Potential of Using Poultry Litter as a Feedstock for Energy Production

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1. Introduction

The United States is the world's largest poultry producer and the second-largest egg producer and exporter of poultry meat. The annual poultry meat production in the U.S. totals over 43 billion pounds (USDA, 2009). In this 20 billion-dollar industry, about 80% of the production consists of broiler meat while turkey meat accounts for most of the remainder (USDA, 2010). According to the USDA 2007 Census of Agriculture, there are over 320,000 documented poultry farms nationwide, and each year millions of tons of poultry litter/manure are generated through these facilities.

Over the years, nutrient-rich poultry litter was largely utilized as a soil fertilizer in crop production, source of cattle feed and as a potting medium in ornamental horticulture, and lawn and garden markets. However, the ban on poultry litter as a cattle feed by the Food and Drug Administration (FDA) in early 2004 due to concerns over BSE (mad cow disease), coupled with increased restrictions on land applications, have intensified the problem of disposing poultry litter in an environmentally safe manner (Livingston, 2004). Land applications of poultry litter are a potential cause of water pollution because of its high phosphorous content. Narrowing disposal options have created new opportunities in using poultry litter as a feedstock for bio-energy production. Using animal biomass as a fuel can eliminate its use in products that might be hazardous to human health, and can also reduce the need for conventional fuels. The purpose of this paper is to document the availability of poultry litter in the U.S. and assess its potential for energy generation with special emphasis on co-firing with woody biomass.

2. Potential of Poultry Litter for Energy Generation

Poultry litter is a mixture of manure and bedding material such as wood shavings, sawdust, peanut hulls, shredded sugar cane, straw, and other dry absorbent low-cost organic materials. Over the years it has found use in agriculture and has been highly valued as a nutrient-rich fertilizer. Composting and land applications are still the most common means of disposing poultry litter. However, land application of poultry litter is associated with environmental consequences such as excess phosphates in water bodies and potential human health risks. In certain areas, pressure on poultry producers is increasing because minimal land is available for manure utilization. Hence, it has become increasingly important to find environmentally sound, economically sustainable, technologically feasible alternative disposal mechanism that offers best social benefits.

Power generation from animal biomass is considered one of the best alternatives to the growing issue of poultry litter management. Recent fluctuations in energy costs and growing attention to greenhouse gas emissions have made poultry litter a potentially stable green fuel source that can help displace the demand for fossil fuels and purchased electricity (*PoultryTech,* 2008). Conversion of litter into energy is carbon dioxide neutral. Poultry litter has good burning qualities due to its composition, making it a potentially excellent source of fuel. Therefore, using it as a fuel may create a new continuous outlet for poultry litter, while improving the efficient utilization of poultry houses (*primenergy.com*, 2010).

Reported heating/ calorific values for broiler litter on an “as produced” basis range from 4,637 to 6,950 BTU/lb. Under moisture and ash free conditions, it can be as high as 7787 to 9000 BTU/lb (Martin, 2006). Heating values are greatly affected by moisture content and ash content of the litter. Energy generation from the poultry litter can be achieved by anaerobic digestion, direct combustion, co-firing, and gasification. At present, these techniques are practiced on the experimental scale and, to some extent, on the commercial scale.

Anaerobic digestion produces the usable energy in the form of biogas (methane). The process involves three general steps;

1. Hydrolysis or liquefaction of animal manure by bacteria into soluble organic compounds
2. Acetogenesis (acid production), or conversion of decomposed matter to organic acids
3. Methanogenesis (biogas production), or conversion of the organic acids to methane and carbon dioxide gas.

The technique is not recommended for relatively dry material such as poultry litter since it would require the addition of a substantial amount of water to create slurry, which is often associated with wastewater management issues (Martin, 2006). If it were mixed with another digester feedstock with a higher moisture content, this might be a more practical solution.

