572	13250	8800
LHV**, Btu/lb as fired	3600-4400	12050	3315

* High Heating Value; ** Low Heating Value

In addition to the characteristics of the litter, the availability of the litter is a significant issue. Maintenance and cleaning practices, as well as the use of bedding materials, can differ from farm to farm. At most poultry operations, wood shavings are used as bedding material and total clean out happens only once every 2-4 years. Having an adequate storage facility is therefore very important in order to prevent rain from falling on the litter and increasing its moisture content. Improper storage can also result in nutrient and pathogen pollution of the soil, groundwater, and surface waters; nevertheless, proper storage can be very expensive.

Combusting poultry litter concentrates the nutrient contents (P and K) in the ash and results in significant volume reduction, thus making it easier to transport. The ash content of the poultry litter is relatively high, requiring high-volume ash-handling equipment and increased attention to particulate removal, slagging, and fouling.[41] The high ash content and the high levels of K and Na increase the chance of fouling and slagging tremendously. Generally, the silica salts formed by K and Na show strong tendencies to become sticky and form slag on the hot surfaces of the combustion equipment and the boiler.[42]

In terms of combustion, air pollution is a substantial issue. One of the advantages of combusting poultry manure is that none of the nitrogen remains in the solid phase. On the other hand, due to the high concentration of nitrogen in the poultry manure, there may be significant fuel NO_x emissions. Nitrogen-oxides dissolved in the moisture of the atmosphere cause acid-rain and immediately end up in surface waters. Therefore, without adequate emission controls, these systems will not lead to improved water quality in the Chesapeake Bay. Selective non-catalytic reduction of NO_x is one of many emission control methods that could be used. Several studies also implied that the ammonia and urea-based compounds in the poultry manure may possibly have an NO_x reducing effect.[43,44,45] Urea reacts with NO_x at temperatures between 1650°F and 2100°F to produce molecular nitrogen (N_2) and water.[46] This is similar to the NO_x reduction mechanism employed in selective non-catalytic reduction (SNCR) flue gas control systems.

Organo-arsenic compounds are added to poultry feed in order to increase weight and improve feed efficiency.[47] Arsenic may therefore be an air pollution concern when burning poultry litter; however, no related studies have been found on this issue.

Poultry litter is considered to be a biomass fuel because, unlike fossil fuel power generation, the combustion of poultry litter adds no new CO_2 to the natural carbon cycle. In addition, the sulfur content of poultry litter is significantly lower in comparison to fossil fuels.

Pilot Scale Test: Energy Products of Idaho

Energy Products of Idaho (EPI) maintains an operating pilot plant in Coeur d'Alene, Idaho. This plant consists of a scaled-down fluidized bed combustor (3-5 MBtu/hr), a fuel metering system, and a delivery system. It also includes flue gas cooling and cleanup equipment with typical boiler and baghouse applications. In bubbling fluidized bed technology, the combustion air is injected at the bottom of the bed which causes the sand bed to be suspended.

The poultry derived fuel (PDF) used in this test program is typical of litter generated throughout the Delmarva poultry producing region. All of the litter used in this program was from the Delmarva Peninsula, but unfortunately no information was available on the size of the facilities that the litter was collected from. The litter was transported via truck in Super Sacks. Upon arrival at EPI's facility, the sacks were emptied and the litter was stored in EPI's fuel storage bunker. This is a three-sided building with a roof and concrete floors. The litter was not pre-processed in any way prior to the pilot plant tests. The objectives of the test program were to evaluate the emission potential of this fuel, to evaluate the slagging tendency of EPI's technology, and to explore conditions which could reduce or eliminate slagging completely.

The test results showed that under established operating conditions there was not any significant ash slagging or accumulation. The typical operating temperature out of the furnace was below 1750^{o}F and the fuel feed rate was around 500 lb/hr. However, when the furnace temperature was raised to between 1800 ^{o}F and 2000 ^{o}F for a short period of time, they observed measurable slagging and ash buildup on the furnace walls.

In terms of emissions, the results were promising. Lime was added to the poultry litter in order to eliminate the SO_2 emissions. 100% of the sulfur was captured and retained in the ash as calcium sulfate. The combustor is also equipped with SNCR technology to reduce the NO_x emissions. The NO_x emissions were much lower than expected, which can be correlated with the ammonia or urea-based compounds in the manure. Significant achievements were reached in HCl capture as well.

This demonstration project showed that the fluidized bed combustion technology is a suitable method to produce energy from poultry litter. With proper design and control, good efficiencies and low emission levels can be achieved. They determined that on a design basis, producing 200,000 pounds of steam per hour and generating 18,000 KW of power required a fuel feed rate of 21.4 tons/hour. For the typical 20 MW facility described above, the required amount of fuel could reach 200,000 dry tons per year, which could be supplied by a poultry operation with an annual capacity of 11 million birds.[48]

EPI has performed additional testing on a variety of PDF from various locations and from various types of facilities (broiler, layer, etc.). They have run pilot plant testing on chicken litter and manure as well as turkey wastes. In all cases, the litter and manure performed very well. A majority of the data collected from these pilot plant tests is proprietary to the firms paying for the tests, but several studies were funded by grants from the U.S. Department of Agriculture and the U.S. Department of Energy and this data is available.

Farm Scale: On-site Combustion

As an alternative to land application in sensitive watersheds, poultry litter could be burned on-site to produce heat and electricity for use on poultry farms. The generated heat could be used to heat the poultry houses and/or to dry the manure before it is fed into the combustion equipment. In addition, the electricity produced could help cover the farm's energy needs, with the surplus being delivered to the local power gird. Both of these uses are potential economic incentives for a farmer.

When considering the installation of a combustion system on a single farm, the interest of the farmer needs to be closely evaluated. Besides the high cost of such equipment, the management and operation costs can increase the overall expenses tremendously. To achieve efficient combustion, the poultry litter must be the right size before it is fed into the combustor. Due to the special composition of poultry litter, this can result in high maintenance requirements. Slagging, fouling, and high levels of corrosion are also factors that need to be eliminated in order for farmers to use such systems.

One of the advantages of the on-site utilization of poultry litter is the elimination of transportation costs. On the other hand, a proper storage facility is needed in order to prevent water and air pollution.

Study: Combustion of Poultry Litter in a Fluidized Bed Combustor (Portugal, Ireland)
A group of Irish and Portuguese researchers studied the combustion of poultry litter and poultry litter mixed with peat in an atmospheric bubbling fluidized bed combustor. The addition of peat was used to improve combustion due to the uncertain combustibility of poultry litter with a high moisture content. The study, however, showed that as long as the moisture content was kept below 25%, there was no need for peat to be added. Besides investigating the effect of moisture content on poultry litter combustion, they also studied air staging and variations in excess air level along the freeboard. The combustor was operated over a temperature range of approximately 1290°F-1830° F. Their main conclusions were: (1) the condition of the fuel supply had a significant influence on the combustion process, (2) the moisture content of the poultry litter had a great effect on the fuel supply, (3) the temperature influenced the reduction level of unburned carbon and hydrocarbons released from the residues, (4) air staging enhanced the combustion of volatiles released from the residues in the riser, and (5) air staging in the freeboard lowered the NO_x emissions.[49]

Fluidized Bed Combustors: Biomass Heating Solutions Limited (Ireland)
The group that was working on the above project is now manufacturing small scale fluidized bed combustors to combust poultry litter for heat/energy. Biomass Heating Solutions Limited (BHSL) is an Irish company based in County Limerick, Ireland that provides a turnkey, on farm solution to the problems of poultry litter disposal for poultry farmers. Several years of research and development involving biomass experts, poultry farmers, and regulatory agencies have led to the development of a boiler system which deals with the two main problems facing the industry: litter disposal and the continuing increase in energy costs.[50]

Their system has been designed to comply with all of the relevant regulations and fits in with the existing technical and physical structures of existing farms. The fuel consumption of the system is approximately 80 lb/hr and it can burn litter with a moisture content of between 25% and 50%. Ash is typically produced at a rate of around 7 lb/hr and is suitable to use as fertilizer. The energy produced by these systems can be used to heat the poultry houses, replacing a portion of the Liquefied Petroleum Gas (LPG) that is typically used. This can result in financial savings for the farmer. The litter that is collected once a flock is removed from a poultry house could provide the fuel to heat the house for the next incoming flock. If a cycle of six weeks is used for each flock, they calculated that a 25,000 bird operation could save over €2000 ($2700) per flock, or approximately €12,000 per year, on LPG and the costs associated with litter disposal. They also estimated a savings of 4 UK tons of LPG, which is equivalent to 12 UK tons of CO_2 reduction.[51] It is important to note that the average temperature in County Limerick, Ireland, which is where this company is based, is between about 39.2°F-48.2°F degrees in winter and 51.8°F-68°F degrees in the summer.[52] This should be taken into account when considering the amount of heat savings, since the amount saved will depend partly upon the climate in which the operation is located.

Feasibility Study: Poultry Litter Combustion (University of Arkansas)
A feasibility study/demonstration project that looked at using broiler litter as a fuel was conducted in Harrison, Arkansas by Tom Costello at the University of Arkansas Division of Agriculture in December 2006. The purpose of this study was to determine whether or not on-farm litter combustion was feasible. In addition, this study collected information that they thought growers should consider when deciding whether or not to invest in furnaces such as these. In order to help the grower make an informed decision, they intended to offer details about the thermal performance of the litter, the amount of material needed daily and annually, the economic implications, the management requirements, the amount of ash produced, and any environmental effects.

The equipment used in this test was a broiler litter-fired combustor prototype that was manufactured by Lynndale Systems Inc. A direct combustion process was used in the furnace and the combustion air was delivered by a fan. There was a thermostat operating in the house which called for heat when the temperature dropped to a certain level. When there was no need for heat, it was exhausted outside of the house. The system was designed to provide heat for the poultry houses. The heated air was distributed longitudinally in the house by several stirring fans. The fuel was obtained from a broiler house's annual cleanout and was stored in a bunker for a year before it was used.

The furnace system was operated during two grow-outs (approximately four months) on the UA Applied Broiler Research Farm in order to provide heat for one of the farm's poultry houses. Fuel use, ash accumulation, and heat extracted were measured during the test. The demonstration was successful in showing the technical feasibility of burning 100% litter in a direct-combustion furnace on a farm. However, the test results showed relatively low furnace system efficiency and ash containing a small portion of carbon. This indicates that litter combustion may have been incomplete. Another potential explanation for the presence of carbon in the ash could be that unburned litter fell into the ash due to improper handling. System design amendments should be implemented to capture the energy of this carbon and to improve combustor efficiency.

Excessive CO levels were also observed during stack emission checks, which is another indicator of incomplete combustion. System modifications to extract the energy from CO would improve system efficiency. The NO_x emission levels were not high, although with system improvements to achieve more complete combustion, the NO_x levels are likely to rise. Particulate emissions were not measured; however, the low amount of ash recovered during the test implies that a significant amount of particulates may have been released into the air.

Once this system is implemented on a farm it would not require a full-time operator. The fuel would need to be loaded into the system two to four times per day and an occasional furnace check would be needed. In a typical chicken operation, approximately one ton of litter would need to be used on a winter day for space heating.

In this study, the economic feasibility of implementing such a system on a grower's farm was also evaluated. In order to achieve significant savings in the conventional fuel consumption that is used annually for space heating, improvements in furnace system performance would be crucial. The objective is to achieve the elimination of 80% of the annual fuel, such as propane, that is used for space heating. To hit this target, system efficiency should be increased to 40% and the fuel feed rate should be increased to 100 lb/hr. If these modifications (either burning fuel at a faster rate or extracting more heat from each unit of fuel) are carried out, the savings from the increased heat generation may provide a net cash flow that could help pay off the investment in the system. Over a seven year period, they calculated that the possible savings could be as much as $24,000.

In order to keep the rain off of the fuel (poultry litter), an adequate storage facility is needed that should ideally be located close to both the poultry house and the furnace. In addition, sufficient storage capacity is also needed for the ash by-product. Prior to starting an operation such as this, potential markets for the ash should be established. Potential products include using the ash as an additive in concrete or using it to manufacture fertilizer.[53]

Industrial Scale: Poultry Litter-Fueled Power Plants

Development of a Poultry Litter-to-Energy Furnace: American Heat and Power LLC
American Heat and Power LLC developed a multiple hearth furnace that uses circle slot jets to introduce combustion air in order to create high turbulence and improved air-fuel mixing. The high turbulence and improved mixing increases control and combustion efficiency and reduces CO and hydrocarbon emissions. This system provides a combustion environment in which the temperature is high enough to achieve complete combustion, but low enough to avoid slagging, agglomeration, and high NO_x emissions.[54] In addition to poultry litter, this furnace can also handle many different types of biomass.

This type of multiple hearth furnace is best suited for a large commercial or industrial scale project, such as a large regional plant. Though technically feasible for an on-farm application, it is not economically feasible. The capacity of a system such as this varies depending on the application. For stand-alone economical viability (no government subsidy), the plant should be sized to process at least 100 tons of litter per day. Typically, capacities would range from 250 tons per day to as much as 1000 tons per day (with multiple units) at a single regional plant. The energy output for a single regional facility is

100,000-35,000 lb/hour for steam only and 10-50 MW for electricity only. Combined heat and power plants would provide a combination of these.

These are multi-million dollar units and although the units have standard sizing criterion, a unique system would need to be specifically designed for each project. As such, pricing is specific to the project. However, as a ballpark estimate, a hypothetical 15 MW plant would cost roughly $2500 per kW and a biomass to steam plant would cost approximately $120 per lb/hour of steam capacity installed.

A facility that uses this technology would require a full-time staff, with plant operators typically working three 8-hour shifts. Maintenance would be commensurate with a mid-sized energy plant and normal maintenance would be provided by the operators. Long term service agreements with equipment suppliers could provide a large portion of the plant's major equipment maintenance.

Poultry Litter-Fueled Power Plants in the UK: Energy Power Resources Ltd
A great example of the successful conversion of poultry litter to energy involves mass burning and step-grade combustion systems.[55] Large scale, centralized power plants fueled with poultry litter can generate 10-55 MW of energy. These kinds of facilities exist in the United Kingdom and are operated by a company called Energy Power Resources Ltd, which was the first company in the world to succeed in turning poultry litter into energy.

The first poultry litter fueled power station was opened in Eye, Suffolk, UK in 1993. This 12.7 MW plant consumes 140,000 tons of chicken litter annually. The fuel consists of poultry litter, horse bedding (12%), and feathers (7%). The employed technology is a conventional moving grate boiler and steam cycle.[56] After on-site use of electricity, the net output is supplied to a 33kV power line for distribution.[57] The wood shavings and straw used in the poultry houses help control the moisture content of the fuel and improve the burning process. The high calcium content of the litter reduces the need for the addition of calcium (lime), which typically is used to help capture the SO_2 and HCl emissions. Negative pressure is used in the storage facility to minimize odorous emissions. The fuel from the different farms is mixed before it is fed into the boiler and the grate system moves the fuel through the furnace. An electrostatic precipitator is used to ensure low dust emissions.[58]

A 13.5 MW plant in Glanford, UK was the world's second poultry litter-fired renewable energy power station. Based on the company's experience with the Eye power plant, they decided to introduce a new technology at the Glanford plant to overcome the problems that had resulted from the higher than expected moisture content of the fuel. The boiler used in Glanford is a chain grate with spreader stockers which blow the fuel into the boiler ensuring that the majority of the fuel is burned in mid-air.[59] In May 2000, the plant was re-commissioned to burn meat and bone-meal (MBM) and in 2004 the plant got permission to burn any other biomass.[60]

The Thetford power station was completed in June 1999 after three years of construction work.[61] With its 38.5 MW capacity, this plant is currently the world's largest poultry litter fueled power plant and Europe's largest biomass fueled electricity generator. This plant requires 420,000 tons of poultry litter annually.[62] Based on the company's experience with their first two plants, they decided to make a number of modifications to this third plant. For example, the Thetford plant uses a much more efficient process to transfer the fuel from the delivery bunkers to the boiler furnace. Spiral screw feeders transfer the litter to a conveyor belt, which moves the litter to the steam generator. The litter is then pneumatically transferred to the boiler furnace. The emissions from this plant are controlled using a cyclone. In addition, a baghouse series is used to achieve increased particulate emission reductions. Unlike the other two plants, the Thetford station injects lime into the flue gas in order to minimize the SO_2 and HCl emissions.[63]

The poultry litter fueled power station in Westfield, Scotland began operating in early 2001. This plant was the first to use the advanced (bubbling) fluidized bed combustion technology with poultry litter. The plant's annual fuel consumption is 110,000 tons and its maximum power output is 9.8 MW. Chicken litter is supplied from farms all over Scotland with 85% being provided by one major company that is under long term contract. Trial combustions showed success in burning feathers.[64]

The combustion ash from all of these plants is further processed to produce high quality agricultural fertilizer containing all of the nutrients needed by plants except for nitrogen.[65] The fertilizer consists mainly of phosphate and potash with sulphur, magnesium, calcium, sodium, and other essential trace elements required by crops and grass. After size grading, the ash is marketed as Fibrophos Fertilisers. In 2005/2006, Fibrophos sold over 70,000 tons of product.[66]

Poultry Litter-Fueled Power Plants in the United States: Fibrowatt LLC

There are several plants proposed in the United States that, if built, would use the same technology as the UK plants. Fibrominn is one of the plants that was proposed and is now being constructed in Benson, Minnesota. This plant is being built by Fibrowatt LLC, which was founded in 2000 by the management team that built the world's first three poultry litter-fueled power plants in the UK, which were discussed earlier. Benson was selected as the location for this plant because it is in the heart of a turkey-growing region. Local turkey litter is expected to provide most of the 2,000 to 2,500 tons of litter that will be needed on a daily basis.[67] The fuel will be trucked to the site following prescribed truck routes established by Fibrominn to minimize the impact of traffic on the local community.[68]

The Fibrominn plant will generate 55 MW of electricity from approximately 700,000 tons of turkey litter and agricultural biomass (including woodchips and sawdust) per year. The plant will be composed of the following parts: an enclosed fuel reception area, a fuel storage hall, a boiler building, a steam turbine and generator, flue gas pollution control equipment, an air cooled condenser, a stack with continuous emission monitoring, a truck weighing and cleaning facility, ash conditioning, and a storage and loading building. The plant will be connected to a new 115 kilovolt power line that will run approximately a quarter of a mile to a major substation owned by Great River Energy. The plant is designed to use "grey" water from the Benson Municipal water treatment facility to meet some of its cooling water requirement.[69] They will also use untreated well water supplied from Benson City wells.[70] Propane or natural gas will be used as the start-up fuel.[71]

The emission controls planned for the plant agree with recent national determinations of Best Available Control Technology (BACT) for similar power plants that use biomass fuels. The plant will use the following procedures and emission control equipment: a high combustion efficiency to ensure a clean burn; the use of Selective Noncatalytic Reduction (SNCR) to control NO_x emission by injecting ammonia-based reactants into the furnace; a spray-dry absorber to control acid gasses (SO_2, H_2SO_4, HCl); and particulate matter removal by a fabric filter baghouse.[72]

The ash will be sent to a nearby facility operated by North American Fertilizer to be converted into high value fertilizer. Eventually they are expected to produce 80,000 tons of fertilizer per year. 400 pounds of this fertilizer will contain roughly the same amount of nutrients as 4 tons of litter. The ash will be conditioned with additional moisture, stored for a period of time, ground and screened to produce uniform size granules, and then marketed as a fertilizer through already existing dealer networks.[73]

As of May 2007, Fibrominn’s system was still being synchronized and its combustion performance was being tested with various biomasses and poultry litter fuels. They expect to start operation in mid-summer 2007.