In **direct combustion**, litter is burned inside boilers under excess air/oxygen. Hot flue gases generated in the process are used to produce steam. Steam turbine generators are used to produce electricity. Given the availability of raw materials, direct combustion is the simplest and most developed bio-energy technology which can be economically feasible on a large scale (Flora and Riahi-Nezhad, 2006). In direct combustion, the particle size of litter used in boilers can significantly affect the calorific value. A study conducted by Whitely et al. (2006) showed that particles larger than 150 μm in size showed the highest calorific value (5 300 BTU lb-1) and lowest ash content in combustion.

The direct combustion technique is currently used for electricity generation in the U.S at commercial scale. Fibrowatt, a U.K. based company is pioneering the technology of combusting poultry litter to produce electricity. The company opened Fibrominn, the first poultry litter-fueled power plant in the U.S. in mid-2007, in Minnesota. The plant uses more than 500,000 tons of poultry litter annually, as well as other biomass, and majority of the fuel is supplied by Minnesota turkey growers. The 55-megawatt power plant produces enough electricity to serve approximately 40,000 homes and sells electricity to the national grid (Fibrowatt, 2010). Fibrowatt is currently working on similar facilities in South Carolina, Arkansas, Georgia, Mississippi and Maryland. An added advantage of combustion for electricity generation is that it produces not only electricity, but also a nutrient-rich by-product that can be used as fertilizer. The by-product contains concentrated forms of phosphorous and potassium, which are important nutrients for plants.

Co-firing is the simultaneous combustion of a complementary fuel, such as animal manure or wood waste, with a base fuel, such as coal in a coal-fired boiler. The biomass can either be introduced via a dedicated feed system or mixed with coal in the coal pile and fed to the boiler through the coal feed system. Co-firing poultry litter in an existing utility boiler may be a viable method of energy generation since the infrastructure already exists. This is a low cost approach for green power generation. Co-firing is the most promising technology for utilizing animal biomass as energy (Martin, 2006). However, Studies suggest that co-combustion of poultry litter is associated with high CO and NOx emissions especially when combusted with coal (Li et al, 2009).

Gasification is a form of pyrolysis or destructive distillation, which simply is a chemical change produced by heating. It uses heat, steam, and pressure to convert organic materials into carbon monoxide and hydrogen that can subsequently be used for the production of a variety of fuels and chemicals. The composition and Btu content of the gas produced depends on the specific process utilized and the characteristics of the carbon source including particle size and moisture content (Martin, 2006).

3. Resource Availability

Broiler operations are the main source of poultry litter/manure. Spatial distribution of poultry production facilities/farms shows geographical concentrations. Broiler production is particularly concentrated in a group of States stretching from Delaware, south along the Atlantic coast to Georgia, then westward through Alabama, Mississippi, and Arkansas (**Figure 1**). The leading broiler-producing State is Georgia, followed by Arkansas, Alabama, Mississippi, and North Carolina (USDA, 2010).

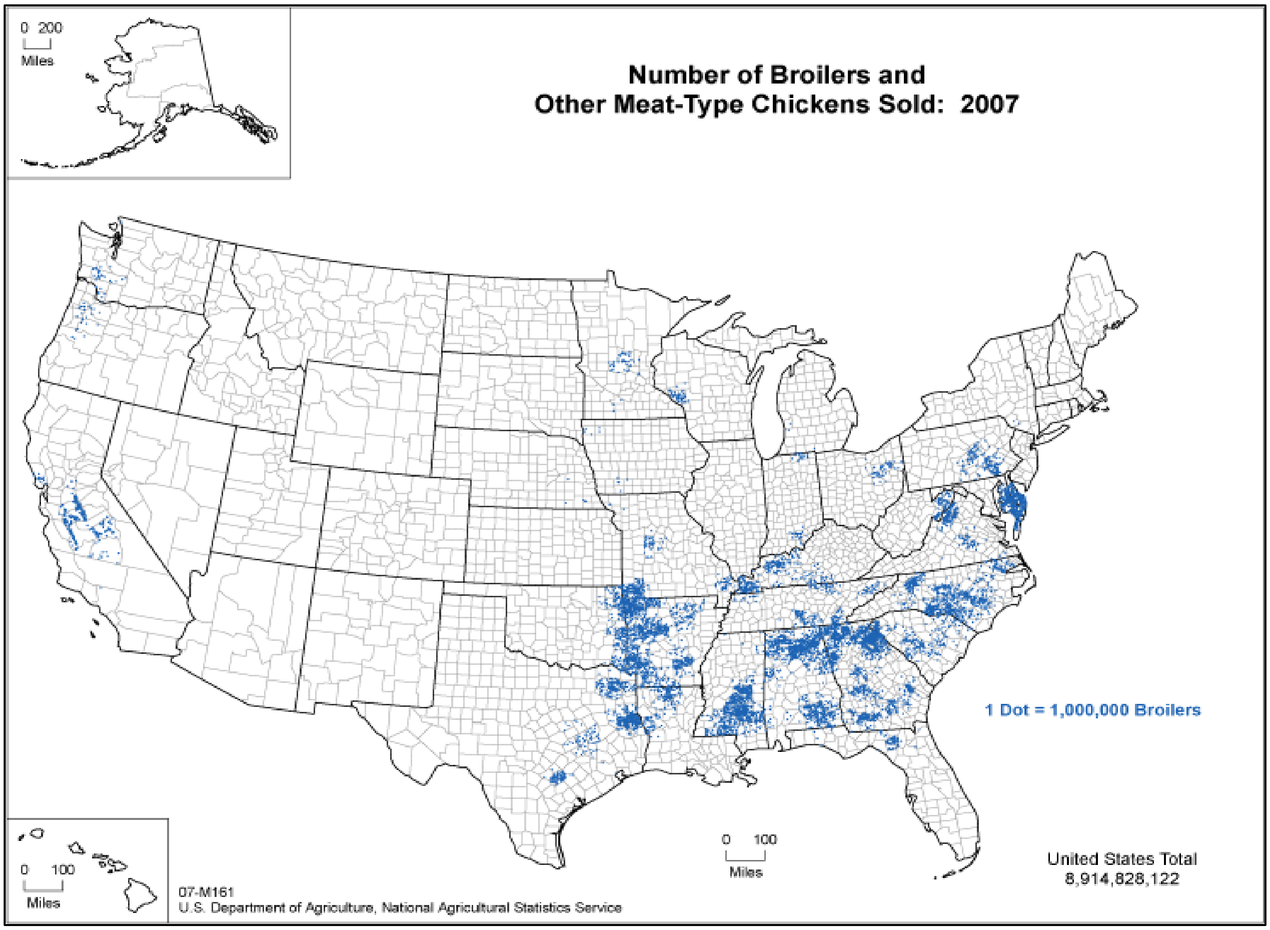

Figure 1: Geographical Distribution of Broiler Production in the U.S. (*Source: USDA, 2007*)

In contrast, the production of turkeys is somewhat more scattered geographically than broiler production (**Figure 2**). Minnesota, North Carolina, Missouri, Arkansas, and Virginia are the top five turkey-producing States in the U.S. (USDA, 2010). In addition, U.S. egg operations also generate significant amount of litter each year. Apart from human consumption, eggs are hatched to provide replacement birds for the egg-laying flocks and to produce broiler chicks for grow-out operations. The top five egg-producing States are Iowa, Ohio, Pennsylvania, Indiana, and Texas (**Figure 3**).