Figure 3. Webcam image of the Fibrominn plant.[74]

FibroShore, a similar plant that has been proposed for Maryland, would generate 38.5 MW of power from up to 300,000 tons of poultry litter and 50,000 tons of forestry residues annually.[75] If built, the plant would be located in the poultry growing area on the lower Eastern Shore of Maryland. Although building a poultry litter-fueled power plant on the Eastern Shore seemed to be promising when Fibrowatt proposed it in the late 1990's, no construction work has begun as of yet. Whether or not there is a sufficient amount of poultry litter available in the region for a power plant of this size is questionable. A large portion of the region's litter is already being used by Perdue AgriRecycle, which is a large-scale litter pelletizing operation located in Sussex County, Delaware. Perdue Incorporated invested more than $13 million in Perdue AgriRecycle, which started operation in 2001 and can process the equivalent of 400 poultry houses worth of litter each year.[76] In addition to the amount of litter available, another factor that will partly determine whether or not FibroShore is built on Maryland's Eastern Shore is the level of subsidy that they are able to obtain from the state.

Fibrowatt continues to pursue the FibroShore project while attempting to gain acceptance from the Eastern Shore poultry growers. Exactly how much excess manure would be available in a radius that is close enough to allow them to avoid the transport of waste over long distances and enormous transportation costs is unknown at this time. Fibrowatt would ideally like to obtain the litter directly from the growers and then transport it by truck to the plant. If this were done, biosecurity issues would need to be taken into account since the trucks would be traveling many miles on public roads between the fuel suppliers and the power plant.

Recently there seems to be an increased interest in a project such as this by Maryland's Attorney General Doug Gansler. In fall 2007 at events such as the Eastern Shore Poultry Summit and a Maryland Business for Responsive Government meeting, Gansler called for a litter-to-energy power plant to be built on the Eastern Shore, even going so far as to say that they have a site and a plan for such a plant.[77,78] Before plans can move forward, however, another obstacle beyond those that have already been mentioned is that a power company must still be found that will agree to buy and distribute the power that this plant would generate. Fibrowatt has said that they will need a 20-year power purchase agreement from either the private sector or the state of Maryland before they will be able to secure bank financing for this $125 million project.[79]

Case Study: Retrofitting Conectiv Vienna Power Station (Vienna, Maryland)
A case study was conducted that looked at how the Conectiv Vienna Power Station could be retrofitted so that it could use poultry litter as a fuel source. The Conectiv Vienna Power Station is located on the Delmarva Peninsula in a region that has a high concentration of poultry growers. Conectiv previously considered replacing systems in the power plant with systems exclusively designed to be fueled by poultry litter. At the time of this case study, this plant was being used as a peaking unit and was fueled with No.6 oil (No.2 oil is used for startup). Two different system modifications were proposed: (1) adding a new stoker boiler or (2) adding a new fluidized-bed boiler specifically designed for poultry-derived fuel. A third proposal that was considered was retrofitting the existing

boiler so that it could burn poultry litter, however this proposal was disregarded because the modifications needed to do this would cost only a little less than the addition of a new boiler.[80] In addition to a new boiler, poultry litter receiving and handling equipment would also be needed in order to successfully retrofit the facility. If the plant was retrofitted, it would have required approximately 400,000 tons of poultry litter per year to produce 35 MW of energy. If the required amount of poultry litter was not available on the Delmarva Peninsula, then supplemental fuels may have been required. Eventually, Conectiv sold the Vienna plant and the matter of retrofitting the facility was dropped.[81]

Study: Poultry Litter as a Fuel Source at the Eastern Correctional Institution Cogeneration Facility (Princess Anne, Maryland)
Working with Maryland Environmental Service, the Maryland Department of Natural Resources Power Plant Research Program (PPRP) completed a study focusing on the reliability and suitability of litter as a fuel source and the ability of the existing Eastern Correctional Institution Cogeneration Facility (ECICF) to burn litter as a fuel. As part of this study, they identified the modifications that would be needed in order to address operating and maintenance-related problems that would arise if ECICF were to primarily burn poultry litter. The cumulative capital cost for the modifications identified was estimated to be approximately $6 million, with a 20-year life-cycle cost of slightly less than the life-cycle cost of continuing the current operations.[82] A full-scale poultry litter test burn was also conducted in 1999. During this test burn, they encountered some problems due to the fouling of the combustion equipment. As a result of the test burn, it was determined that significant additional modifications to the ECICF would be necessary in order for the facility to be able to burn poultry litter. Eventually, they determined that the conversion of the facility would be technically unfeasible and economically questionable. The revised cost of modifications was 30% higher than the original cost estimates.[83]

Co-burning

In order to offset the few adverse qualities of poultry litter, such as its high moisture content and its slagging and fouling characteristics, dilution with other biomass fuels may be a suitable solution. Blending the poultry litter with sawdust or wood (e.g. willow) as it is fed into the combustion equipment has been suggested as the best dilution alternative. The decreased moisture and ash content would improve the combustion and conversion processes. Burning poultry litter with switchgrass might be less beneficial due to the silica content of switchgrass, which could react with the sodium and potassium present in the poultry litter causing slagging and persistent deposition on heat exchangers.[84]

Combusting poultry litter combined with conventional fuels, such as coal, in an existing power plant may be another option. A potential benefit to burning coal with poultry litter is that excess sulfur may be absorbed by the potassium, sodium, or calcium that is present in the litter. Co-firing biomass fuels with coal would reduce SO_2 and NO_x levels in the existing pulverized-coal fired power plants.[85] On the other hand, sulfur and chlorine could form compounds that would cause deposition or corrosion of the equipment. The ash deposits would reduce the heat transfer and would be more difficult to remove compared to deposits generated during coal combustion.[86] In addition to co-firing poultry litter with conventional fuels, another option would be to co-fire poultry litter with unconventional fuels, such as waste coal.

Study: Co-Firing of Coal and Broiler Litter (Texas A&M University)
Researchers at Texas A&M University conducted a study that looked at co-firing coal and broiler litter fuels for power generation. This study focused on analyzing and understanding the characteristics of broiler litter as a fuel source and determining its potential for being co-fired with coal. As part of this study, a 90:10 blend of coal and broiler litter was used to fuel existing coal-fired combustion devices. This 90:10 blend (coal 90: litter 10) resulted in a fuel quality and cost that was similar to coal and a fouling potential that was less than pure litter. The long-term goal of this study is to develop an animal biomass and coal co-firing technology. However, before this can be done, researchers indicated that further testing is needed to better determine the combustion efficiencies and the fouling and corrosion potential of broiler litter fuels.[87]

Study: Combustion of Poultry Waste with Natural Gas (Morgan State University)
Two researchers at Morgan State University in Maryland were investigating the co-combustion performance of poultry waste with natural gas in an advanced swirling fluidized bed combustor. Three different types of fuel were investigated: poultry litter (the lower layer of the poultry farm composting windrows), poultry manure (the surface layer of the poultry farm composting windrows), and sawdust. The poultry waste samples were collected from Maryland’s Eastern Shore. The results of this study indicate that excess and secondary air play an important role in achieving stable combustion with the given ash and moisture content in wastes. They found that the co-combustion of poultry waste has the following advantages: (1) it potentially lowers fuel costs since biomass fuel is cheaper than fossil fuel; (2) it minimizes waste; and (3) it reduces air pollution, water pollution, and soil contamination. This study shows that the swirling fluidized bed combustor waste disposal system is a cost effective and environmentally friendly solution for disposing of poultry litter and manure.[88]

Gasification

The gasification process converts most wastes that contain carbon into a combination of gases in an air-deficient (or oxygen-deficient) environment. The resultant gas is composed primarily of carbon monoxide and hydrogen. In addition, it also contains carbon dioxide, methane, and water. This mixture of gas can be used as a fuel for boilers, internal combustion engines, or gas turbines. The combustible gas produced from most waste sources contains varying amounts of tars and particulate matter that may need to be removed prior to further use.[89]

Gasification of coal is a well documented and proven technology that has been used since the early 1800’s.[90] To handle feedstocks of widely different physical and chemical properties, various designs have been developed. These designs differ in their method of feedstock introduction, the type of bed material (if used), the operating pressure and temperature, the presence or absence of steam inputs, and whether the reaction heat is supplied internally or externally.[91]

The quality of gas (H_2, CO, CH_4, etc.) generated in the system is influenced by fuel characteristics, gasifier configuration, and the amount of air, oxygen, or steam introduced. The moisture content of the fuel has an impact on gas quality; the wetter it is the more heat is consumed by evaporation and the less energy remains for volatilization. Better gas quality is achieved at lower temperatures; however, when the temperature drops too low the char oxidation reaction is put down and the overall heat release decreases.[92] Gasification can be used with poultry litter and other difficult to process bio-wastes.

Since gasification occurs at a lower temperature than combustion and takes place with only a limited oxygen supply, the risk of NO_x emissions is lower. Instead, the nitrogen present in the manure forms ammonia.[93]

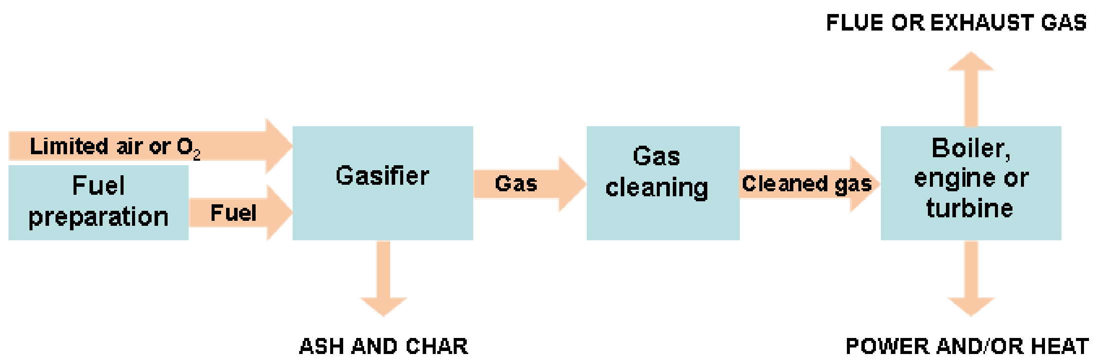

Figure 4. Flow chart for the gasification process.[94]

BARC Gasification Facility (Beltsville, Maryland)
The USDA Agricultural Research Service (ARS) is conducting a feasibility study on the construction and use of a gasification facility at the Beltsville Agricultural Research Center (BARC) in Beltsville, Maryland. This study is being done under an agreement with the U.S. Department of Energy's National Energy Technology Laboratory. The 1-2 megawatt gasification unit that is being constructed at BARC will be used to test the suitability of a variety of feedstocks for generating steam and electricity. Feedstocks that will be tested include animal manure, other farm wastes, and specialty biomass crops such as switchgrass and poplar trees. The electricity and steam that is generated by this unit will be used by the BARC labs, offices, and farm buildings. In addition to analyzing the potential of a variety of feedstocks, this feasibility study will also look at whether this technology could be transferred to rural communities and farm cooperatives.[95, 96]

Coaltec Energy Test Facility
The Coaltec Energy Gasification Test and Demonstration Facility is located in the Coal Research Park of Southern Illinois University in Centerville, Illinois. Several different types of alternative fuels, including turkey litter, have been successfully tested in this commercial-scale modular designed coupled gasifier.

The system at this facility includes a gasifier, an oxidizer, and an exhaust stack. The stack emissions and the gas composition between the gasifier and the oxidizer are measured by gas analyzers. A test burn of poultry litter was conducted on November 16-18, 2005 with litter supplied by West Michigan Turkey. The purpose of this test was to determine the feasibility of using poultry litter as a fuel in an energy producing project and to use the data from the test to develop a design and evaluate economics for a power generation project.


Figure 5. Primary gasifier unit.[97]


Figure 6. Front of gasifier and feed hopper.[98]

Demonstration Project: On-Farm Gasification System, Frye Poultry Farm (West Virginia)
Based on the results of the above mentioned project, a small scale gasification unit has been constructed by Coaltec Energy on a poultry farm owned by Josh Frye in

Wardensville, West Virginia. The purpose of this demonstration project is to prove the economic viability and feasibility of converting poultry litter into energy using a gasifier unit. At the time that this report was written, the first test burns had been conducted and the equipment optimization had taken place.

The system on the Frye farm is a fixed bed gasification unit that is used to produce heat from poultry manure in order to provide heating for the farm's three chicken houses. Although this unit will only be heating three houses, it has the ability to heat up to a total of six houses. In addition to saving the farmer money on propane costs, heating the chicken houses with heat generated by this unit rather than by propane is expected to improve bird health since it provides dryer heat to the houses, thus reducing the humidity level in the house and lowering ammonia generation and exhaust.[99]

The moisture content of the manure varies depending on where in the chicken house it was collected and whether or not there was a hole in the roof through which the rain could drain onto the floor of the house, thus increasing the manure's moisture content. Wetter fuel makes it more difficult to maintain the gasification process and causes less energy to be gained from the process. The three houses on the Frye farm will be cleaned after every flock (6 weeks), which provides a total of approximately 70 tons of litter. On occasions when the litter is too wet, it will be blended with wood chips. This is what happened on the first day of the test burn. The mortality will also be gasified in the unit. The preliminary results showed improvement in the performance of the gasifier when the dead birds were mixed with the litter. The reason for this is uncertain, but one possibility is that the fat of the birds improved the process.

The labor required to maintain and feed this unit is very low because it is equipped with a control panel that can be managed remotely, the temperature and emissions are measured with automatic sensors, and the computer calls for fuel when it's needed. A hopper will be attached to the unit which will gradually feed the gasifier. This hopper will need to be filled with fuel every three days, except for when the fuel requirement is relatively low, such as in the summer when the hopper will need to be filled even less frequently, perhaps only once a week. The litter doesn't need any preparation; it will be used as it is when it comes out of the barn. Two storage facilities will be built on the farm close to the gasifier, one for the litter and one for the ash/char.

In the primary stage of the process used by this system, a relatively low temperature (around 1300^{o} F) and oxygen starved conditions are maintained. The resulting product is a gas mixture (synthesis gas or syngas) which is burned in the secondary chamber at 2000^{o}F to generate heat. The volume of the ash that is produced is significantly lower than the original litter, causing it to be cheaper to transport. The ash content of the litter is expected to range between 18%-20%, thus if 750 tons of litter were gasified in this system per year, then they should be left with approximately 150 tons of ash per year.[100] The ash is odor and pathogen free and has characteristics that make it suitable for land application.

Another end product that this system could produce, rather than ash, is bio-char. The bio-char product would contain all of the phosphorus, potassium, and micronutrients that were originally present in the litter. The fertilizer value of char is higher than that of the ash because it contains a portion of the nitrogen that was not oxidized in the gasification process. It also contains some of the carbon that was not totally oxidized. What is special about bio-char is that it is much more effective than other organic matter, such as common leaf litter, compost, or manures, in retaining most nutrients and keeping them available for plants. Interestingly, this is also true for phosphorus which is not at all retained by 'normal' soil organic matter.[101] Bio-char also behaves as a carbon sink which is effective in the mitigation of climate change. However, because the benefits of biochar are just now beginning to be understood and studied, the Frye Farm does not expect to be able to find a market for it any time in the near future. Therefore, they have decided that they will instead make and try to market the conventional ash. It is thought that cultivating a viable market for this product is much more realistic, especially in the near term.[102]

The equipment being installed on the Frye farm is manufactured by Westwood Energy and costs approximately $600,000. Funding for portions of this project has been provided by the Natural Resources Conservation Services through a Conservation Innovation Grant and from the West Virginia Department of Agriculture. The poultry grower also expects to receive payback from the propane savings, which is expected to total about $30,000-$40,000 per year. Additional income could also potentially be gained by trading nutrient and carbon credits and selling the char as agricultural fertilizer.

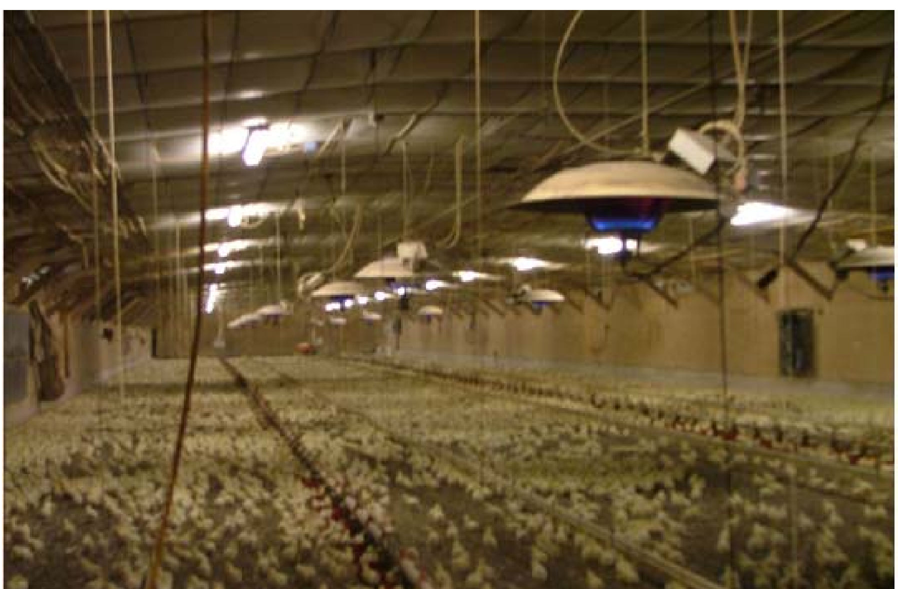

Figure 7. Chicken house with space heaters at the Frye Poultry Farm.[103]

Figure 8. Gasifier at the Frye Poultry Farm.[104]

Several other poultry litter fueled gasification units have been proposed in the Chesapeake Bay watershed and throughout the U.S., but many of them have not actually been constructed.

Case Study: Poultry Litter-Fueled Boiler at Perdue Feed Mill (Bridgeville, Maryland)
A case study was conducted that evaluated the feasibility of building a poultry litter fueled boiler at the Perdue Feed Mill in Bridgeville, MD in order to produce steam for the feed mill operation.[105] They evaluated cost, capacity, location, access, biosecurity, and air and solid waste management issues. The mill at Bridgeville was selected for the case study because it is strategically located for an average delivery of 28 miles or less from the farms and it is also close to a major highway. If all of the five mills were converted so that they could use litter for fuel, they would consume approximately 24,000 tons of litter per year. The fuel demand is relatively low and the system would require only one or two deliveries per day. A 1,500 cubic foot storage facility would provide 48-hour storage and on-farm storage would be used to buffer deliveries of small quantities. Nine different boiler suppliers were considered and only two of them had litter test burned. The estimated capital costs of the system varied from $600,000 to $1,200,000 depending on the plant configuration.