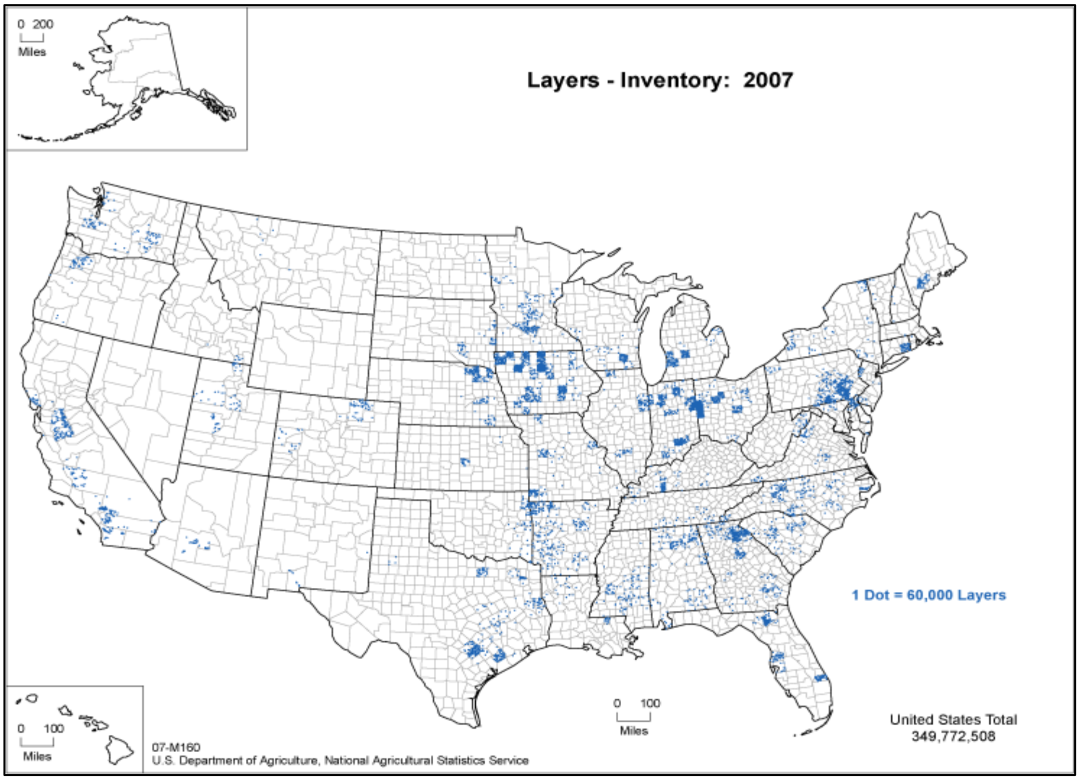

Figure 2: Geographical Distribution of Turkey Production in the U.S. (*Source: USDA, 2007*)

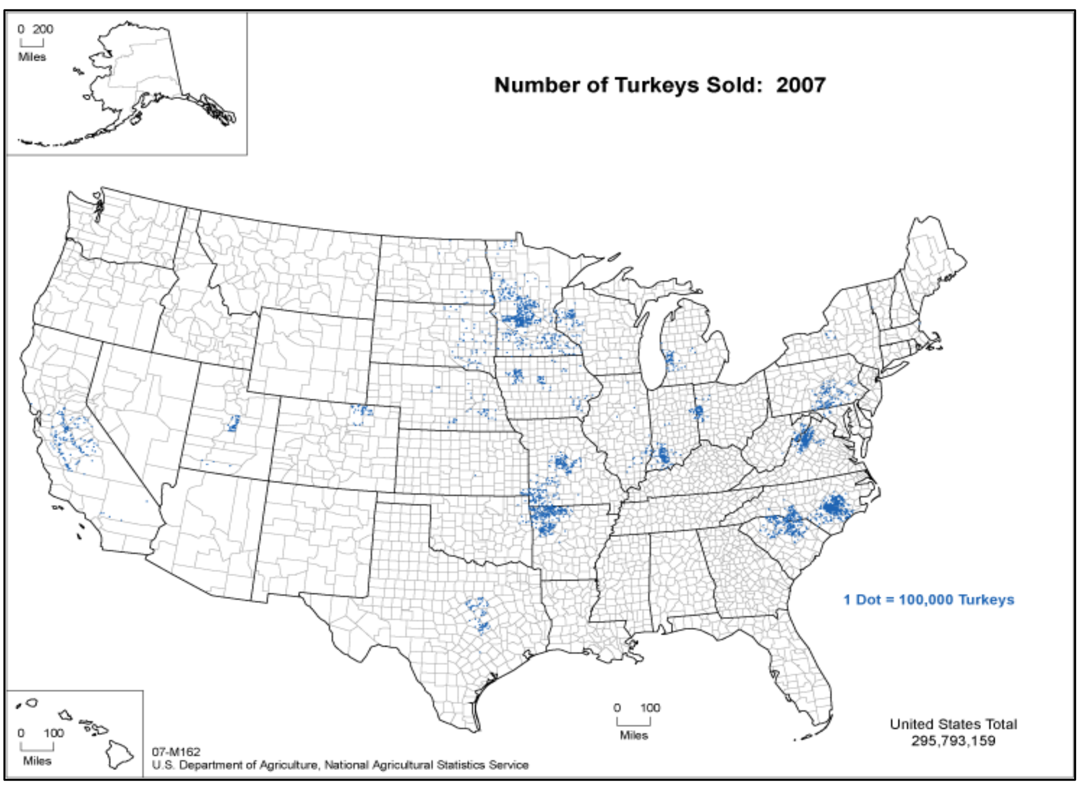

Figure 3: Geographical Distribution of Egg Operations in the U.S. (*Source: USDA, 2007*)

Consequently, poultry manure production also follows the distribution pattern of poultry operations. As illustrated by **Figure 4**, poultry manure availability is more concentrated in South Eastern states such as Georgia, Arkansas, Alabama, Mississippi, and North Carolina with only exception being California. This is an important logistic to consider in citing bio-fuel facilities utilizing poultry litter since the cost of transportation can become prohibitively expensive.

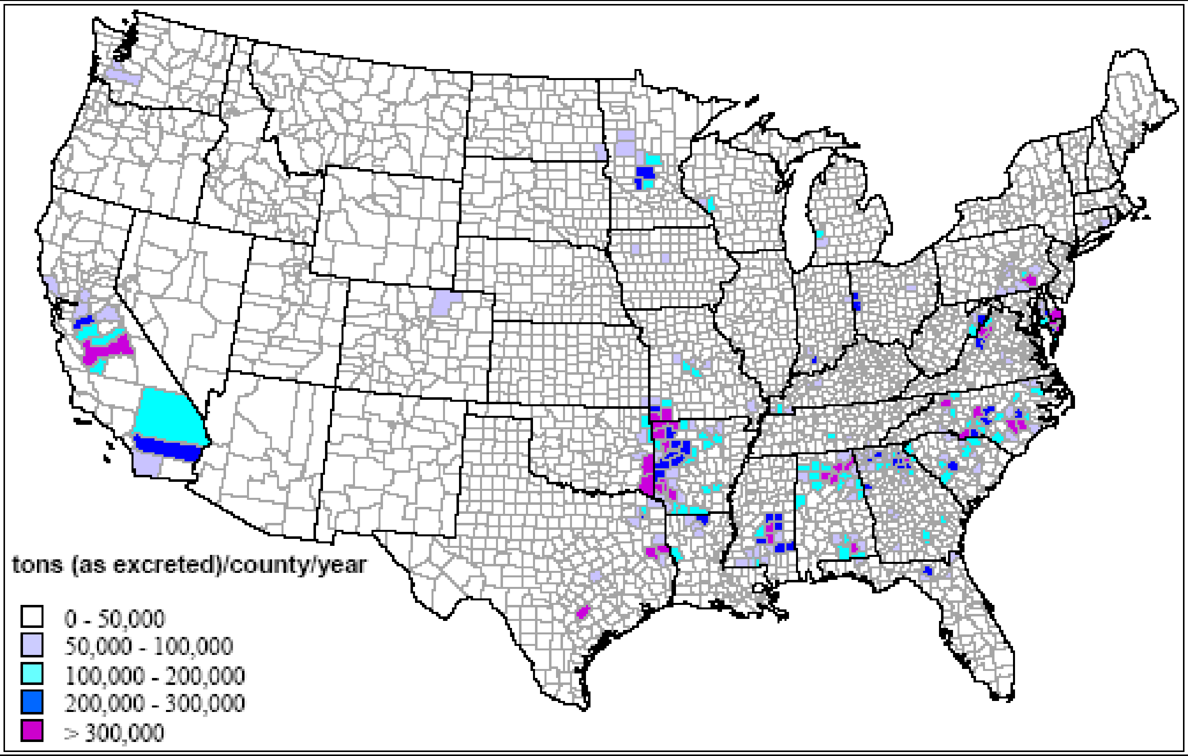

Figure 4: Poultry manure production in the continental United States
(Source:www.thepoultrysite.com)