Proposed Cogeneration Facility: Allen Family Foods, Inc. (Hurlock, Maryland)
Several years ago (around 2001) Allen Family Foods, Inc. was planning to install a 4 MW co-generation facility (CHP) to generate electricity and steam by processing poultry manure in a poultry processing plant in Hurlock, MD. CHx Engineering, a Michigan based engineering firm that specializes in the design, construction, and operation of solid

waste gasification systems, was expected to be the builder, owner, and operator of the proposed cogeneration facility.[106] Currently two fuel oil fired boilers are used to generate the required steam for the processing plant, using over 300,000 gallons of No.6 fuel oil per year. Using poultry litter from nearby growers as a fuel would greatly reduce the company's dependence on fossil fuels and their need to buy commercial power. The surplus electrical power from the facility could be sent to the gird and the ash could be collected and used as a commercial fertilizer.[107] Staged oxidation would substantially reduce the chemical reaction between nitrogen and oxygen, thereby reducing NO_x production. No significant air quality impacts were expected and it was anticipated that the facility would comply with all federal and Maryland state air regulations.[108] Finally due to financial difficulties and problems with the design firm, which was unable to meet the conditions of the contract, the plans were dropped.

Proposed Poultry Litter Gasification Unit: Allen's Hatchery, Inc. (Linkwood, Maryland)
Within the last year, Allen's Hatchery, Inc. in cooperation with REM Engineering, Inc. tried to get Dorchester County, Maryland to allow a poultry litter gasification unit to be constructed and operated adjacent to its protein conversion plant in Linkwood, Maryland. There were no technical, design, or financial barriers that precluded their poultry litter gasification plant. The proposed gasification unit was expected to consume about 1 ½ tractor-trailer loads of manure a day, which equals approximately 14,000 tons per year. The litter would have been supplied from 25-30 poultry farms in Delaware and Maryland[109] and the boiler would have produced 15 million BTU and 10,000 lbs of steam per hour, replacing about 12 percent of the fossil fuel used at the facility.[110] Nitrous and sulfur oxides would have been cleaned by the naturally occurring ammonia and calcium within the waste and particulate emissions would have been captured by a fabric filter. They also highlighted that the REM boiler stack would not have emitted arsenic. The ash produced as a byproduct of this system would have contained 20 percent phosphorus, 13-14 percent potassium, around 14 percent calcium, and some magnesium and it would have been sent to fertilizer companies to be mixed with nitrogen.[111] They were planning to begin construction in September 2006, but due to political reasons, this system was never installed. The state approved the unit, but there was opposition from the Dorchester County commissioners.[112]

Proposed Poultry Litter Gasification (CHP) Unit: Tyson Foods, Inc. (Virginia)
Approximately seven years ago, Tyson Foods, Inc. worked on a project to have a litter gasifier electric-producing unit built at its processing plant site on the Eastern Shore of Virginia. Again, for a variety of reasons, it did not happen. The three major obstacles that the proposed Tyson gasification project encountered were:

(1) They had trouble securing a consistent source of litter. It was difficult to get the growers to commit.
(2) The company that was going to build the gasifier for the project went out of business.
(3) They were having difficulty acquiring the building permit from the County Board of Supervisors; however, since the project was abandoned, they never finished going through this process.[113]

Pyrolysis

Pyrolysis is the thermal degradation of organic waste in the absence of oxygen that produces oil, combustible gases, and carbonaceous char. The portion of each product produced is dependent on the conditions of the process, temperature, heating rate, and pre-treatment.[114] The typical pyrolysis temperature ranges from 750°F-1500°F.[115] At lower temperatures and longer reaction times a larger amount of oil is produced and at higher temperatures the proportion of gases increase. The gas consists mainly of CO_2, CO, H_2, CH_4, lower concentrations of other hydrocarbon gases, and uncondensed pyrolysis oil. The ratio of gas product ranges from 10-20%. The caloric value of the gas can reach about half that of natural gas and can be further used for energy generation such as for powering the pyrolysis unit.

The percentage of generated liquid, which is mentioned in different literature as bio-oil, pyrolysis oil, biocrude, or pyrodiesel, can reach up to 60-70%. The oils derived from the pyrolysis of waste materials tend to be chemically very complex, mainly composed of carbohydrate, lignin, and other decomposition compounds.[116] This liquid product is generally unstable, acidic, corrosive, viscous, and includes both water and ash contents, however, bio-oil can be refined further and used as a diesel-like fuel.[117] A notable feature of pyrolysis oil is that it can be produced at a location different from where it is finally used by applying transportation and storage infrastructure similar to that used for conventional liquid fuels.[118]

The solid product of the pyrolysis process is char, which contains noncombustible inorganic material and carbon. The ratio of char generation ranges from 10-40% depending on the composition of the feedstock and the conditions of the process. Phosphorous, potassium, calcium compounds, and other trace elements are expected to concentrate in the char. The amount of nitrogen compounds retained is uncertain.[119] The char byproduct could potentially be used and marketed as a fertilizer.

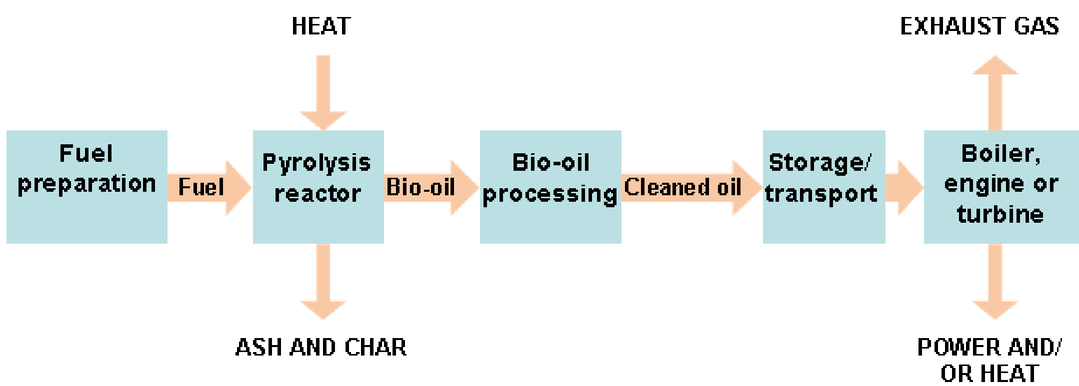

Figure 9. Flow chart of the pyrolysis process.[120]

Study: Pyrolysis Technology (Virginia Tech)

Foster Agblevor of Virginia Tech and his research team are working on developing a rapid pyrolysis technology to produce value added products, such as bio-oil, slow-release fertilizer, and producer gas, from poultry litter.[121] Another objective of their project is to evaluate the char fraction as a slow release fertilizer to land application. Their research is part of a concentrated effort by Virginia Tech researchers, Virginia Cooperative Extension specialists and agents, conservation organizations, state agencies, and private industry to determine the most effective means to support the agricultural community and manage excess nutrients in the Shenandoah Valley.[122] The National Fish and Wildlife Foundation's Chesapeake Bay Targeted Watershed Program funds this research through a $1 million grant. $406,000 of this grant will be devoted to the construction, installation, and demonstration of a portable pyrolysis unit.

Through their research, the team has successfully pyrolyzed poultry litter samples in a bubbling fluidized bed pyrolysis reactor at three different temperatures ranging from 840^{o}F to1020^{o}F. They achieved lower pyrodiesel yields using the poultry litter compared to when they used other biomass feedstocks. It was 23 wt% to 43 wt% and they attributed this to the high ash content of the poultry litter. Improving the condensation of the oils might cause this percentage to be higher. The energy content of the oil is almost two times as much as that of raw poultry litter. Due to the heterogeneity of the litter, the char yield varied quite randomly from 22 wt% to 40 wt% with a carbon content of about 48%. This material is odorless and potentially bio-safe. They conducted a leaching study of the generated char in order to determine the effect of pyrolysis on the release of P, K, and Ca. Compared to the corresponding raw poultry litter, the char released the P, K, and Ca more slowly, showing that the char may potentially be able to be used as a slow-release fertilizer.

This study did not focus on how the nitrogen content of the poultry litter is split between the three phases, but it did make some measurements on the nitrogen content of the different products. The percentage of N in the bio-oil is about 8%, which is higher than in fossil fuels or raw litter. The char also contains some nitrogen, which might increase the value of the bio-char as a fertilizer. The potential markets for bio-oil (which is easily transportable) include chemicals, electricity generation, process heat, and heating and cooling (including heating poultry houses).

Although this study demonstrated the potential of poultry litter pyrolysis, further research is needed to test the effectiveness of the char as a fertilizer and to evaluate the generated pyrodiesel in furnaces to determine its suitability as a heating oil. The gaseous emissions released during the pyrolysis process and during the combustion of the bio-oil should also be analyzed.

Combined technologies

One of the main criticisms of the bioethanol manufacturing process is that it uses too much fossil fuel to power the ethanol plant, which results in high costs and high greenhouse gas emissions. If fossil fuel was not used in the production of bioethanol, then no additional CO_2 would be added to the atmosphere when bioethanol was used as a fuel.

Powering an ethanol plant with poultry manure may be a way to help reduce production costs and to provide a use for the excess manure in the watershed. The installation of a CHP unit would be a suitable way to power an ethanol plant since it can generate steam and electricity reliably. The most common CHP technology used in ethanol plants today consists of a gas turbine-electric generator unit placed in tandem with a waste heat boiler. The turbine-driven generator provides electricity for the facility and the turbine exhaust is used in a waste heat boiler to produce process steam.[123]

In November 2006, Panda Ethanol Inc. announced its plans to build an ethanol plant in Muleshoe, Texas that will generate 100 million gallons of ethanol per year. The steam used in the ethanol production process will be generated by gasifying more than 1 million pounds of cattle manure annually.[124] A similar facility is already under construction in Hereford, Texas where cattle manure will be converted to energy using a fluidized bed system supplied by Energy Products of Idaho (EPI).[125]

Cellulosic ethanol

Converting poultry litter into liquid fuels is attractive for several reasons, although a recent assessment of litter-to-ethanol options concluded that the characteristics of litter make it much less attractive than other biomass feedstocks and that cellulose-to-ethanol conversion technologies are not yet ready for commercialization.[126]

IV. Status of Political Interest and Support

Federal Policies

The United States government is currently showing an increased interest in the development and use of alternative energy. For example, in his 2007 State of the Union address, President George W. Bush discussed the need to diversify the country's energy supply by continuing to change the way that we generate electric power.[127] During his address, he also introduced a new initiative, Twenty in Ten, to reduce gasoline usage in the United States by 20% by 2017. In order to help reach this goal, President Bush proposed a new alternative fuel standard that would require the production of 35 billion gallons of renewable and alternative fuels in 2017, an amount that is expected to replace approximately 15 percent of the country's projected annual gasoline usage. This proposal is nearly five times the country's previous renewable fuel standard of 7.5 billion gallons by 2012.[128]

In addition to this initiative, there are also other federal policies in place that encourage alternative energy production. Two such policies are the Federal Farm Bill and the Energy Policy Act of 2005. These policies encourage the production of alternative energy through provisions that support research, provide financial assistance, and promote alternative energy technologies. It is important to note, however, that many of these provisions focus primarily on energy sources other than manure, such as cellulosic biomass. Despite this, these policies may be able to indirectly benefit manure-to-energy projects by increasing the country's interest and enthusiasm in renewable energy and thereby encouraging the development and use of additional renewable energy technologies, potentially even technologies that use manure as an energy source.

Federal Farm Bill

The Federal Farm Bill dictates federal agricultural policy and funding, thus it is an important document to understand when determining the federal government's support of agriculture-based energy production. The 2002 Farm Bill, which is the most current version of this policy, is the first Farm Bill to contain an energy title (Title IX). Title IX promotes the development of agriculture-based renewable energy by encouraging the federal procurement of biobased products, providing grants and loans for renewable energy projects, and funding research and development of agricultural energy technologies. Sections of Title IX that contain financial incentives for the production of biomass energy include Section 9003 *Biorefinery Development Grants*, Section 9006 *Renewable Energy System and Energy Efficiency Improvements*, Section 9008 *Biomass Research and Development*, and Section 9010 *Commodity Credit Corporation Bioenergy Program*. The Farm Bill's Rural Development Title (Title VI) and Conservation Title (Title II) also contain potential financial incentives for agricultural renewable energy projects. Section 6401 of the Rural Development Title amends the Value-Added Agricultural Market Product Development Grants Program to allow renewable energy systems to qualify for grants and Section 2301 of the Conservation Title authorizes the Conservation Innovation Grants Program.

Although sections 9003 and 9010 of the 2002 Farm Bill contain incentives for certain types of biomass energy production, they do not offer incentives for manure-to-energy projects. Section 9003, which has not received funding from Congress since its creation in 2002, offers grants for the development and construction of biorefinery projects, whereas Section 9010, which was not authorized for FY07, offers payment support for the production of ethanol and biodiesel. Manure-to-energy projects would not qualify for funding under either of these programs. They may, however, be eligible for funding under the third Title IX section mentioned above, Section 9006.

Section 9006 established the Renewable Energy Systems and Energy Efficiency Improvements Program, which provides grants, loans, and loan guarantees to farmers, ranchers, and rural small businesses for the development of renewable energy projects and energy efficiency improvements. This program has proved to be very popular since its creation in the 2002 Farm Bill, with applications typically exceeding the program's available funds (see Figure 10). Between 2003 and 2005, this program awarded 434 projects a total of more than $66 million in grants and $10 million in loan guarantees. Of the grants that were awarded during this time period, 38% were for energy efficiency projects and 62% were for renewable energy projects. Renewable energy systems that have received grants from this program include wind turbines, anaerobic digesters, biofuel production facilities, and solar electric systems.[129]

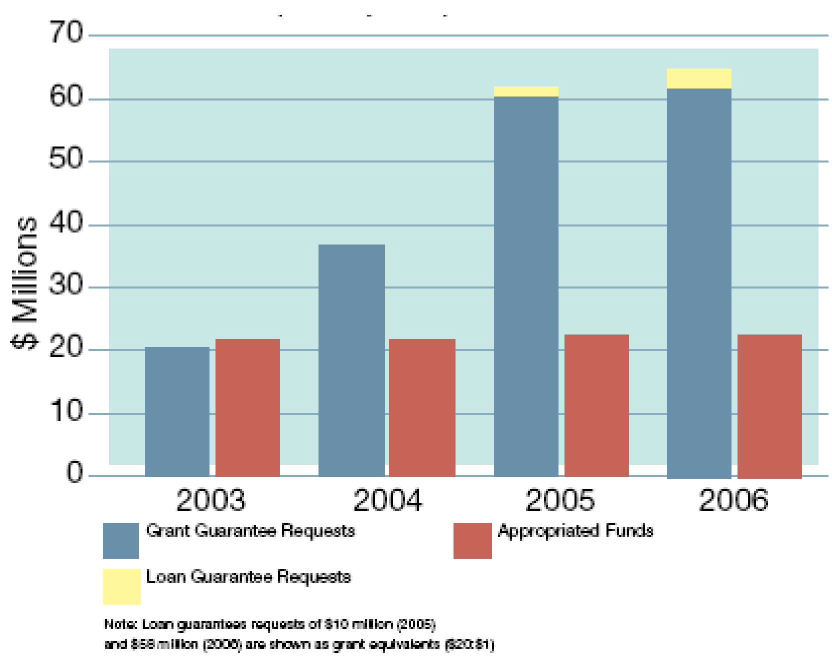

Figure 10. Grant/loan requests for the Section 9006 program compared to appropriated program funds.[130]

Section 9008 of the 2002 Farm Bill re-authorized the Biomass Research and Development Act of 2000, which provides for the distribution of grants through the Biomass Research and Development Initiative. Grants distributed under this program are awarded to eligible applicants for research, development, and demonstrations of biobased products, bioenergy, biofuels, biopower, and related processes.[131] Because these grants are primarily for research purposes, these grants may not be an appropriate funding source for manure-to-energy projects without a research focus.

The Value-Added Producer Grants Program, which was amended in Section 6401 of the Rural Development Title, may also be able to provide financial assistance to manure-to-energy projects. This program provides grants that can be used for planning activities and working capital for marketing value-added agricultural products and for farm-based renewable energy. Almost 950 grants have been awarded since the beginning of this program, including grants for anaerobic digestion projects.[132]

The Conservation Innovation Grant Program (CIG) is a third potential Farm Bill funding source for manure-to-energy projects. This program was authorized under the Environmental Quality Incentives Program (EQIP) by the Conservation Title in the 2002 Farm Bill. CIG provides grants to eligible applicants in an effort to stimulate the development and adoption of innovative conservation approaches and technologies that address natural resource conservation concerns. Because of this, manure-to-energy projects that enhance water resources by improving water quality may be eligible to receive grants from this program.

The 2002 Farm Bill's energy title programs have been largely successful to date. In his testimony before the U.S. Senate's Agricultural, Nutrition, and Forestry Committee in May 2007, Howard A. Learner, executive director for the Environmental Law and Policy Center, stated that: "With this Committee's leadership and only a modest financial investment, the 2002 Farm Bill took vital steps toward achieving energy independence through rural clean energy development. The Farm Bill's Energy Title programs are a model for successful agriculture and energy policy. Those programs which have received appropriations have been successful".[133]

As alluded to in the above statement, appropriate funding is needed for the operation and success of these programs. Unfortunately, program funding is often below authorized levels. Table 3 shows the authorized funding levels for several of the aforementioned Farm Bill sections, as well as the enacted and proposed funding levels for FY05-07.

Table 3. Funding levels for four of the sections related to bioenergy incentives in the 2002 Farm Bill.[134]

2002 Farm Bill Section	Authorized Level	FY05 Enacted	FY06 Enacted	FY07 Proposed
Section 9006: *Renewable Energy System and Energy Efficiency Improvements*	FY03-07: $23 million/yr FY07: $3 million/yr (FY07 reduced by the Deficit Reduction Act of 2005)	$23 million	$23 million	$10.2 million
Section 9008: *Biomass Research and Development Act*	FY03-07: $14 million + $49 million = $63 million/yr FY06-15: $200 million/yr (FY06-15 reauthorized in the Energy Policy Act of 2005)	$14 million	$12 million	$12 million
Section 9010:*Commodity Credit Corporation Bioenergy Program*	FY03: $115.5 million/yr FY04-06: $150 million/yr	$100 million	$60 million	$0 (not authorized for FY07)
Section 6401: *Value-Added Agricultural Market Product Development Grants Program*	$40 million/yr	$15.5 million	$20.5 million	$20.3 million

Although the energy programs in the 2002 Farm Bill are a good starting point, there is still room for improvement. Congress is reauthorizing the Farm Bill in 2007, providing an opportunity for changes and revisions to be made to the policy's clean energy programs. As part of their recommendations for the next Farm Bill, the Environmental Law and Policy Center (ELPC) has proposed that Congress improve the Renewable Energy Systems and Energy Efficiency Improvements Program (Section 9006) by:

1. Increasing funding from the current $23 million annual appropriation to at least $250 million by 2012.
2. Creating a block grant rebate program.

3. Restructuring the grants as production-based payments to prevent projects from losing some of the value of the federal production tax credit.
4. Expanding eligible applicants to include all farming operations.
5. Providing competitive grants to support feasibility studies and market development plans for renewable energy projects.
6. Increasing loan guarantee limits.[135]

ELPC considers an increase in funding to be the "single most important improvement to the Section 9006 program".[136] As mentioned previously, applications for this program typically exceed available funds, thus leaving many worthy projects unfunded. Improving and expanding this program would help provide more farmers, ranchers, and rural small business with assistance and funding for on-site and small-scale energy projects.