Quantity of litter produced by poultry operations tends to vary greatly depending upon the bedding material used, type of birds, market weight, number of flocks, field conditions, time of year and moisture content (Donald et al, 1996). Therefore, estimating the amount of litter produced by poultry operations is difficult. However, researchers have used different methods (such as using the relationship between flock's feed intake and fresh manure output) to develop accurate estimates on litter production (Flora and Riahi-Nezhad, 2006; Parker et al, 2002). In this analysis, poultry litter estimates were made based on figures published in past works. The amount of litter generated annually by broilers was assumed to equal 1.2 tons per 1,000 birds per year (Carr 2002) while the same figure for turkeys was assumed to be 12.3 tons per 1,000 birds per year (Flora and Riahi-Nezhad, 2006). The number of broilers and turkey produced annually by leading states are available in 2007 Census of Agriculture data sets. Only broiler and turkey industries were considered since average litter production data for other types of poultry were unavailable or difficult to obtain. Accordingly, **Table 1** and **Table 2** show the litter estimates for broilers and turkey operations respectively for the last two years. Although these figures are likely to be underestimates of the actual litter availability, they provide valuable insights to the relative availability of raw materials to be used in bio-energy production.

Table 1: Litter Estimates for Broiler Operations (2008 & 2009)

	Year 2008		Year 2009	
State	Number (1000 heads)	Litter Tons	Number (1000 heads)	Litter Tons
AL	1,062,900	1,275,480	1,002,300	1202760
AR	1,160,000	1,392,000	1,050,900	1261080
DE	242,900	291,480	231,500	277800
FL	63,800	76,560	42,000	50400
GA	1,409,200	1,691,040	1,322,000	1586400
KY	306,100	367,320	307,000	368400
MD	298,600	358,320	291,900	350280
MN	44,900	53,880	44,800	53760
MS	840,700	1,008,840	793,400	952080
NC	796,100	955,320	759,600	911520
OH	57,500	69,000	56,400	67680
OK	237,800	285,360	226,000	271200
PA	160,900	193,080	153,500	184200
SC	236,900	284,280	237,800	285360
TN	199,700	239,640	189,700	227640
TX	641,000	769,200	668,700	802440
VA	250,300	300,360	240,800	288960
WV	85,700	102,840	82,700	99240
WI	51,700	62,040	45,800	54960
Other States	862,600	1,035,120	803,700	964440
*Total	9,009,300	10,811,160	8,550,500	10260600

**Excludes States producing less than 500,000 broilers.*

Table 2: Litter Estimates for Turkey Operations (2008 & 2009)

	Year 2008		Year 2009	
State	Number (1000 heads)	Litter Tons	Number (1000 heads)	Litter Tons
AR	31,000	381,300	29,000	356700
CA	16,000	196,800	15,000	184500
IN	14,500	178,350	15,000	184500
IA	9,000	110,700		
MN	48,000	590,400		
MO	21,000	258,300	18,500	227550
NC	40,000	492,000	35,500	436650
OH	6,000	73,800	5,200	63960
PA	11,500	141,450	9,000	110700
SC	12,500	153,750	11,900	146370
SD	4,700	57,810	4,500	55350
UT	4,100	50,430	3,200	39360
VA	18,000	221,400	17,000	209100
WV	3,800	46,740	3,300	40590
**Other States	32,988	405,752	80,259	987185.7
Total	273,088	3,358,982	247,359	3042515.7