Renewable energy from agricultural sources is a priority issue for many of the farmers and stakeholders in the Chesapeake Bay watershed. In 2005, Pennsylvania, Virginia, Maryland, West Virginia, Delaware, the District of Columbia, and the Chesapeake Bay Commission developed a report entitled *2007 Federal Farm Bill: Concepts for Conservation Reform in the Chesapeake Bay Region.* The purpose of this report was to provide recommendations to Congress regarding the 2007 Farm Bill reauthorization. The report's recommendations were based on the outcome of forty listening sessions that were held throughout the Chesapeake Bay watershed involving more than one thousand individuals and stakeholder organizations. One of the five priority actions recommended by the report for the 2007 Farm Bill involved the production of renewable energy from agricultural sources. This recommendation stated that the Farm Bill should "provide increased support for the viability of agriculture by providing farmers with assistance in market development, renewable energy applications, and risk management". Specifically in regards to renewable energy and manure, the stakeholders suggested that the 2007 Farm Bill "target increased funding to facilitate the development of renewable energy production including biofuels and manure to energy solutions" and "provide cost-share funds and ready approval for a much wider array of tools and practices that enable farmers to create a value-added off-farm use of manure and poultry litter".[137]

USDA has also recognized that renewable energy is an important issue that should be addressed in the next Farm Bill. On January 31, 2007, Agriculture Secretary Mike Johanns unveiled USDA's 2007 Farm Bill proposals. Keep in mind that these are only proposals. At the time that this report was written, the final version of the federal 2007 Farm Bill had not yet been developed. USDA's proposal package for the 2007 Farm Bill included more than $1.6 billion in new renewable energy funding, including $500 million for a bioenergy and biobased product research initiative, $500 million for a renewable energy systems and efficiency improvements grants program, and $210 million to support an estimated $2.1 billion in loan guarantees for cellulosic ethanol projects in rural areas.[138]

In their proposal, USDA listed several recommendations for Energy Title IX detailing how the federal government could support the production of renewable energy in the country's agricultural sector. These recommendations include the following:

1. Create a new, temporary cellulosic bioenergy program to provide direct support to cellulosic ethanol producers.
2. Reauthorize and improve the Federal Procurement of Biobased Products program.
3. Reauthorize the Renewable Energy Systems and Energy Efficiency Improvements loan guarantee program.
4. Reauthorize the Renewable Energy Systems and Energy Efficiency Improvements grant program.
5. Add a biomass reserve program to the Conservation Reserve Program (CRP).
6. Increase the annual competitive grant funding in the Biomass Research and Development Act of 2000 for biomass research, focusing on cellulosic ethanol.
7. Create a Bioenergy and Bioproducts Research Initiative to expand USDA and university research.
8. Authorize mandatory funding for Forest Service Research in order to develop and improve technologies that use woody-biomass for energy production.[139]

Five of these eight recommendations may potentially benefit manure-to-energy projects and technologies by providing funding, accelerating research, and helping create markets. As mentioned earlier, however, many of these recommendations focus primarily on energy feedstocks other than manure.

Energy Policy Act of 2005

The Energy Policy Act of 2005 is another federal policy that contains provisions for agricultural renewable energy production. Title IX of this Act, which is dedicated to energy research, development, demonstration, and commercial application, includes a subtitle on agricultural biomass research and development programs (Subtitle D). This subtitle consists of eight sections:

Section 941 *Amendments to the Biomass Research and Development Act of 2000*
Section 942 *Production incentives for cellulosic biofuels*
Section 943 *Procurement of biobased products*
Section 944 *Small business bioproduct marketing and certification grants*
Section 945 *Regional bioeconomy development grants*
Section 946 *Preprocessing and harvesting demonstration grants*
Section 947 *Education and outreach*
Section 948 *Reports*

Similar to the USDA 2007 Farm Bill proposal, many of these sections focus primarily on agricultural energy feedstocks other than manure. For example, Sections 942 and 946 are dedicated to cellulosic biomass.

The Biomass Research and Development Initiative, which was previously re-authorized in Section 9008 of the 2002 Farm Bill, was amended by Section 941 of this Energy Policy Act. Section 941 increased authorization of this initiative to $200 million for FY06-15 (see Table 3) and it expanded the initiative beyond just research to include the development and demonstration of biobased fuels and products.[140]

Unfortunately, funding for biomass programs in the Energy Policy Act is expected to fall short of authorized levels in fiscal year 2007. The President's FY07 budget provides only $161.7 million for these programs, totaling just 11% of the authorized funds.[141]

State Policies

When looking at political incentives and impediments for manure-to-energy projects, state policies, in addition to federal policies, need to be taken into account. The Chesapeake Bay watershed includes parts of six states: Maryland, Virginia, Pennsylvania, Delaware, West Virginia, and New York, as well as the District of Columbia. Due to individual state policies and regulations, different regions of the watershed have different levels of acceptance for renewable energy projects.

Based on the policies and regulations that have been enacted thus far, it seems as if the watershed as a whole is showing an increased interest in renewable energy. In fact, some of the watershed states even seem to be showing an increased interest specifically in litter-to-energy projects. For example, Maryland's Attorney General Doug Gansler is currently pushing for a large commercial-scale litter-to-energy plant to be built on Maryland's Eastern Shore. This plant, if built, would be similar to the Fibrominn plant that was recently built by Fibrowatt in Benson, Minnesota.[142]

Renewable Portfolio Standards

A renewable portfolio standard (RPS) encourages the increased production and use of renewable energy by requiring that a certain amount of the electricity sold by an electrical utility be generated by renewable energy resources. To date, a national RPS has not yet been adopted by the federal government. The Senate version of the Energy Policy Act of 2005 included a mandatory RPS, but the provision was dropped due to opposition in the House. The Senate version would have required all utilities under the jurisdiction of the Federal Energy Regulatory Commission (FERC) to generate at least 10 percent of their electricity from renewable sources by 2020.[143] Although an RPS was not included in the Energy Policy Act, the Act did require the federal government to purchase an increasing portion of its power from renewable sources, specifically 3% in fiscal year 2007 and increasing to 7.5% in 2013.[144]

Even though there is not currently a federal RPS, a number of states throughout the country have adopted jurisdictional renewable portfolio standards. In the Chesapeake Bay watershed, such policies have been adopted by Delaware, Maryland, Pennsylvania, New York, and the District of Columbia. As of October 2007, Virginia and West Virginia were the only two states in the watershed that had not yet adopted such a policy, although Virginia had adopted a voluntary renewable energy portfolio goal.[145]

Delaware's RPS, which was enacted in 2005 and revised in 2007, requires that the state's electric utilities use renewable energy to generate at least 20% of the electricity that they sell in Delaware by 2019, of which 2% must be generated by solar photovoltaics. Eligible renewable technologies include solar thermal electric, solar water heat, photovoltaics, landfill gas, wind, biomass, hydroelectric, geothermal electric, anaerobic digestion, tidal energy, wave energy, ocean thermal, and fuel cells using renewable fuels.[146]

Maryland enacted their Renewable Energy Portfolio Standard and Credit Trading Act in May 2004 and revised it in 2007. The RPS included in this act requires that renewable energy be used to generate at least 9.5% of the energy sold by Maryland's electric utilities by 2022. Eligible renewable energy sources are divided into two tiers. Tier 1 requirements begin at 1% in 2006 and increase to 9.5% in 2022 (2% of which must come from solar power). Tier 2 requirements begin at 2.5% and remain at that level until 2019 when Tier 2 is eliminated. Tier 1 sources include solar; wind; qualifying biomass (excluding sawdust); methane from the anaerobic decomposition of organic materials in a landfill or wastewater treatment plant; geothermal; ocean; fuel cells powered by methane or biomass; and small hydroelectric plants. Tier 2 sources include hydroelectric power, waste-to-energy facilities that were in existence as of January 1, 2004, and possibly poultry litter incineration. Poultry litter incineration will only be included as a Tier 2 source if it is determined that there is a "sufficient quantity of poultry litter available for the economic viability of any existing and operating entity that is sited on the Delmarva Peninsula and that, as of July 1, 2004, processes and pasteurizes chicken litter as fertilizer".[147] Maryland's Attorney General Doug Gansler recently urged state lawmakers to revise this law in order to include poultry litter-to-energy systems as a Tier 1 source. This change, however, has not yet been made.[148]

In November 2004, Pennsylvania enacted Act 213, which is the Alternative Energy Portfolio Standards Act of 2004. The RPS in this act requires that Pennsylvania's electric utilities use renewable energy sources to generate 18% of the electricity that they sell to customers by May 31, 2021. Specifically, 8% of their electricity must be generated from Tier 1 renewable energy sources and 10% must be generated from Tier 2 renewable energy sources. Tier 1 sources include photovoltaic energy, solar-thermal energy, wind, low-impact hydro, geothermal, biomass, biologically-derived methane gas, coal-mine methane, and fuel cells. Tier 2 sources include waste coal, distributed generation systems, demand-side management, large-scale hydro, municipal solid waste, pulping process and wood-manufacturing byproducts, and integrated combined coal gasification technology.[149]

New York adopted a statewide RPS in September 2004. Their standard, which applies to investor-owned utilities, requires that 25% of the state's electricity be generated by renewable sources by the end of 2013. At the time that this standard was adopted, 19% of the state's electricity was already being generated by renewable sources. Eligible sources identified in this RPS are photovoltaics, landfill gas, wind, biomass, hydroelectric, fuel cells, CHP/cogeneration, biogas, liquid biofuel, anaerobic digestion, tidal energy, wave energy, ocean thermal, ethanol, methanol, and biodiesel. These sources are divided into two tiers: a Main Tier and a Customer-Sited Tier. Sources eligible for the Customer-Sited Tier include fuel cells, photovoltaics, wind turbines, and anaerobic digestion systems.[150] Anaerobic digestion systems were added to this list in November 2005 after a petition was filed by the Farm Bureau of New York.[151]

The District of Columbia's RPS, which was enacted in January 2005, requires that 11% of the electricity sold in DC be generated by renewable sources by 2022. Eligible renewable sources are divided into two tiers. The percentage of electricity required from Tier One sources begins at 1.5% in 2007 and increases to 11% by 2022, whereas the percentage of electricity required from Tier Two sources begins at 3.5% and decreases to 0% by 2022. Tier One sources include solar, wind, biomass, landfill gas, waster-treatment gas, geothermal, ocean, and fuel cells fueled by Tier One sources. Tier Two sources include hydropower and municipal solid waste.[152]

Virginia's renewable portfolio standard differs from that of the other states in that it is a voluntary goal rather than a requirement. This goal, which was established in April 2007, encourages investor-owned utilities to produce a percentage of the electricity that they sell in VA from eligible renewable energy sources. Eligible sources include solar, wind, geothermal, hydropower, wave, tidal, and biomass energy, with wind and solar power receiving a double credit towards RPS goals. As incentives for the utilities to participate, the state will allow for RPS program cost recovery and they will provide a performance incentive in the form of an increased rate of return for each of the RPS goals that are reached. This voluntary program outlines a set of three goals:

- Goal I: 4% of base year (2007) sales in 2010 generated by renewable sources
- Goal II: 7% of base year (2007) sales in 2016 generated by renewable sources
- Goal III: 12% of base year (2007) sales in 2022 generated by renewable sources[153]

Similar to RPS policies, there is an initiative called 25x'25 that, if adopted, may help encourage the development and use of agricultural renewable energy technologies throughout the region. 25x'25 is a renewable energy initiative that is grassroots-led and supported that calls for agriculture to supply a significant portion of the country's energy in the coming years. The 25x'25 vision is that "by the year 2025, America's farms, ranches, and forests will provide 25 percent of the total energy consumed in the United States, while continuing to produce safe, abundant and affordable food, feed, and fiber".[154]

In order to meet this goal, the 25x'25 action plan calls on farmers, ranchers, and forest landowners to: produce biomass and create value-added energy feedstocks and biobased products from plant residues, processing byproducts and animal wastes; generate electricity using wind power, solar energy and biogas emissions; and increase the production of liquid transportation fuels. Although this action plan does not specifically mention generating energy from poultry litter, litter-to-energy technologies may still indirectly benefit from the plan's efforts to implement supportive policies in a number of areas, including policies that:

- Increase production of renewable energy
- Deliver renewable energy to markets
- Expand renewable energy markets
- Improve energy efficiency and productivity
- Strengthen conservation of natural resources and the environment[155]

Over 350 key groups, such as the American Farm Bureau Federation and the National Farmers Union, have announced their support for this initiative. In addition, several governors in the Chesapeake Bay region have endorsed the 25x'25 vision: Pennsylvania's Governor Ed Rendell, Virginia's Governor Tim Kaine, Maryland's former Governor Robert Ehrlich, and New York's former Governor George Pataki. There is also federal interest. In January 2007, 25x'25 Concurrent Resolutions that would establish 25x'25 as a national vision were re-introduced in both houses of Congress.[156]

Maryland's Water Quality Improvement Act of 1998

Maryland's Water Quality Improvement Act of 1998 increases the need for alternative uses of poultry litter within the state. This Act imposes new regulations that are aimed at reducing nutrient loads into the Bay from animal production. These regulations include new restrictions on the application of poultry litter to cropland as fertilizer. Because of these new restrictions, land application of poultry litter is not always feasible. This makes alternative uses of poultry litter, such as energy production, more desirable. The Inter-Agency Nutrient Reduction Oversight Committee was created in order to carry out the provisions of this act. This Committee recognized the potential need for alternative uses of poultry litter and they provided funds from the Animal Waste Technology Fund, which is no longer authorized, for pilot studies on alternative uses, including energy production.[157]

Maryland's Statewide Plan for Agricultural Policy and Resource Management

On June 16, 2006, the Maryland Agricultural Commission released a new agricultural strategic plan entitled "Statewide Plan for Agricultural Policy and Resource Management". The Commission developed this plan in conjunction with an Advisory Committee and American Farmland Trust. This state plan focuses on three issue areas: 1) enhancing profitability; 2) ensuring an adequate base of well-managed agricultural land; and 3) advancing research, education, and the advocacy of agriculture. These issue areas were selected based on public input.

The section of this plan that relates to litter-to-energy projects is the Enhancing Profitability section. One of the three marketing endeavors identified in this section is the promotion of bio-energy product development and use: "Ethanol and biodiesel production and the use of biomass would enhance the market for some of Maryland's agricultural products and byproducts, help diversify current production, and help offset increasing energy prices". In order to promote this market endeavor, this plan recommends that the state support incentives that would increase the production and use of bio-energy. Although poultry litter is considered a form of biomass, the specific actions recommended in this plan focus primarily on ethanol and biodiesel production.[158]

Pennsylvania's Energy Development Plan (Draft)

In Pennsylvania, the Pennsylvania Energy Development Authority (PEDA) was created by the state's Energy Development Authority and Emergency Powers Act of 1982. This authority has the ability to help finance energy projects by awarding grants, loans, and loan guarantees and by issuing revenue bonds and notes. PEDA released its most recent Energy Development Plan in draft form in April 2006. This document describes PEDA's energy policy goals and outlines a plan for the authority's distribution of financial and technical assistance. The five policy objectives that are listed in this plan are:

1. Enhancing energy security and energy diversity
2. Promoting cleaner, more environmentally beneficial energy production
3. Increasing economic growth for the clean energy sector
4. Furthering technological innovation in critical areas and promoting energy efficiency
5. Increasing public confidence and support in clean energy technologies

Technologies that PEDA considers to be advanced energy technologies include solar energy, wind, low-impact hydro-power, geothermal, biologically derived methane gas, biomass, fuel cells, coal-mine methane, waste coal, coal liquefaction, coal polygeneration, integrated gasification combine cycle, biodiesel, ethanol, and demand management measures.[159] PEDA's adoption of this plan may result in increased funding and support for litter-to-energy projects within the state.

Air Quality Regulations

All litter-to-energy projects are required to be in compliance with federal and state air quality regulations. The regulations that a project needs to comply with are very site/project specific. They depend on several factors, including:

- The amount of emissions allowed in the site's current permit
- How the proposed project will affect the site's emissions
- The size of the project
- What type of equipment will be used
- Whether the site is in an attainment or non-attainment area (explained below)
- Whether or not the project will trigger PSD or Title V (explained below)[160]

Because every project must comply with all relevant air quality regulations, the fact that there are litter-to-energy projects already in existence is evidence that projects such as these are capable of meeting the current requirements.

Air Quality Requirements

As part of the Clean Air Act, the U.S. Environmental Protection Agency is required to set National Ambient Air Quality Standards (NAAQS) for certain air pollutants. EPA has developed standards for six "criteria pollutants": ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. These pollutants have been selected to serve as air quality indicators. Geographic areas that meet the NAAQS for these pollutants are classified as "attainment areas", whereas geographic areas that exceed the NAAQS are classified as "nonattainment areas". According to EPA, "nonattainment classifications may be used to specify what air pollution reduction measures an area must adopt and when the area must reach attainment".[161] EPA's AirData website provides information on which U.S. counties are classified as nonattainment areas:
http://www.epa.gov/air/data/nonat.html?us~USA~United%20States.

The Clean Air Act and its amendments also establish several air quality permitting programs, including the New Source Review (NSR) program, the Prevention of Significant Deterioration (PSD) permitting program, and the Title V Operating Permit program. The NSR and PSD programs require that a permit be obtained before construction is started on a new major or significant source of air pollution or before modifications are made to an already existing major or significant source of air pollution.[162] "Major" sources of pollution typically have the potential to emit at least 100 tons per year of a criteria pollutant, whereas "significant" sources of pollution surpass a designated threshold for either a criteria pollutant or for certain non-criteria pollutants.[163] NSR and PSD permits specify necessary air pollution control devices, emission limits, and operation procedures. Pollution sources in nonattainment areas are required to obtain nonattainment NSR permits, whereas pollution sources in attainment areas are required to obtain PSD permits. If a source does not require either of these permit types, it may still be required to obtain a minor NSR permit.[164] Minor NSR permits are often issued to prevent the construction of sources that would interfere with NAAQS attainment.[165]

Title V permits are designed to reduce violations of air pollution laws. They do this by consolidating all of a facility's air pollution requirements into one document; adding monitoring, testing, and/or record keeping requirements; and requiring the facility to annually report whether or not it is in compliance with the permit's pollution limits. Title V permits are required for major industrial sources and certain other sources.[166]

Title V permits, NSR permits, and PSD permits are usually issued by state and local permitting authorities, although PSD permits are also sometimes issued by the EPA. The following state agencies are responsible for issuing permits in the watershed:

- Maryland Department of the Environment
- Delaware Department of Natural Resources and Environmental Control
- Pennsylvania Department of Environmental Protection
- Virginia Department of Environmental Quality
- West Virginia Department of Environmental Protection
- New York State Department of Environmental Conservation

As mentioned previously, the necessary permits and requirements are very project specific. Therefore, it is important that the appropriate department be contacted during the planning stages of a project to determine what the permit requirements are for that particular project.

It may be difficult to acquire air quality permits for combustion processes in some regions, such as the Delmarva Peninsula, due to the region's already poor air quality status.[167] As a result of their degraded air quality, Delaware, which is located on the Delmarva Peninsula, does not allow the construction of off-site poultry litter incineration facilities. Their regulations permit only on-site poultry litter incineration by farmers, with litter being supplied only by the farm on which the system is located on and the adjacent farm.[168]

In order to help limit air quality degradation in Maryland, the state places restrictions on project size. Since smaller projects are less efficient and are therefore often unable to meet particulate matter and visible emission standards, projects in eastern and western Maryland are required to have a rated heat input of at least 13 million BTU per hour and projects in central Maryland are required to have a rated heat input of at least 35 million BTU per hour.[169]

Virginia's Department of Environmental Quality is currently trying to determine whether or not litter-to-energy projects should be classified as incinerators. If they do decide to classify them as incinerators, then every project, regardless of its size, would require a state permit.[170]

Air Emissions from an Industrial Scale Litter-to-Energy Project

Several years ago, Fibrowatt, LLC proposed that an industrial scale poultry litter fueled power plant called FibroShore be built on Maryland's eastern shore. If this plant were built, it would be required to meet stringent air emission permit limits. These limits would be set by the Maryland Department of the Environment. Air pollutants that would be limited by permit conditions would most likely be particulate matter, nitrogen oxides, carbon monoxide, sulfur dioxide, and hydrogen chloride.[171] In order to meet these emission limits, the FibroShore plant proposed to install the following emission control techniques:

- Particulate Matter**:** Fabric Filter
- Nitrogen Oxides**:** Selective Noncatalytic Reduction or Selective Catalytic Reduction
- Carbon Monoxide and Volatile Organic Compounds**:** Good Combustion Practice
- Sulfur Dioxide**:** Spray-Dry Adsorber (scrubber) and a Fabric Filter
- Hydrogen Chloride**:** Spray-Dry Adsorber (scrubber)[172]

Limits for most of the emitted pollutants would be based on Best Available Control Technology (BACT) requirements. However, because Maryland is located in the U.S. EPA designated Ozone Transport Area, emission limits for nitrogen oxides would be based on the more stringent Lowest Achievable Emissions Rate (LAER) technology requirements. Permit compliance would be monitored by either continuous emission monitors or by periodic stack emissions tests.[173] In addition to the air pollutants already mentioned, a plant such as this would also emit small amounts of metals, ammonia, arsenic, mercury, and organic compounds such as dioxin.[174,175]

In 2001, Alternative Resources, Inc. conducted a preliminary analysis of the expected air emissions from the proposed FibroShore plant. As part of this study, they compared the expected emissions from the FibroShore plant to emissions from wood, oil, and coal power plants:

<u>Metals:</u>
FibroShore ≤ Wood, Oil, Coal

<u>Particulate Matter:</u>
FibroShore ≈ Wood ≈ Oil ≈ Coal

<u>Dioxins:</u>
Wood, **FibroShore** < Coal

<u>Nitrogen Oxides:</u>
FibroShore ≈ Wood ≈ Oil ≈ Coal

<u>Acid Gases:</u>
Wood < **FibroShore** < Oil, Coal

<u>Carbon Monoxide:</u>
FibroShore ≈ Wood ≈ Oil ≈ Coal

According to their findings, the FibroShore plant is expected to emit amounts of particulate matter, nitrogen oxides, carbon monoxide, and trace metals that are similar to emissions from wood, oil, and coal power plants; whereas FibroShore's anticipated dioxin emissions are expected to be less than those from coal plants and their acid gas emissions are expected to be less than those from both coal and oil plants.[176]

After conducting this analysis, Alternative Resources, Inc. concluded that: "The FibroShore plant, as planned, can reasonably be expected to meet all applicable air regulations of the MDE and U.S. EPA. Thus, the prospects for successful permitting of the plant in Maryland are excellent".[177] While the FibroShore plant is only a proposal, construction of a similar Fibrowatt plant, called Fibrominn, is currently underway in Benson, Minnesota. In 2002, the Citizens' Board of the Minnesota Pollution Control Agency unanimously approved the air quality permit for the Fibrominn plant, indicating that this facility would meet all of the federal and state air quality requirements.[178]

By burning poultry litter and forestry residue instead of fossil fuels, facilities such as the proposed FibroShore plant and the Fibrominn plant could provide significant reductions in greenhouse gas emissions. According to the Alternative Resources, Inc. report, the FibroShore plant, which was designed to produce 40 megawatts of electric power, "would avoid about 583,000; 403,000; and 291,000 tons per year of greenhouse gas emissions, respectively, compared with generating the same power using coal, oil, or natural gas fuels".[179] Litter-to-energy facilities emit carbon dioxide, which is a type of greenhouse gas; however, the U.S. EPA does not consider this to be a greenhouse gas emission because the combustion of poultry litter and forestry residue simply recycles carbon that is already in the environment. It does not release new carbon into the environment, which is what occurs when fossil fuels undergo combustion.[180]

V. Economic Incentives and Impediments

Litter-to-energy systems are currently very expensive, with costs typically ranging anywhere from several hundred thousand dollars to over one hundred million dollars. Because of these high costs, financial assistance is nearly always needed to make these projects economically feasible. Forms of financial assistance that litter-to-energy projects may be eligible for include tax credits, grants, and loans.

Tax Credits

Federal Tax Credit

The federal renewable energy production tax credit (PTC) is a per kilowatt-hour tax credit for electricity that is generated by qualified renewable energy resources. Eligible sources include electricity produced from wind power, geothermal power, biomass, landfill gas, hydroelectric, small hydroelectric, municipal solid waste, refined coal, and Indian coal. The PTC provides a maximum 1.9 cents per kilowatt-hour benefit for the first ten years of a renewable energy facility's operation. Technologies such as wind, solar, geothermal, and "closed-loop" bioenergy facilities can receive the maximum tax credit, whereas technologies such as "open-loop" biomass, incremental hydropower, small irrigation systems, landfill gas, and municipal solid waste receive a tax credit of lesser value. In December 2006, the Tax Relief and Health Care Act of 2006 extended this credit through 2008. According to the Database of State Incentives for Renewables and Efficiency

(DSIRE), certain poultry-waste energy resources are considered to be eligible for this tax credit.[181]

Maryland Tax Credit

Maryland is the only Chesapeake Bay watershed state that offers a state tax credit for renewable electricity production, and it is one of two watershed states that has a tax credit program that may be able to benefit manure-to-energy systems. Maryland's tax credit is called the Clean Energy Production Tax Credit and eligible electricity sources include electricity generated by wind, geothermal energy, solar energy, hydropower, small irrigation power, municipal solid waste, and biomass resources. Eligible biomass resources include anaerobic digestion; landfill gas; wastewater-treatment gas; and cellulosic material that is derived from either forest-related resources (excluding old-growth timber), waste pallets, and crates or agricultural sources. According to DSIRE: "An individual or corporation that applies for and receives certification from the Maryland Energy Administration may claim a credit equal to 0.85 cents per kilowatt-hour against the state income tax, for a five-year period, for electricity generated by eligible resources. The electricity generated must be sold to an unrelated person during the taxable year".[182] Unless anaerobic digestion or thermal decomposition processes are used, litter-to-energy projects may not be eligible for this tax credit at this time.[183]

Pennsylvania Tax Credit

Pennsylvania is the other watershed state that has a tax credit program that may be able to benefit manure-to-energy systems. In July 2007, the Pennsylvania General Assembly and Governor Rendell approved Act 55, which included a new tax credit program for agriculture and participating businesses called the Resource Enhancement and Protection Program (REAP). This program offers transferable tax credits to farmers for the establishment of a number of conservation practices that will help protect the area's natural resources. A farmer who is enrolled in this program would be eligible for up to $150,000 in tax credits over the life of the program. Applicants may receive between 25% and 75% of project costs as state tax credits, depending on the type of best management practice implemented.[184, 185] Since eligible best management practices include alternative manure technologies, manure-to-energy systems may be able to benefit from this new program.[186]

Funding Sources

There are also many potential funding sources for manure-to-energy systems and research. A list of some of the past and present funding sources is found in Appendix B. Not all manure-to-energy projects will be eligible for all of the funding sources listed in this table. The listed funding programs have varying objectives, applicant types, and award amounts.

The following are several examples of funding programs that have provided financial assistance to various manure-to-energy projects to date (please note that this is not a complete list and that other funding sources may have also funded similar projects):

- Anaerobic digestion
    - Farm Pilot Project Coordination, Inc.
    - PA Energy Harvest Program

- Renewable Energy Systems and Energy Efficiency Improvements Program
    - Small Business Innovation Grant
    - Sustainable Energy Fund of Central Eastern Pennsylvania
    - Value-Added Producer Grants*
- Pyrolysis
    - PA Energy Harvest Program
    - Small Business Innovation Grant*
- Gasification
    - Conservation Innovation Grant*
    - Farm Pilot Project Coordination, Inc.*
- Bio-Oil
    - Farm Pilot Project Coordination, Inc.*
- Biomass Heat System
    - PA Energy Harvest Program*

* At least one of the funded projects indicated that it specifically used poultry litter as a fuel, rather than another manure type

Profit Options

Once a litter-to-energy system is installed and operating, there are also a number of ways that it could potentially generate a profit. These options include net metering, green pricing programs, renewable energy certificates (RECs), trading programs, ash sales, and heat generation. The potential profit options are discussed in more detail below and are summarized in Appendix C. Not all of these options are currently available for a litter-to-energy project in the Chesapeake Bay watershed; however, they are worth mentioning because they could one day be offered in this region.

In addition, it is important to note that although there are a number of potential profit options in existence, a litter-to-energy project may not be able to benefit from all of these options due to certain regulations. For example, participating in net metering, green pricing programs, and trading programs may affect the number of RECs, if any, that a renewable energy project receives.

Net Metering

With net metering, you do not necessarily make a profit. Instead, the energy that is generated by the litter-to-energy project can be used to offset the site's energy consumption. Essentially, this means that during times when electricity generation exceeds electricity use, the excess electricity is banked for use at another time. The electricity that is banked replaces electricity that would have been purchased at the retail rate. When the amount of excess electricity generated in a billing period exceeds the amount of electricity consumed in a billing period, the customer is usually credited for this 'net excess' at either the retail rate or at the avoided cost rate, depending on the state.[187] In order to participate in a net metering program, the customer must have a bi-directional meter. Bi-directional meters register the flow of electricity both to and from a site. Residential and small commercial sites are often already equipped with a bi-directional meter, although sometimes a new meter will need to be installed.[188]

If net metering programs are not available, then the customer is only able to use the electricity that they generate to offset the electricity that they are using at that instant. They cannot bank excess electricity to be used at another time. Without a net metering program, excess electricity can often be sold to the utility, but only at the avoided cost price, which is much lower than the retail price.[189] Fortunately net metering programs are offered in all of the Bay states, although the details of these programs vary between jurisdictions. Appendix D describes the rules for net metering as of Spring 2007 in each of the Bay states. Please note that biomass is included as an eligible technology in all of these programs.

Green Pricing Programs

Green pricing is an optional utility service in which participating customers pay a premium on their electric bills to support the utility's investment in renewable energy technologies. Several states have adopted policies that require electricity suppliers to offer green power options; however, none of the watershed states have adopted such policies as of yet.[190] Despite this, some of the electrical utilities located in the watershed do offer green pricing options to the customers in their service area.

In Maryland, Virginia, and Washington D.C., local electrical utilities such as Baltimore Gas and Electric, Pepco, and Dominion Virginia Power offer their customers the option of purchasing green power, which is provided by Pepco Energy Services. Pepco Energy Services, which is a subsidiary of Pepco Holdings, Inc., is a leader in supplying renewable electricity in the Mid-Atlantic region. The two programs that Pepco Energy Services offers through the aforementioned utilities are the NewWind Energy Program, which offers electricity generated by wind farms, and the Green Electricity Program, which offers electricity generated by a variety of renewable sources, including hydroelectric plants, solar panels, wind farms, and biomass fuels. In March 2007, the premium that a customer could pay to participate in these programs ranged from $0.1156 and $0.1319 per kWh, depending on the utility.[191] In addition to these pricing programs, green pricing programs are also offered by certain utilities in the watershed states of Pennsylvania and New York.[192]

Currently none of the optional green pricing programs offered by the utilities in the Chesapeake Bay watershed include energy generated from manure. Because of this, litter-to-energy projects in the watershed may not benefit from current green pricing programs; however, they may be able to benefit from similar programs in the future. A green pricing program that supports farmers generating energy from cow manure is already operating in Vermont.

Central Vermont Public Service (CVPS), which is the largest of Vermont's twenty-one utilities, created a green pricing program called Cow Power in late 2004. This program gives customers the option of paying a premium of 4 cents per kWh on their electric bill in order to support the generation of renewable energy by dairy farms in the region. The premium paid by the customers often goes directly to the participating farmers. In addition to receiving the 4 cent premium for every kWh bought by CVPS, the farmers are also paid 95% of the market price for the electricity that they generate and sell back to the utility. If customers request more Cow Power kWh's than are being produced by the dairy farms, then the premium will either go towards purchasing Renewable Energy Certificates from other renewable energy sources in the region or it will be deposited into the CVPS Renewable Development Fund. Money from the Renewable Development Fund is used to provide incentives to farmers in order to promote farm energy generation.[193]

Dairy farms that participate in the CVPS Cow Power program generate energy through the anaerobic digestion of agricultural products, bi-products and wastes, specifically cow manure. There are three dairy farms currently producing electricity for this program and another three farms are expected to be online by the end of 2007. Each of these farms produce, or is expected to produce, between 1.2 and 3.5 million kWh's of electricity annually.[194]

At first there were doubts about whether or not customers would be willing to pay a premium for this optional service. Today, however, over 3,700 customers have opted to enroll in the CVPS Cow Power program.[195] When enrolling, customers are given the option of purchasing 25%, 50%, or 100% of their electricity through the Cow Power program. This typically increases their monthly electric bill between $5 and $20.[196] The positive support that the Cow Power program has received so far suggests that one day programs similar to this may also be available in other regions of the country, perhaps in the Chesapeake Bay watershed. If this does happen, it could potentially provide an additional income stream for farmers who generate electricity using poultry litter.

Renewable Energy Certificates

Certified projects that generate renewable electricity earn renewable energy certificates (RECs), which are also known as tradable renewable certificates, renewable energy credits, green certificates, and green tags. Rather than representing the actual electricity that is generated by a renewable energy project, RECs instead represent the electricity's environmental attributes. RECs can usually be sold separately from the electricity that is generated by the project, thus providing the producers with another source of profit.[197] RECs, which are typically in 1 megawatt-hour units, were being sold for between $200 and $300 in 2006.[198]

RECs provide a way for a customer to purchase renewable energy even if their local electricity supplier does not offer a green power option. When RECs are purchased, a customer does not necessarily receive a "delivered" power product, which is when the project's generated electricity is fed directly into the electric grid that the customer is connected to. However, by purchasing RECs, the customer is still able to offset a portion of their electricity use with energy generated by a renewable source. Typically local energy producers sell their RECs to a broker, who then aggregates them and sells them to a buyer.[199]

It is important to note that in some states, participating in other profit options may affect the number of RECs that a renewable energy producer receives. For example, if a producer in the watershed wishes to receive carbon offset credits for their renewable energy system, then they must agree to surrender and retire any REC credits that their project qualified for.[200]

Trading Programs

In addition to RECs, litter-to-energy projects may potentially be able to generate greenhouse gas and water quality credits. As mentioned previously, litter-to-energy projects can provide significant reductions in greenhouse gas emissions. The Chicago Credit Exchange (CCX), which is the nation's only greenhouse gas emissions market, allows CCX members who are unable to reduce their emissions to purchase credits from members who make extra emission cuts or from verified offset projects. One carbon credit is equal to one metric ton of carbon dioxide emissions.[201] Eligible agricultural offset projects currently include methane capture and combustion, no-till and low-till farming, grass cover planting, and certain renewable energy systems.[202, 203] In order for a renewable energy system to qualify for this program, the energy it generates must not be sold as "green" energy or be used to meet renewable portfolio standard mandates. In addition, any REC credits the project qualified for must be surrendered and retired.[204]

Water quality credit trading programs are also beginning to emerge in the Chesapeake Bay watershed. These programs allow a pollution source to achieve its pollution reduction requirements by purchasing credits from a credit-generating source in the same watershed. Depending on the program, the credits can be generated by either point or nonpoint sources. Point sources are sources that discharge pollution at an identifiable "end of pipe" location, such as wastewater treatment plants. Nonpoint sources are diffuse sources of pollution that cannot be attributed to a specific location, such as agricultural runoff. Litter-to-energy projects that reduce nutrient pollution and provide a water quality benefit may one day be eligible to earn marketable credits in trading programs such as these, although no such trade has taken place as of yet. Water quality credit trading programs that allow point-to-nonpoint trades were recently established in Pennsylvania and Virginia and have been proposed in Maryland, Delaware, and West Virginia.[205] In April 2007, it was reported that a typical nutrient credit was worth between $2 and $9 for the reduction of approximately 1.6 pounds of pollutants.[206]

Ash Sales

Another potential way to profit from litter-to-energy production is to sell the nutrient-rich ash byproduct as fertilizer. This was suggested in a number of reports, including *Economic Value of Poultry Litter Supplies in Alternative Uses* by Erik Lichtenberg, Doug Parker, and Lori Lynch,[207] *Poultry Litter to Energy: Technical and Economic Feasibility* by B.R. Bock,[208] and *Economic and Technical Feasibility of Energy Production from Poultry Litter and Nutrient Filter Biomass on the Lower Delmarva Peninsula* by Antares Group Incorporated, T.R. Miles Technical Consulting, Inc., and the Foster Wheeler Development Corporation.[209]

The litter-to-energy process concentrates nutrients such as phosphorus and potassium in the ash, creating a product that is denser and more stable than raw manure.[210] In addition, the ash lacks the pathogens and odors that are typically present in poultry litter feedstock.[211] According to Bock's report, "these benefits greatly simplify export and use of poultry litter nutrients outside of concentrated poultry areas".[212] Selling the ash as a fertilizer would also make a project such as this more economically viable. After taking into account transportation costs, additional processing costs, and marketing costs, Bock's report determined that the net fertilizer value of poultry litter ash at an energy plant would likely range from $25 to $75 per ton.[213] Another estimate, which was conducted in 2002, determined that ash sales would likely bring in between 0.7 and 1.3 cents per kilowatt-hour of energy generated.[214] These sales would potentially be able to help offset the cost of the project, as well as provide an additional source of income. In addition to ash, bio-char is another byproduct produced by some of the thermal processes discussed in this report that could also potentially be sold as a fertilizer.

Heat Generation

Besides providing a possible source of income for farmers, litter-to-energy systems may also provide a way for them to save in operating costs. Certain on-site litter-to-energy systems, such as gasifiers, could be used to heat a site's poultry houses. Using heat generated by a litter-to-energy system would displace some of the fossil fuel that is traditionally needed to heat the houses. This could potentially result in a significant cost savings because, according to an article by the Foundation for Organic Resources Management, Inc., "fuel for space heating is typically the single greatest operating expense for broiler and turkey producers in the United States".[215] Assuming that the price of propane is $1 per gallon and each house uses 4,000-6,000 gallons of propane per year, a typical four-house broiler operation would spend between $16,000 and $24,000 per year on propane.