***Other States include State estimates not shown and States suppressed due to disclosure.*

4. Current Markets and Demand for Poultry Litter

Despite growing environmental concerns and restrictions, land applications and composting are still the main use of poultry litter. Poultry litter contains significant amounts of nutrients essential for plant growth. The most important are the macronutrients, nitrogen, phosphorus, and potassium and other essential nutrients in lesser or trace amounts. Market prices for poultry litter are predominantly based on hauling distances and transport costs. For instance, current advertised prices at Georgia Poultry Federation Litter Market website (2010) vary from $10 to $27 per ton and prices depend on hauling distance. Potential poultry litter handling costs include cleanout of the houses, transport to another location if the litter is sold and transportation is provided, and application costs either to the farmer's own land or another farmer's land. In many cases, poultry litter is exchanged for cleanout and hauling services rather than sold. A survey on Tennessee poultry growers found that the average cost of cleanout exceeds $1200 per house or about $7 per ton (Jensen et al, 2010). Although prices vary widely depending on area/location, individual situations and deals, there are instances of growers being paid well over $32 a ton. Otherwise, in North Carolina, general market price at present ranges between $10 to $20 per ton as fertilizer (Hubbard, 2010).

A recent study conducted on West Virginia poultry farms to understand farmer perceptions about using poultry litter as a substitute for commercial fertilizers revealed that farmer willingness to pay varied from $15.5 to average market prices which were $6.5 per ton in the region (Collins and Budumuru, 2005). A majority of growers reported transferring some or all their litter off-farm largely due to insufficient agricultural land resources. Similar study in Tennessee found most farmers interviewed used litter on-farm (Jensen et al, 2010). In Georgia, poultry litter was priced around $14 a ton and an average farmer using poultry litter as fertilizer paid as much as $21a ton in 2008 (extension.org, 2008).

Pelletization is the second largest use of poultry litter on the Delmarva Peninsula (Lichtenberg, 2002). Pelletization technology was pioneered by Perdue AgriRecycle, LLC, a joint venture between Perdue Incorporated, and AgriRecycle. The plant located in Delaware can process the equivalent of 400 poultry houses worth of litter (150,000 tons) each year and its main product MicroStart 60® is mainly marketed for turf and horticultural industries while a significant percent is exported (PerdueAgrirecycle, 2010). At present, the company acquires raw materials from Delaware, Maryland Eastern Shore and Virginia Eastern Shore poultry producers. AgriRecycle does not pay a price for poultry litter; in exchange participating poultry growers receive professional cleanout services and hauling. However, according to estimates by Lichtenberg in 2002, the company could pay on average as much as $8.50 per ton of raw litter while earning a premium of $10 per ton of palletized products sold.

With growing interest on green energy, the latest demand for poultry litter is coming from the renewable energy sector. Many bioenergy power plants are still operating at small or experimental scale. Currently, a 55 megawatt power plant predominantly utilizing poultry litter is operated by Fibrowatt in Minnesota. The plant has a capacity to utilize 500,000 tons of poultry litter annually, but currently operating under its full capacity due to environmental regulations (Fibrowatt, 2010). Fibrowatt is planning similar plants in North Carolina, Arkansas, Georgia, Mississippi and Maryland.

Competition between Fibrowatt Ltd. and other buyers of chicken litter combined with increasing commercial fertilizer prices is expected to keep the demand for poultry litter strong. For instance, prices paid by other farmers for chicken litter in North Carolina shot up in 2009 largely due to high commercial fertilizer costs, and using poultry litter as cattle feed during a hay shortage (Hubbard, 2010). However, contracts with Fibrowatt are likely to provide a price security for poultry growers in the long run especially when demand for chicken litter falls due to lower commercial fertilizer prices. At present, Fibrowatt has secured contracts to purchase litter with about 20 percent of the Tyson Foods Inc. contract chicken farms in Wilkes and nearby counties in North Carolina. As reported in the article by Hubbard (2010), “the 10-year contracts offered by Fibrowatt pay poultry growers $2 to $2.50 per ton of litter if Fibrowatt contract haulers remove litter from chicken houses and load it on trucks or $4 to $4.50 per ton if growers remove and load litter on contractors’ trucks. Growers get higher pay at these two levels ($2 to $2.50 or $4 to $4.50) for litter with less moisture. These pay ranges increase during the 10 years, based on a percent of the Consumer Price Index”.