Reducing fuel costs, however, may not directly benefit poultry growers on the Delmarva Peninsula. In this region, contracts between poultry growers and poultry companies differ from contracts used in most other regions of the country. On the Delmarva Peninsula, contracts require that the poultry company pay for the propane used by the poultry grower. Because the propane is already provided free of charge to the poultry grower, they would not directly benefit from any savings in fuel cost (although the poultry company could decide to pass this savings on to the grower). Due to this difference in contracts, litter-to-energy technologies that can be used to offset electric costs on a farm may be more beneficial to growers in this region than technologies that can be used to offset propane costs.[216]

VI. Conclusions

The findings of this report suggest that using poultry litter for energy generation is a potential use for excess litter found in the Chesapeake Bay watershed. From a technological standpoint, the thermal processing of poultry litter is generally feasible. The main technological concerns regarding these systems typically involve fuel handling, maintenance issues, emissions control, and slagging and fouling of the equipment. Combustion and gasification are well studied and the actual implementation of these technologies shows that in most cases, the main barriers instead tend to be economical, political, or based on litter availability. The political and economic incentives and impediments that have been discussed throughout this report are summarized in the following boxes:

Incentives & Support	Disincentives & Impediments
• The amount of excess litter in the watershed is expected to increase due to loss of cropland, more concentrated animal operations, transition to phosphorus-based plans, and other regulations that limit land application. • Increased interest in alternative energy by federal and state governments. • Programs in existence that encourage the development and use of alternative energy (but not specifically manure-to-energy technologies). • Financial assistance options in existence that may be able to provide support for projects. • Potential income options that may be available for projects now or in the future.	• A consistent source of litter must be identified. • Many of the programs that support renewable energy focus on energy sources other than manure, such as cellulosic biomass, wind, and solar. • Financial assistance is needed to make projects economically feasible. • A project may not be able to benefit from all potential profit options due to certain regulations. • It may be difficult to acquire air quality permits for litter-to-energy processes in some regions due to already poor air quality.

There are two potential scales for a litter-to-energy system: either a large commercial-scale system or a small farm-scale system. Commercial-scale litter-to-energy technologies have already been proven and have been implemented successfully in the UK with large economies of scale. The first poultry litter-fueled power plant in the US also recently began operation in Benson, Minnesota. The viability of a system such as this in the Chesapeake Bay watershed would depend on the region's ability to provide a consistent and adequate litter supply and on the facility's ability to receive adequate financing and support for things such as plant construction and litter transport. As of 2007, no large commercial-scale litter-to-energy systems had been implemented in the Chesapeake Bay watershed, although a plant had been proposed by Fibrowatt for Maryland's eastern shore.

Farm-scale litter-to-energy technologies may also hold promise for the Chesapeake Bay watershed. These systems do not require such a large litter supply, they avoid high transportation costs, and they could potentially help promote farm viability through operational cost-savings and income. A good example of an on-farm operation is the on-farm gasification system that was recently constructed on the Frye poultry farm in West Virginia. Systems such as this can be used to heat a farm's poultry houses. Although on-farm litter-to-energy systems pose significant challenges for farmers, the potential benefits and attractiveness of these technologies are increasing along with increasing energy prices and manure management regulatory pressures. The technical viability of these systems depends on furnace reliability, sufficient fuel storage and handling, and the presence of heat distribution and control systems. In addition to the technological challenges that are associated with farm-scale technologies, other challenges that need to be overcome in order to make farm-scale systems more feasible include high system cost and the time required by the farmer for operation and maintenance.

Deciding which type of system, either farm-scale or commercial-scale, would be the most viable in the Chesapeake Bay watershed and would best meet the needs of the region is not necessarily a clear-cut decision due to a number of factors. A summary of the pros and cons of farm-scale and commercial-scale systems is found below:

Small Farm-Scale

Pros

- Avoids high transportation costs
- Avoids road damage and air emissions caused by litter transporting vehicles
- Does not require a large, constant litter supply
- Provides energy benefits to the farmer and helps promote farm viability through energy cost savings (propane, electricity)
- Provides income generation for the farmer through value-added by-products (ash, electricity, renewable energy credits, nutrient trading, carbon trading)
- Provides an efficient alternative for on-site disposal of poultry carcasses
- Biosecurity of facilities maintained due to on-site litter processing
- Potentially improves bird health and bird quality by reducing the levels of introduced water vapor and ammonia emissions within the poultry houses (compared to heating with propane)

Cons

- Limited number of experimental-level farm-scale litter-fueled systems in existence
- On-farm storage of litter needed for extended periods of time
- Higher system capital cost per unit of energy produced
- Higher operational and maintenance costs (financial and labor) for the farmer

Large Commercial-Scale

Pros

- Several large commercial-scale litter-fueled energy plants are already successfully operating
- On-farm storage of litter is reduced or eliminated
- Lower system capital cost per unit of energy produced
- Lower operational and maintenance system costs (financial and labor) for the farmer compared to farm-scale systems located on-site
- Energy and employment benefits provided to the community

Cons

- Requires a large, consistent litter supply
- High transportation costs
- Litter transporting vehicles may negatively impact roads and air quality
- Biosecurity measures must be taken into account due to off-site litter transportation
- Higher system capital costs which typically require government subsidies for sustainable economics
- Does not provide direct energy benefits to the farmer and continues reliance on purchased energy sources (propane, electricity) for farm operations
- Does not replace the use of propane heat in the poultry houses, thus it does not provide the benefit to bird health that may result from using the litter-generated heat rather than propane heat
- Does not necessarily provide the farmer with income generation through value-added by-products (ash, electricity, renewable energy credits, nutrient trading, carbon trading); the appropriate programs would need to be in place in order for the farmer to benefit from these options
- Does not provide the farmer with an alternative for on-site disposal of poultry carcasses, which can be a benefit of small farm-scale systems

In conclusion, both farm-scale and commercial-scale litter-to-energy systems may be a potential way to use the excess litter found in the Chesapeake Bay watershed. The findings of this report suggest that litter-to-energy systems are, for the most part, technologically feasible; however, there are other challenges that must be overcome to make these systems a viable option in the Chesapeake Bay watershed, including high system cost and the issue of litter availability. In addition, there are still a number of variables that need to be better understood in order to determine whether litter-to-energy systems are truly feasible in the Chesapeake Bay watershed and whether or not they should be promoted by organizations such as the Chesapeake Bay Program. Below is a list of questions and issues that still need to be better addressed.

If current and future research studies and demonstration projects explore these issues and their findings indicate that projects like this should be pursued in the Chesapeake Bay watershed, then steps that could be taken to increase the feasibility and promote the adoption of litter-to-energy systems in this region include:

- Educating farmers on the feasibility and benefits of litter-to-energy projects
- Increasing the number of renewable energy programs that litter-to-energy projects qualify for (both for financial assistance and profit options)
- Working with EPA and USDA to incorporate litter-to-energy technologies into their grant program priorities
- Talking with states to assess how their existing programs could be used to promote litter-to-energy systems

Recommendations for Further Research

Environmental Impacts

- What level of nutrient load reduction can be achieved through the use of a litter-to-energy system? A more in-depth analysis is needed to quantify the reduction resulting from the use of litter-to-energy systems versus the status quo (e.g. land application).
- What sort of air emissions do these systems release (type and amount)? Although there is already some information on this, additional information would be useful.
- What impact do the air emissions from these systems have on water quality?
- Are there potential toxic air pollution concerns that need to be better addressed (such as those resulting from the release of airborne arsenic)?
- Are state and federal air permitting programs set up to allow for these types of operations?

Poultry Litter Supply

- How much excess litter is available in different regions of the Chesapeake Bay watershed? What other factors affect litter supply (e.g. price of energy and other market forces)? Is there enough excess litter to support a large commercial-scale litter-to-energy plant?

Co-Firing / Blending Potential

- What is the combustion performance of poultry litter when co-firing with conventional fuels (e.g. coal or natural gas) and unconventional fuels (e.g. waste coal)?

- If there is an insufficient amount of litter for an energy generation system, could the litter be blended with other biomass feedstock, agricultural waste, or sewage sludge?
- What are the optimal blending ratios, the required combustion/gasification conditions, and the necessary pollutant emission controls when co-firing or blending the litter?
- Do the ammonia and urea-based compounds found in poultry litter have a NO_x reducing effect? Several studies have indicated that they may. This issue should be further investigated.

Cost

- How much does an on-farm litter-to-energy system cost? On-farm systems are still relatively new and many of the current systems have been constructed as part of demonstration or research projects, making it difficult to determine the cost of future systems.
- How much money would a farmer need to put up to get a system installed and operating on his farm?
- What is the potential payback timeframe for a litter-to-energy system? Several ongoing studies are expected to quantify this. Understanding this component is critical in determining the marketability of these systems.

Ash / Bio-Char

- Is there a viable market for the ash and bio-char byproducts? A number of projects have already shown that these byproducts can be used as fertilizer.
- What price could these byproducts be sold for?
- Are there other potential uses for these byproducts (e.g. construction, activated carbon production)?
- How do the ash characteristics vary under different combustion/gasification conditions?

Farmer Willingness

- Are farmers in the Chesapeake Bay watershed willing to participate in litter-to-energy projects? If it is determined that litter-to-energy systems are viable and should be promoted in the watershed, then education and outreach efforts will be needed to encourage farmer adoption of these systems.
- How much time must a farmer devote to operating and maintaining an on-farm litter-to-energy system?

Appendix A. Litter-to-Energy Technology Examples

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
COMBUSTION		The combustion process usually takes place at temperatures as high as 3600º F and requires either stoichiometric conditions (consuming reagents in the exact proportions required for a given reaction) or an excess amount of oxygen. The main products are CO_2, H_2O, and ash.						
Pilot Scale Combustion Test: Energy Products of Idaho (EPI)[i]	*Fluidized bed combustor*. The objectives of this test program were to: (1) evaluate the slagging tendency of EPI's technology and explore conditions that could reduce or eliminate it completely; and (2) evaluate the emission potential of poultry litter when used as a fuel.	Commercial/large scale (scaled down for research)	21.4 tons/hour On a yearly basis it could be supplied by 11 million birds	20 MW	- The litter was not pre-processed - No significant ash slagging or accumulation - Typical operating temperature out of the furnace was below 1750º F	- NO_x: SNCR was used (emission was lower than expected → ammonia or urea-based compounds in the manure) - 100% of the sulfur was captured with lime - Significant HCl capture	The ash is suitable for use as a soil supplement. Other disposal methods will also be evaluated.	No info
Poultry Litter-Fueled Power Plants in the UK: Energy Power Resources Ltd[ii, iii]	*Mass burning and step-grade combustion systems.* Energy Power Resources Ltd was the first company in the world to succeed in turning poultry litter into energy. They have since constructed plants at a number of locations in the UK, including Eye, Thetford, Westfield, and Glanford.	Commercial	110,000-420,000 tons of litter per year	10-55 MW	24/7 operators required	The emissions are controlled and meet the applicable air emission standards.	The ash is further processed to produce high quality agricultural fertilizer. After size grading, the ash is marketed by Fibrophos.	No info

[i] Michael L. Murphy, *Fluidized Bed Technology Solution to Animal Waste Disposal*, Energy Products of Idaho, presented at the Seventeenth Annual International Pittsburgh Coal Conference, September 2000 (accessed February 2007); available from http://www.brbock.com/RefFiles/FluidBedSolutions.pdf.
[ii] B.P. Kelleher, J.J. Leahy, A.M. Henihan, T.F. O'Dwyer, D. Sutton, and M.J. Leahy, *Advances in poultry litter—a review*, 2002, Bioresource Technology 83: 27-36.
[iii] Energy Power Resources Limited (accessed Winter/Spring 2007); available from www.eprl.co.uk

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Poultry Litter-Fueled Power Plant in the US: Fibrominn (Benson, Minnesota)[iv]	Fibrominn is the first poultry litter-fueled power plant in the U.S. It began operation in mid-2007. It was built by Fibrowatt LLC.	Commercial	500,000 tons/year (2,000 – 2,500 tons/day) They will burn mainly turkey litter, although the plant will also burn hay, straw, out-of-condition grain, and upland hay.	55 MW	24/7 operators required	- NO_x emissions controlled by SNCR - SO_2, H_2SO_4, HCl controlled by a spray-dry absorber - Particulate matter controlled by a fabric filter baghouse	The ash will be sent to a nearby facility operated by North American Fertilizer to be converted into high value fertilizer.	Cost of project: Approximately $150 million
Proposed Poultry-Litter Fueled Power Plant: FibroShore (Maryland's Eastern Shore) [v]	FibroShore is a poultry-litter fueled power plant that has been proposed by Fibrowatt LLC.	Commercial	Up to 300,000 tons of poultry litter and 50,000 tons of forestry residue annually.	38.5 MW	24/7 operators required	- Emission control techniques would be used to control particulate matter, NO_x, CO, VOCs, SO_2, and HCL	No info	Cost of project: Approximately $125 million
Development of a Poultry Litter-to-Energy Furnace: American Heat and Power LLC[vi]	A modified *Multiple Hearth Furnace* has been developed in which the combustion air is introduced by Circle Slot Jets that create high turbulence and increased air-to-fuel mixing. The poultry litter is burned in a controlled environment at temperatures high enough to allow complete combustion, but low enough to avoid agglomeration and slagging in the ash end exhaust.	Large commercial or industrial scale. This technology is best suited for a large regional plant. Though technically feasible for on-farm application, they have found that it is not economically feasible.	For stand-alone economical viability (no government subsidy), the plant should be sized to process at least 100 tons of litter per day. Typically, capacities would range from 250 tons per day to as much as 1000 tons per day (with multiple units) at a single regional plant.	Steam only output: 100,000 - 350,000 lbs/hour Electricity only output: 10 - 50 MW Combined heat and power plants would provide a combination of these.	- The facility would require a full-time staff. Plant operators would probably work three 8-hour shifts. - Maintenance would be commensurate with a mid-sized energy plant. Normal maintenance would be provided by the operators. - Long term service agreements with equipment suppliers could provide a large portion of the plant's major equipment maintenance.	- HCL, Cl_2, SO_2, HF, and PM reduction by wet scrubber - Very low NO_x emissions	Concentrated fertilizer	These are multi-million dollar units and although the units have standard sizing criterion, a unique system would need to be specifically designed for each project. As such, pricing is specific to the project. However, as a ballpark estimate, a hypothetical 15 MW plant would cost roughly $2500 per kW and a biomass to steam plant would cost approximately $120 per lb/hour of steam capacity installed.

[iv] Fibrominn, *Frequently Asked Questions and Answers* (accessed Winter/Spring 2007); available from http://www.bensonmn.org/fibrominn/faq.html.
[v] Bill Miles, FibroShore Project Representative, *FibroShore: Domestic Renewable Energy Production from Poultry Litter and Forestry Residues*, Presented to Maryland's O'Malley Administration, June 2007.
[vi] Darren Habetz and Richard Echols, *Development of Successful Poultry Litter-to-Energy Furnace*, written for presentation at the 2006 ASABE Annual International Meeting, Portland, Oregon, July 9-12, 2006.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Study: Combustion of Poultry Litter in a Fluidized Bed Combustor (Portugal, Ireland)[vii, viii]	*Atmospheric bubbling fluidized bed combustor.* This project studied the effect of the moisture content on combustion, the variations in excess air level along the freeboard, and air staging.	Pilot scale/ research	No info	No info	- The addition of peat was used to improve combustion due to the uncertain combustibility of the high moisture content poultry litter. - Operation temperature: 1290°F - 1830°F	- The air staging in the freeboard lowered the NO_x emissions	No info	No info
Fluidized Bed Combustors: Biomass Heating Solutions Limited (County Limerick, Ireland)[ix]	This company manufactures *fluidized bed combustors* to combust chicken litter for heat/energy.	Small / farm scale	80 lb/hr litter with a moisture content of 25 - 50%.	45-115 KW	No info	No info	7 lb/hr (suitable for use as a fertilizer)	No info
Feasibility Study: Poultry Litter Combustion (University of Arkansas)[x]	*Broiler litter-fired direct combustor prototype* manufactured by Lynndale Systems Inc. The purpose of this test was to determine whether on-farm litter combustion is feasible. The system was designed to provide heat for poultry houses.	Small / farm scale	1 ton of litter per day in winter	Peak heat output: 93k btu/h (to achieve significant savings in propane this needs to be 175k btu/h)	- Doesn't require a full time operator. - The fuel would be loaded two to four times per day and an occasional furnace check would be needed. - 15-30 minutes of labor per day plus 30 minutes ash handling every 1-3 days.	- Excessive CO (indicator of incomplete combustion) - NO_x emissions levels were not high - PM levels were not measured	A small amount of ash was recovered (this implies that a significant amount of particulates may have been released into the air)	According to Tom Costello (University of Arkansas), a reasonably efficient furnace could pay for itself as long as the capitol costs were less than $20,000-$30,000. It remains to be seen what the sales price for a commercial product would be.

[vii] P. Abelha, I. Gulyurtlu, D. Boavida, J. Seabra Barros, I. Cabrita, J. Leahy, B. Kelleher, and M. Leahy, *Combustion of poultry litter in a fluidized bed combustor*, 2003, Fuel 82: 687-692.
[viii] Biomass Heating Solutions Limited (accessed Winter/Spring 2007); available from http://biomass.ie/index.html.
[ix] Biomass Heating Solutions Limited (accessed Winter/Spring 2007); available from http://biomass.ie/index.html.
[x] Thomas A. Costello, *Feasibility of On-Farm Broiler Litter Combustion*, Spring 2007, AVIAN Advice, Vol. 9 (1): 7-13.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Case Study: Retrofitting Conectiv Vienna Power Station (Vienna, Maryland)[xi, xii]	Conectiv considered replacing systems in this power plant with systems exclusively designed to be fueled by poultry litter. Two different system modifications were proposed: (1) the addition of a new *stoker boiler*, or (2) a new *fluidized-bed boiler* specifically designed for poultry-derived fuel. Eventually, Conectiv sold the Vienna plant and the matter of retrofitting the facility was dropped.	Commercial	1,920 tons per day (400,000 tons of poultry litter per year)	35 MW	No info	- NO_x: air staging - SO_2, HCl: lime addition - PM: cyclone and baghouse	The ash could have been used as a fertilizer.	Expected cost: $52. 2 million
Study: Using Poultry Litter as a Fuel Source at the Eastern Correctional Institution Cogeneration Facility (ECICF) (Princess Anne, Maryland)[xiii, xiv]	Working with MES, PPRP completed a study that analyzed the reliability and suitability of litter as a fuel source and the ability of ECICF to burn litter as a fuel. They identified the modifications that would be needed for ECICF to primarily burn litter and a full-scale litter test burn was conducted.	Commercial	54,000 tons of litter per year	4 MW	No info	- Emission controls required for NO_x, HCl, and PM	Ash would have been used as a fertilizer or fertilizer feedstock.	Cost of modifications: $5.9 million + an additional 30% identified later

[xi] Northeast Regional Biomass Program, *Case Study 1: Repowering Vienna Station, Vienna, Maryland*, Appendix F in "Economic and technical feasibility of energy production from poultry litter and nutrient filter biomass on the lower Delmarva Peninsula", 1999 (accessed Winter/Spring 2007); available from http://www.nrbp.org/pdfs/pub20b.pdf.
[xii] B. R. Bock, *Poultry Litter to Energy: Technical and Economic Feasibility*, 2000 (accessed January 2007); available from http://www.msenergy.ms/Bock-National%20Poultry%20Waste%20_8-15-00_.pdf.
[xiii] Environmental Resources Management, *Eastern Correctional Institution Cogeneration Facility Full-Scale Poultry Litter Test Burn, Report of November 1999*, PPES-00-1, Prepared for Maryland Environmental Service, July 2000 (accessed Winter/Spring 2007); available from http://esm.versar.com/pprp/eci/2-Test%20Burn%20Report%20PDF.pdf.
[xiv] Environmental Resources Management, *Comprehensive Engineering and Socioeconomic Assessment of Using Poultry Litter as a Primary Fuel at the Eastern Correctional Institution Cogeneration Facility*, Volume I, Prepared for Maryland Environmental Service, October 2000 (accessed Winter/Spring 2007); available from http://esm.versar.com/pprp/eci/1-VolumeI-IIPDF.pdf.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Study: Co-Firing of Coal and Broiler Litter (Texas A&M University)[xv]	This study looked at co-firing coal and broiler litter fuels for power generation. As part of this study, a 90:10 blend (coal 90: litter 10) was used to fuel existing coal-fired combustion devices. This blend resulted in a fuel quality and cost that was similar to coal and a fouling potential that was less than pure litter.	Research scale	No info	No info	No info	No info	No info	No info
Study: Combustion of Poultry Waste with Natural Gas (Morgan State University, MD)[xvi]	Study of the co-combustion performance of poultry waste with natural gas in an *advanced swirling fluidized bed combustor*.	Pilot scale	No info	No info	No info	No info	No info	No info
Project: Poultry Litter as a Fuel Source for Poultry Growers (Penn State)[xvii]	Penn State received a grant from the PA Dept. of Ag. The co-investigators are Dennis Buffington, Mike Hulet, and Paul Patterson. They will assist a number of farms in installing litter-to-energy systems that will serve as demonstration sites. Combustion systems and gasification systems may be used.	Farm scale	Varies depending on system	Varies depending on system	Unknown Goal: No more than one hour per day for farmer	No info	The ash could be used as fertilizer. The farmer could either keep the ash or it could potentially be shipped back to the integrator.	The costs of the systems vary. The goal is to use systems that would have a 3-year payback (based on propane use). At this time, it is thought that this is a reasonable goal; however, this project is still in its early stages. The first system is not expected to be installed until early 2008. The farmer will be responsible for paying for the system, but Penn State will assist with the legwork. Farmers could potentially receive financial assistance through cost-share programs.

[xv] S. Mukhtar, K. Annamalai, B. Thien, and S.C. Porter, *Summary: Co-Firing of Coal and Broiler Litter (BL) Fuels for Power Generation- BL Fuel Quality and Characteristics,* Texas Animal Manure Management Issues , September 2003 (accessed November 2007); available from http://tammi.tamu.edu/coalitter.html.
[xvi] S. Zhu and S.W. Lee, *Co-combustion performance of poultry wastes and natural gas in the advanced Swirling Fluidized Bed Combustor (SFBC)*, 2005, Waste Management, 25: 511-518.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
GASIFICATION	Gasification occurs in a limited air or oxygen supply. The typical temperature ranges from 1100°F to 1800 °F and the products are syngas (CO, H_2) and ash.							
Case Study: Poultry Litter-Fueled Boiler at Perdue Feed Mill (Bridgeville, Maryland)[xviii]	A case study was conducted to evaluate the feasibility of building a poultry litter fueled boiler at the Perdue Feed Mill in Bridgeville, MD to produce steam for the feed mill operation.	Small scale	24,000 tons per year	8 mm Btu per hour	The two maintenance and operation workers that are already working at the mill would have handled the operation.	- Baghouse dust collector on the fuel handling system - Mechanical collector for PM	30 tons of ash per week (agricultural use)	$600,000 to $1,200,000 depending on the plant configuration.
Feasibility Study: Gasification Facility (Beltsville, Maryland)[xix, xx]	USDA ARS is conducting a feasibility study on the construction and use of a gasification facility at the Beltsville Agricultural Research Center (BARC). This unit will be used to test the suitability of a variety of feedstocks, including animal manure. This study will also look at whether this technology could be transferred to rural communities and farm cooperatives.	Research scale	No info	1-2 MW Electricity and steam generated by this unit will be used by the BARC labs, offices, and farm buildings.	No info	No info	No info	No info

[xvii] Paul Patterson, Penn State Department of Poultry Science, phone conversation, December 12, 2007.
[xviii] Northeast Regional Biomass Program, *Case Study 2: New Gasifier-Boiler for a Feed Mill, Bridgeville, MD*, Appendix G in "Economic and technical feasibility of energy production from poultry litter and nutrient filter biomass on the lower Delmarva Peninsula", 1999 (accessed Winter/Spring 2007); available from http://www.nrbp.org/pdfs/pub20b.pdf.
[xix] USDA Agricultural Research Service, *Science Update,* Agricultural Research Magazine Vol. 55, No. 8, September 2007 (accessed November 2007); available from http://www.ars.usda.gov/is/AR/archive/sep07/sci0907.htm.
[xx] Don Comis, *ARS Center Searches for "Opportunity Fuels"*, March 30, 2007 (accessed November 2007); available from http://www.ars.usda.gov/is/pr/2007/070330.htm.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Demonstration Project: On-farm Gasification System, Frye Poultry Farm (Wardensville, West Virginia)[xxi, xxii]	A *fixed bed gasification unit* was constructed on the Frye poultry farm. This unit will produce heat from poultry manure to provide heating for the farm's chicken houses. This unit was constructed by Coaltec Energy.	Small/ farm scale	500-1000 lbs/hr	No info	- A control panel measures the temperature and the emissions. - This system can be managed remotely. - The computer calls for fuel when it's needed. - A hopper will be attached to the unit which will gradually feed the gasifier. - The litter doesn't need any preparation.	- NO_x, and SO_x can be controlled - The system meets all air emission requirements	- The ash content of the litter is 18%-20% - Plan to market the ash for land application - Bio-char could be produced instead, but finding a market for it would be more difficult at this time	$600,000. Funding is provided for portions of this project by NRCS through a Conservation Innovation Grant and from the West Virginia Department of Agriculture.
Proposed Cogeneration Facility: Allen Family Foods, Inc. (Hurlock, Maryland)[xxiii, xxiv]	CHx Engineering proposed constructing and operating a cogeneration facility at the existing Allen Foods poultry processing plant to generate electricity and steam using litter as the primary fuel. Finally, due to financial difficulties and problems with the design firm, which was unable to meet the conditions of the contract, the plans were dropped.	Commercial	40,000 tons per year	4 MW	No info	- NO_x emissions reduction by staged oxidation - No significant air quality impact, in compliance with regulations	The ash would have been used as commercial fertilizer.	No info

[xxi] Coaltec Energy USA, Inc., *Poultry Litter Project: Frye Poultry Farm* (accessed November 2007); available from http://www.coaltecenergy.com/poultrylitterproject.html.
[xxii] Matt Harper, personal email correspondence, 2007.
[xxiii] Gary Walters, Diane Mountain, Daniel Goldstein, and Peter Hall, *Environmental Review of the Allen Family Foods/CHx Engineering Cogeneration Project*, Prepared for the Maryland Department of Natural Resources Power Plant Research Program, November 2002 (accessed Winter/Spring 2007); available from http://esm.versar.com/pprp/bibliography/PPSE-AFF-01/PPSE-AFF-01.pdf.
[xxiv] CHP in the Food and Beverage Manufacturing Industry, *Allen Family Chicken Processors* (accessed Winter/Spring 2007); available from http://www.sentech.org/CHP4foodprocessing/industryleaders.htm.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Proposed Poultry Litter Gasification Unit: Allen's Hatchery, Inc. (Linkwood, Maryland)[xxv, xxvi, xxvii]	Allen's Hatchery, Inc. in cooperation with REM Engineering, Inc. was planning to construct a poultry litter gasification unit. They were planning to begin construction in September 2006, but for several reasons, the county government would not allow this unit to be installed.	Commercial	1 ½ tractor-trailer loads per day (14,000 tons per year, supplied by 25-30 farms)	15 million BTU per hour	No info	- NO_x cleaned by the naturally occurring ammonia in the litter - Sulfur-oxides captured by the calcium within the manure - PM removed by fabric filter	The ash would be sent to fertilizer companies to be mixed with nitrogen.	No info
Proposed Poultry Litter Gasification (CHP) Unit: Tyson Foods, Inc. (Virginia's Eastern Shore)[xxviii]	Tyson Foods, Inc. worked on a project to have a litter gasifier electric-producing unit built at its processing plant site on the Eastern Shore of Virginia. For a variety of reasons, this unit was not built. The three major obstacles they encountered were: (1) they had trouble securing a consistent source of litter; (2) the company that was going to build the gasifier went out of business; and (3) they had difficulty acquiring a building permit.	No info	No info	No info	No info	No info	The ash would have been used as fertilizer.	No info

[xxv] Glenn Rolfe, *Poultry Waste a Source of Fuel*, 2005 (accessed Winter/Spring 2007); available from http://www.remenergy.com/The%20Leader%20and%20State%20Register%2011-03-05.pdf.
[xxvi] Pete Macinta, "Boiler 'not a done deal'", *Daily Banner*, January 18, 2006 (accessed Winter/Spring 2007); available from http://www.remenergy.com/DAILY%20BANNER.pdf.
[xxvii] Chesapeake Bay Program, Minutes from the October 18, 2007 Regional Manure and Litter Use Technology Task Force Conference Call.
[xxviii] Bill Ricken, phone conversation, May 31, 2007.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Poultry Litter Gasifier System: Biomass Technology Group (The Netherlands)[xxix]	Biomass Technology Group (BTG) developed a farm-scale gasifier system with close cooperation from poultry farmer Duis v.o.f. This system uses a *bubbling fluid bed gasifier*.	Farm-scale	900 tons per year	- Annual electricity output: 450 MWh - Electricity is mainly used on-site; the surplus is delivered to the power grid - Heat of the CHP unit is supplied to the boiler	No info	No info	Ash could be sold as fertilizer or for road construction.	€ 450,000 (approximately $614,000), resulting in a payback period of 7 years. This was a 'first-of-its-kind' installment and the company thinks that the payback period can be improved. They expect scaling-up, replication, and further optimism to lower the expected payback period for a similar system to a period of less than five years.
Poultry Litter-Fueled Power Plant: Plant Carl (Franklin County, Georgia)[xxx, xxxi]	This proposed plant, which is being built by Earth Resources, Inc. (ERI), will be a typical traditional boiler-turbine operation that will feed the fuel (chicken litter, woody biomass, and other renewable resources) into a *bubbling fluidized bed*. Construction is expected to be completed in late 2008.	Commercial-scale	Chicken litter and woody inert biomass will be placed into the furnace at a rate of 800 tons/ day.	20 MW	Will be operated on a 24-hour continual basis for a planned 350 days per year. ERI anticipates that the plant will require approximately 21 full-time employees.	No info	The ash will be sold at the site as a fertilizer.	Received a $28 million loan from USDA Rural Development's Utilities Program.

[xxix] Biomass Technology Group (accessed Fall 2007); available from http://www.btgworld.com.
[xxx] Earth Resources Inc., *Environmental Assessment: Plant Carl (Carnesville, Georgia)*, Prepared for U.S. Department of Agriculture, December 2006 (accessed Fall 2007); available from http://www.usda.gov/rus/water/ees/pdf/Plant%20Carl%20EA121506.pdf.
[xxxi] Anne Mayberry, "Georgia Alternative Energy Plant to be Fueled by Wood and Poultry Waste", Rural Cooperatives Vol. 74, No. 4, July/August 2007 (accessed Fall 2007); available from http://www.rurdev.usda.gov/rbs/pub/jul07/utility.HTM.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Poultry Litter Gasification System: Hillandale-Gettysburg LLC Poultry Farm (Adams County, Pennsylvania)[xxxii]	This plant is being built by Energy Works North America LLC. It is expected to be completed in late 2008.	Large farm-scale	This plant will use manure from the 3. 5 million chickens on the farm. It will get rid of 85% of the farm's manure.	3.5 million kilowatt-hours of electricity per year.	There will be one full-time person working at the facility 8 hours per day. When there is no one working after hours, someone will be on-call just in case a problem arises.	Not yet determined	They are planning to try to market the ash as both a feed supplement and a fertilizer additive.	$6.5 million. Primarily being funded through private investment, although the project also received a $410,250 state grant from the Pennsylvania Energy Development Authority in fall 2007.
Project: Poultry Litter as a Fuel Source for Poultry Growers (Penn State)	Both combustion systems and gasification systems may be used. See description in the combustion section for more details (page 64).	---	---	---	---	---	---	---
PYROLYSIS	Pyrolysis is a relatively low temperature (390°-1100 ° F) process that occurs when almost no oxygen is present. The main products are oils and tars.							
Pilot Project: Mobile Pyrolysis Unit, Renewable Oil International LLC and Mills Poultry Farm (Franklin County, Alabama)[xxxiii]	This pilot project uses a mobile pyrolysis unit to produce nutrient rich ash and vapor that is converted to bio-oil. The technology provider is Renewable Oil International, LLC.	Farm-scale	Pilot project will treat 3 poultry houses on the Mills Poultry Farm (22,000 birds per house).	Creates bio-oil, which is a low-grade fuel that can be used for furnaces or heaters to warm poultry houses.	No info	No info	The nutrient-rich ash is a marketable product.	Received a grant from the Farm Pilot Project Coordination, Inc.

[xxxii] Dan Miller, "State Grants to Fuel Alternative Energy Projects" ,The Patriot-News, Oct. 17, 2007 (accessed November 2007); available from http://www.pennlive.com/business/patriotnews/index.ssf?/base/business/119263114478600.xml&coll=1.
[xxxiii] Farm Pilot Project Coordination, Inc., *Poultry Projects* (accessed Fall 2007); available from http://www.fppcinc.org/poultry.htm.

	Description	Scale	Litter Requirement	Energy Output	Operation/ Maintenance	Emissions	Ash	Cost
Study: Pyrolysis Technology (Foster Agblevor, Virginia Tech)[xxxiv, xxxv]	Foster Agblevor of Virginia Tech and his research team are working on developing a *rapid pyrolysis technology* to produce value added products, such as bio-oil, slow-release fertilizer, and producer gas, from poultry litter. Through their research they successfully pyrolyzed poultry litter samples in a *bubbling fluidized bed pyrolysis reactor*.	Small/ farm-scale	No info	No info	No info	The gaseous emissions should be analyzed through the pyrolysis process and during the combustion of the bio-oil.	An objective of the project is to evaluate the char fraction as a slow release fertilizer for land application.	The NFWF's Chesapeake Bay Targeted Watershed Program funds their research through a $1 million grant. $406,000 of the grant will be devoted to the construction, installation, and demonstration of a portable pyrolysis unit (see next row).
Portable Pyrolysis Unit: Oren Heatwoles's Poultry Farm (Rockingham County, Virginia)[xxxvi]	Researchers from Virginia Tech, Virginia Cooperative Extension, and other ag and environmental agencies are conducting a pilot project that will use a portable pyrolysis unit to turn poultry litter into bio-oil and char. They plan on installing the unit in late 2007 on Heatwole's farm. If the unit works, they may move the portable unit to other nearby farms.	Farm-scale	No info	- Create bio-oil to be used on the Heatwole farm to heat the poultry houses and possibly the farmer's residence. - The synthetic gas byproduct will be used to run the pyrolysis unit.	No info	No info	The char could be used as a slow-release fertilizer.	This project has received grants from the National Fish and Wildlife Federation, the Virginia Poultry Federation, and the Farm Pilot Project Coordination Inc.

[xxxiv] F.A. Agblevor and S.S. Kim, *Final Report on Thermal Conversion of Poultry Litter to Pyrodiesel and Fertilizer*, Prepared for the Virginia Poultry Federation, Inc., under contract no. 208-11-110º-002-814-1, November 2006.
[xxxv] Lori Greiner, "Solving an Age-Old Problem", *Innovations*, Virginia Tech College of Agriculture and Life Sciences, January 2007 (accessed Winter/Spring 2007); available from http://www.cals.vt.edu/news/pubs/innovations/jan2007/problem.html.
[xxxvi] Jenny Jones, "Poultry Goes to Work on Energy Problem", The Daily News Record, August 10, 2007 (accessed Fall 2007); available from http://www.dnronline.com/news_details.php?AID=11626&CHID=1.

Appendix B. Potential Funding Sources for a Manure-to-Energy Project

Program or Funding Opportunity	Eligible Region	Eligible Applicants	Range of Awards	Description	Website
Clean Water State Revolving Fund (CWSRF) Programs	All States	Local governments, nonprofits, businesses, farmers, and individuals	Low-interest loans are limited to the construction costs for the portion of the project with a water quality benefit	In the CWSRF program, each state maintains revolving loan funds to provide independent and permanent sources of low-cost financing for a wide range of water quality infrastructure projects. State CWSRF programs were established and continue to be capitalized by grants from the U.S. EPA with states matching 20%. CWSRF programs provided more than $5 billion annually in recent years to fund water quality protection projects for wastewater treatment, nonpoint source pollution control, and watershed and estuary management.	http://www.epa.gov/owm/cwfinance/cwsrf (All state CWSRF program websites are linked to EPA-Headquarters' website)
Conservation Innovation Grants Program (USDA NRCS)	All states	State and local governments, non-governmental organizations, federally-recognized tribes, and individuals	Maximum of $1,000,000	"Conservation Innovation Grants (CIG) is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging the Federal investment in environmental enhancement and protection, in conjunction with agricultural production." (http://www.nrcs.usda.gov/programs/cig/pdf_files/CIGfactsheet3-1-06.pdf)	http://www.nrcs.usda.gov/programs/cig/
Farm Pilot Project Coordination, Inc.	All states	Farm operations	Varies by project	"Farm Pilot Project Coordination, Inc. (FFPC), a non-profit organization, was designated by Congress to assist in implementing innovative treatment technologies to address the growing waste issues associated with animal feeding operations." (http://www.fppcinc.org/)	http://www.fppcinc.org/
National Research Initiative: Biobased Products and Bioenergy Production Research (USDA CSREES)	All states	Land-grant institutions, state-controlled institutions of higher education, private institutions of higher education, state or local governments, for-profit organizations, small business, non-profits, and state agricultural experiment stations	$0-$500,000	"Program activities will expand science-based knowledge and technologies to support the efficient, economical, and environmentally friendly conversion of biomass, more specifically agricultural residuals, into value-added industrial products and biofuels." (http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1073)	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1073
Renewable Energy Systems and Energy Efficiency Improvements Program (USDA)	All states	Farmers, ranchers, and rural small businesses	Renewable energy grants: $2,500-$500,000 (not to exceed 25% of project costs); Loan Guarantees: $5,000-$10,000,000 (up to 50% of project costs)	"The 2002 Farm Bill established the Renewable Energy Systems and Energy Efficiency Improvements Program under Title IX, Section 9006. This section directs the Secretary of Agriculture to make loans, loan guarantees and grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and make energy efficiency improvements." (http://www.rurdev.usda.gov/rbs/farmbill/what_is.html)	http://www.rurdev.usda.gov/rbs/farmbill/what_is.html
Small Business Innovation Research: Animal Manure Management (USDA CSREES)	All states	Small businesses	$80,000-$350,000	"The objective of the Small Business Innovation Research (SBIR) Animal Manure Management research area is to develop new or improved technologies and environmentally sound approaches for improved management of animal manure that will reduce the adverse impact of animal manure on the environment and people, and improve the economics of animal production by optimizing manure management technologies and creating value-added products derived from animal manure." (http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1221)	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1221

Program or Funding Opportunity	Eligible Region	Eligible Applicants	Range of Awards	Description	Website
Value-Added Producer Grants (USDA Rural Development)	All states	Independent producers, farmer and rancher cooperatives, agricultural producer groups, and majority-controlled producer-based business ventures	$3,000-$300,000 (in 2006)	"Grants may be used for planning activities and for working capital for marketing value-added agricultural products and for farm-based renewable energy." (http://www.rurdev.usda.gov/rbs/coops/vadg.htm)	http://www.rurdev.usda.gov/rbs/coops/vadg.htm
Chesapeake Bay Small Watershed Grants Program (National Fish and Wildlife Foundation)	Chesapeake Bay Watershed	Eligible: non-profit 501(c) organizations or local governments; NOT Eligible: individuals, state and federal government agencies, or private for-profit firms	Project Planning and Design Grants: $10,000-$30,000; Implementation Grants: $20,000-$200,000	"The Chesapeake Bay Small Watershed Grants Program provides grants to organizations and local governments working on a local level to protect and improve watersheds in the Chesapeake Bay basin, while building citizen-based resource stewardship. The purpose of the grants program is to support protection and restoration actions that contribute to restoring healthy waters, habitat, and living resources of the Chesapeake Bay ecosystem." (http://www.nfwf.org/AM/Template.cfm?Section=Browse_All_Programs&Template=/CM/ContentDisplay.cfm&ContentID=3768)	http://www.nfwf.org/AM/Template.cfm?Section=Browse_All_Programs&Template=/CM/ContentDisplay.cfm&ContentID=3768
Chesapeake Bay Targeted Watersheds Grant Program (National Fish and Wildlife Foundation)	Chesapeake Bay Watershed	Eligible: non-profit 501(c) organizations, universities, and local or state governments; NOT Eligible: individuals, federal government agencies, and private for-profit firms	Maximum of $1,000,000	"The overall goal for the Chesapeake Bay Targeted Watersheds Grant Program is to expand the collective knowledge on the most innovative, sustainable, and cost-effective strategies- including market-based approaches- for reducing excess nutrient loads within specific tributaries to the Chesapeake Bay. To achieve this goal, the program awards grants of up to $1 million on a competitive basis to projects that target and reflect diverse conditions (e.g., urban, rural, suburban) and sources of nutrients (e.g., agricultural, stormwater, other non-point sources) that exist throughout the Chesapeake watershed." (http://www.nfwf.org/AM/Template.cfm?Section=Browse_All_Programs&Template=/CM/ContentDisplay.cfm&ContentID=3750)	http://www.nfwf.org/AM/Template.cfm?Section=Browse_All_Programs&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=4248
Green Energy Fund's Research and Development Program	Delaware	Applicants located within DE for projects conducted in DE	Up to 35% of project cost, but not exceeding $250,000	"The Green Energy Fund's Research and Development Program offers grants to projects that develop or improve renewable energy technology in Delaware. The Department of Natural Resources and Environmental Control will accept proposals for Research and Development Program grants for qualifying projects that improve the engineering, adaptation, or development of products or processes that directly relate to renewable energy technology." (http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=DE04F&state=DE&CurrentPageID=1&RE=1&EE=0)	http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=DE04F&state=DE&CurrentPageID=1&RE=1&EE=0
Chesapeake Bay Trust's Pioneer Grant Program	Maryland	Organizations and public agencies in Maryland (includes public and private schools and universities; non-profit organizations; youth clubs, service groups, and community associations; municipal, county, state, and federal agencies; soil and water conservation districts; forestry boards; and resource conservation/development councils)	Up to $150,000	"The 2007 Pioneer Grants Program is designed to help organizations demonstrate, analyze, and deliver to users innovative approaches, technologies, techniques, and practices that will lead to water quality improvements in local streams, rivers, and ultimately, the Chesapeake Bay. The Trust seeks pre-proposals in the fields of agriculture or environmentally sensitive land development that focus on direct or indirect reduction of nutrient and sediment inputs to the Bay in the following ways: 1) Demonstration of an existing technology or practice, 2) Economic analysis of technology or best management practices, and 3) Delivery to users." (http://www.cbtrust.org/site/c.enJIKQNoFiG/b.2028497/k.5880/Pioneer_Grant_Program.htm)	http://www.cbtrust.org/site/c.enJIKQNoFiG/b.2028497/k.5880/Pioneer_Grant_Program.htm

Program or Funding Opportunity	Eligible Region	Eligible Applicants	Range of Awards	Description	Website
Animal Waste Technology Fund	Maryland	---	---	NO LONGER AUTHORIZED (Originally authorized in the Maryland Water Quality Improvement Act of 1998)	---
Metropolitan Edison Region Sustainable Energy Fund- Grants and Loans	Pennsylvania (Metropolitan Edison Service Territory)	Any organization, governmental entity, individual or corporation in the Metropolitan Edison service territory	Grants: Maximum of $25,000;	"First Energy established the Metropolitan Edison Company Sustainable Energy Fund (Met Ed Region) within Berks County Community Foundation in 2000 with an initial contribution of $5,700,000. The purpose of the fund is to promote: the development and use of renewable energy and clean energy technologies; energy conservation and efficiency; sustainable energy businesses; and projects that improve the environment in the companies' service territories, as defined by their relationship to the companies' transmission and distribution facilities." (http://www.bccf.org/pages/gr.energy.html)	http://www.bccf.org/pages/gr.energy.html
Penelec Region Sustainable Energy Fund of the Community Foundation for the Allegheníes- Grants and Loans	Pennsylvania (FirstEnergy's Penelec Service Territory)	Any organization, governmental entity, individual or corporation in FirstEnergy's Penelec service territory	Grants: Maximum of $25,000; Loans: Maximum of $500,00	"The Penelec Sustainable Energy Fund was funded in 2000 as a result of energy deregulation and utility settlement agreements in Pennsylvania. The fund promotes the use of renewable energy, energy conservation and efficiency, and renewable energy business initiatives." (http://www.cfalleghenies.org/penelec.htm)	http://www.cfalleghenies.org/penelec.htm
Pennsylvania Energy Development Authority (PEDA) Grants	Pennsylvania	Businesses, non-profit corporations, PA colleges and universities, and local governments (research projects not eligible for grant financing)	Maximum of $1,000,000	"The Pennsylvania Energy Development Authority (PEDA) is offering grant funding for clean, alternative energy projects in Pennsylvania, and investment in Pennsylvania's energy sector. PEDA is seeking applications for innovative, advanced energy projects, and for businesses interested in locating or expanding their alternative energy manufacturing or production operations in the Commonwealth." (http://www.depweb.state.pa.us/enintech/lib/enintech/peda/2007application/peda_pdf_7000-uk-dep4010.pdf)	http://www.depweb.state.pa.us/enintech/cwp/view.asp?a=1415&q=504241
Pennsylvania Energy Harvest Grant Program	Pennsylvania	501(c)(3) non-profit organization; a county or municipal government; a school district, college or university; a conservation district; a for-profit business registered with the PA Department of State as a corporation, limited liability partnership, limited partnership, or limited liability company; or a watershed organization recognized by DEP	$18,000-$1,000,000 (in 2006)	"Pennsylvania Energy Harvest Grants are intended to address the dual concerns of energy and environmental quality. As such, proposals must simultaneously reduce or supplement the use of conventional energy sources and lead to improvements in water or air quality." (http://www.depweb.state.pa.us/energy/lib/energy/docs/energyharvest/2007application/eh_pdf_7000-bk-dep3087.pdf)	http://www.depweb.state.pa.us/energy/cwp/view.asp?a=1374&q=483024

Program or Funding Opportunity	Eligible Region	Eligible Applicants	Range of Awards	Description	Website
Sustainable Development Fund administered by The Reinvestment Fund, Inc. (TRF)	PECO Energy Service Territory (Pennsylvania)	Businesses or organizations working or planning to work in the PECO Energy service territory	Grants: Average approximately $25,000	"TRF's Sustainable Development Fund (SDF) offers innovative financing in the areas of renewable and clean energy. SDF serves customers from PECO Energy's service territory and is dedicated to promoting: renewable energy and advanced clean energy technologies among residential, commercial, institutional, and industrial customers; energy conservation and energy efficiency among residential, commercial, institutional, and industrial customers; and sustainable energy businesses that benefit customers in its service area." (http://www.trfund.com/sdf/)	http://www.trfund.com/sdf/
Sustainable Energy Fund of Central Eastern Pennsylvania	Pennsylvania (PPL Service Territory)	Commercial, industrial, non-profit, local government, and state government usually located in the PPL service territory (research projects not eligible for grant financing)	Varies by project	"The Sustainable Energy Fund (SEF) invests in projects related to its mission to promote the use of renewable energy, clean energy technologies, energy conservation, and educational programs that benefit customers in the PPL energy service territory." (http://www.thesef.org/kb/?View=entry&EntryID=36)	http://www.thesef.org/
West Penn Power Sustainable Energy Fund	West Penn Power Service Territory (Pennsylvania)	Grants: non-profit companies and community-based organizations in the West Penn Power service territory; Commercial Loans: manufacturers, distributors, retailers, and service companies in the West Penn Power service territory	Varies by proposal	"The West Penn Power Sustainable Energy Fund (WPPSEF) invests in the deployment of clean energy technologies throughout the West Penn Power service region in Pennsylvania. Investments are made to: promote the use of renewable and clean energy; promote energy conservation and energy efficiency; and to promote the attraction, establishment and retention of sustainable energy businesses." (http://www.wppsef.org/)	http://www.wppsef.org/
Chesapeake Bay Restoration Fund	Virginia	State agencies, local governments, and public or private not-for profit agencies, institutions, or organizations (Individuals not eligible)	Varies by project	"In 1995, legislation was passed creating the Chesapeake Bay Restoration Fund Advisory Committee. The Advisory Committee was given the responsibility of developing goals and guidelines for the use of moneys collected from the sale of the special Chesapeake Bay license plates. By December 1 of each year, the Advisory Committee is to present to the Governor and the General Assembly a plan for expending these funds. The Advisory Committee will recommend that such expenditures be in the form of financial grants for the support of specific Chesapeake Bay projects. Preferences will be given to environmental education and action-oriented conservation and restoration projects within Virginia's Chesapeake Bay watershed." (http://dls.state.va.us/groups/cbrfac/GUIDELNS.HTM)	http://dls.state.va.us/groups/cbrfac/GUIDELNS.HTM
Virginia Energy and Environment Network (VEEN) Request for Proposal	Virginia	DEADLINE FOR THIS RFP WAS JANUARY 2007	Maximum of $200,000	"This funding opportunity is targeting opportunities to study the feasibility of using alternative feedstock for energy production and overcoming barriers associated with alternative energy projects." (http://www.eng.odu.edu/veen/Grant_Info/Biomass_RFP_06-001_Rev1.pdf)	http://www.eng.odu.edu/veen/

Appendix C. Potential Profit Options for a Litter-To-Energy Project

Profit Type	Description	Profit Potential	Currently available in CB watershed states?
Net Metering	With net metering, the energy that is generated by the litter-to-energy system can be used to offset the site's energy consumption. In order to participate in net metering, the system must be connected to the electric grid.	Net metering allows for savings in electrical costs by allowing generated electricity that exceeds the site's current electricity use to be banked for use at another time. The electricity that is banked replaces electricity that would have been purchased at the retail rate. In addition, when the amount of excess electricity generated in a billing period exceeds the amount of electricity consumed in a billing period, the customer is usually credited for this 'net excess' at either the retail rate or at the avoided cost rate, depending on the state.	Net metering programs are offered in all of the Chesapeake Bay watershed states. Biomass is included as an eligible technology in all of these programs.
Green Pricing Programs	A green pricing program is an optional utility service in which participating customers pay a premium on their electric bills to support the utility's investment in renewable energy technologies. A green pricing program in Vermont called Cow Power directly benefits farmers who generate electricity from cow manure using anaerobic digestion.	In Vermont's Cow Power program, farmers receive the 4 cent premium for every kWh bought by the electric utility, in addition to being paid 95% of the market price for the electricity that they generate and sell back to the grid.	Although no states in the watershed have adopted policies that require electricity suppliers to offer green power options, several of the electrical utilities in the watershed do offer green pricing programs. Currently, none of these programs include energy generated from manure and none offer a payment system to farmers similar to that of Vermont's Cow Power Program.
Renewable Energy Certificates	Certified projects that generate renewable electricity earn renewable energy certificates (RECs), which are also known as tradable renewable certificates, renewable energy credits, green certificates, and green tags. Rather than representing the actual electricity that is generated by a renewable energy project, RECs instead represent the electricity's environmental attributes.	RECs can usually be sold separately from the electricity that is generated by the project, thus providing the producers with another source of profit. RECs, which are typically in 1 megawatt-hour units, were being sold for between $200-$300 in 2006. Typically, local energy producers sell their RECs to a broker, who then aggregates them and sells them to a buyer. It is important to note, however, that in some states, participating in other profit options such as net metering, green pricing programs, and trading programs, may affect the number of RECs, if any, that a renewable energy producer receives.	No matter where they are located in the U.S., certified projects that generate renewable electricity are eligible for RECs.
Greenhouse Gas Trading Programs	The CO_2 that litter-to-energy systems emit is not considered to be a greenhouse gas because the combustion of poultry litter simply recycles carbon that is already in the environment and it does not release new carbon. Therefore, these projects may be eligible for carbon credits. One carbon credit is equal to one metric ton of carbon dioxide emissions. The Chicago Credit Exchange (CCX) allows CCX members who are unable to reduce their emissions to purchase credits from members who make extra emissions cuts or from verified offset projects. Certain renewable energy systems are considered to be eligible offset projects.	In order for a renewable energy system to qualify for this program, the energy it generates must not be sold as "green" energy or be used to meet renewable portfolio standard mandates. In addition, in order for the CCX offset credits to be issued, any REC credits the project qualified for most be surrendered and retired.	The Chicago Credit Exchange is a national program.
Water Quality Trading Programs	Water quality trading programs allow a pollution source to achieve its pollution reduction requirements by purchasing credits from a credit-generating source in the same watershed. Depending on the program, these credits can either be generated by point or nonpoint sources. Litter-to-energy projects that reduce nutrient pollution and provide a water quality benefit may one day be able to earn marketable credits in these trading programs.	In April 2007, it was reported that a typical nutrient credit was worth between $2 and $9 for the reduction of approximately 1.6 pounds of pollutants.	Water quality credit trading programs that allow point-to-nonpoint trades were recently established in PA and VA and have been proposed in MD, DE, and WV. A trade involving a litter-to-energy system has not yet taken place.
Ash Sales	Litter-to-energy production creates a nutrient-rich ash byproduct which can potentially be sold as fertilizer. The litter-to-energy process concentrates nutrients such as phosphorus and potassium in the ash, creating a product that is denser and more stable than raw manure. In addition, the ash lacks the pathogens and odors that are typically present in poultry litter feedstock.	After taking into account transportation costs, additional processing costs, and marketing costs, a report by B.R. Bock determined that the net fertilizer value of poultry litter ash at an energy plant would likely range from $25 to $75 per ton. Another estimate, which was conducted in 2002, determined that ash sales would likely bring in between 0.7 and 1.3 cents per kilowatt-hour of energy generated.	The ash that is generated by litter-to-energy systems in the Chesapeake Bay watershed could potentially be sold as a fertilizer as long as a market can be found.
Heat Generation	Certain on-site litter-to-energy systems, such as gasifiers, could be used to heat a site's poultry houses. Using heat generated by a litter-to-energy system would displace some of the fossil fuel that is traditionally needed to heat the houses.	This could potentially result in a significant cost savings because, according to an article by the Foundation for Organic Resources Management, Inc., "fuel for space heating is typically the single greatest operating expense for broiler and turkey producers in the United States." A typical four-house broiler operation spends between $16,000 and $24,000 per year on propane for heat generation, assuming that the price of propane is $1 per gallon and each house uses 4,000-6,000 gallons of propane per year.	Reducing fuel costs may not directly benefit poultry growers on the Delmarva Peninsula. In this region, contracts require that the poultry company pay for the propane and litter used by the poultry grower. Because the propane is already provided free of charge to the poultry grower, they would not directly benefit from any savings in fuel cost (although the poultry company could decide to pass this savings on to the grower).

Appendix D. Rules for Net Metering in the CB Watershed States

	Eligible Technologies	Applicable Sectors	Limit on System Size	Limit on Overall Enrollment	Treatment of Net Excess	Utilities Involved
Delaware	Photovoltaics, Wind, Biomass, Hydroelectric	Commercial, Residential	25 kW	None	Varies by utility	All utilities (applies to municipal utilities only if they opt to compete outside their municipal limits)
Maryland	Photovoltaics, Wind, Biomass, Anaerobic Digestion	Commercial, Residential, Schools, Local Government, State Government, Federal Government	200 kW (500 kW with MD Public Service Commission approval)	34.7 MW (0.2% of state's adjusted peak load for 1998)	Credited at retail rate to customer's next bill for up to 12 months	All utilities
New York	Photovoltaics, Wind, Biomass	Residential, Agricultural	10 kW for solar; 25 kW for residential wind; 125 kW for farm-based wind; 400 kW for farm-based biogas	0.1% of 1996 demand per IOU for solar; 0.2% of 2003 demand per IOU for wind; 0.4% of 1996 demand per IOU for farm-based biogas	Credited monthly at retail rate, except for wind greater than 10 kW, which is credited monthly at avoided-cost rate. Accounts reconciled annually at avoided-cost rate.	All utilities
Pennsylvania	Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Fuel Cells, Municipal Solid Waste, CHP/Cogeneration, Waste Coal, Coal-Mine Methane, Anaerobic Digestion, Other Distributed Generation Technologies	Commercial, Industrial, Residential, Nonprofit, Schools, Local Government, State Government, Federal Government, Agricultural, Institutional	50 kW residential; 1MW non-residential; 2MW customers with systems that are part of microgrids or are available for emergency use	No limit specified	Customer compensated monthly at utility's avoided-cost rate	Investor-owned utilities
Virginia	Solar Thermal Electric, Photovoltaics, Wind, Biomass, Hydroelectric, Geothermal Electric, Muncipal Solid Waste, Tidal Energy, Wave Energy	Commercial, Residential, Nonprofit, Schools, Local Government, State Government, Institutional	500 kW non-residential; 10 kW residential	0.1% of a utility's annual peak demand	Credited to following month, then either granted to utility annuallly or credited to following month	Investor-owned utilities, electric cooperatives
Washington, DC	Solar Thermal Electric, Photovoltaics, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, CHP/Cogeneration, Anaerobic Digestion, Tidal Energy, Microturbines	Commercial, Industrial, Residential	100 kW	None	Credited to customer's next bill at utility's retail rate	All utilities
West Virginia	Photovoltaics, Landfill Gas, Wind, Biomass, Fuel Cells, Small Hydroelectric	Commercial, Residential	25 kW	0.1% of utility's total load participation (utility tariff provision)	Credited to customer's next bill at utility's retail rate	All utilities

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