New opportunities in renewable energy sector to use poultry litter as a feed stock for bio-fuel generation has created a growing interest among poultry farmers. For instance, a study conducted to identify Farmer Willingness to Supply Poultry Litter for Energy Conversion in Tennessee found that most farmers are willing to sell their poultry litter at $15 to $25 per ton (Jensen, 2010). Large scale farmers who are currently facing disposal issues were willing to sell litter at less than $15 per ton.

5. Environmental and Social Issues of Energy Production using Poultry Litter

Other than technological barriers that need to be overcome, various environmental and social issues also restrain the efficient utilization of poultry litter in energy production. Issues vary depending on the method used to convert litter into energy (energy.sc.gov, 2010).

5.1 Issues on the anaerobic digestion of poultry litter for energy production

- The appropriateness of anaerobic digestion for poultry litter: Since anaerobic digestion is better suited for layer manure wastes that are high in moisture content, significant amounts of water have to be added for poultry litter to be amenable for anaerobic digestion.
- The need to dispose of a liquid stream and wet sludge is a big issue in anaerobic digestion, specifically the disposal of phosphate nutrients.
- Anaerobic digestion would be more difficult to implement on a small (on-site) scale since it requires a longer start-up period compared to combustion and gasification, and thereafter it needs consistent caring and frequent maintenance.
- The produced biogas must be used immediately since it cannot be stored.

5.2 Issues on the combustion and co-firing of poultry litter for energy production

- The public response to a perceived incinerator: The general public is opposed to establishing poultry-litter-burning incinerators in the area. They believe that this kind of operation may deplete the property value and that by products and waste fumes and gases from incinerators may cause health problems.
- The need for air pollution control devices: It is important to assemble air pollution control devices to regulate emissions from incinerators to reduce air pollutants from disposal wastes.
- The location of primary combustion facility for co-firing the litter: Primary combustion facility and the co-firing center should be located in close proximity to minimize transportation costs
- Air pollution issues when co-firing poultry litter with coal: NOx generation can be significant for co-firing coal with poultry litter. This is attributed to the high saw dust content in the poultry litter.

5.3 Issues on the gasification of poultry litter for energy production

Certain issues related to gasification are similar to those with combustion and co-firing of poultry litter. For example, the public response to a perceived incinerator and the need for air pollution control devices are similar to the combustion and co-firing. Other than that the following issues have been identified with gasification of poultry litter (energy.sc.gov, 2010).

- Relatively limited full-scale applications
- As in the anaerobic digestion, the gas produced cannot be stored and must be used immediately.

6. Opportunities and Threats in the Industry

To be commercially successful, energy from poultry litter should be technically viable, economically feasible, and also should be acceptable from the customer's perspective. Even though identified opportunities and associated threats for energy from poultry litter give an idea about the appropriateness of the poultry litter as an energy source, a full system analysis must be performed prior to making conclusions.

6.1 Opportunities for energy from poultry litter

- Excellent option for reducing operating expenses while also addressing environmental concerns associated with traditional litter management practices. In case land application of poultry litter is not allowed, this technology will be a viable means to dispose of poultry litter
- Opportunity for obtaining carbon credits for producing energy from poultry litter.
- Utilizing some of the waste energy for heating could greatly enhance system economics.

- Energy content in the litter varies from about 3800 to 5000 Btu depending on the bedding material used, the number of flocks produced on the bedding prior to clean-out, and the moisture content of the litter. With a conversion system efficiency of 70% and an average of 4600 Btu energy per pound, 65 tons of surplus litter could provide about 86% of the thermal energy needed for a typical broiler house. An average of $3.00 per ton of litter to the grower and an average propane cost of $0.75 per gallon, a farmer's net savings from use of surplus litter as fuel would be about $3,700 per year per house (thepoultrysite.com, 2010).
- Shafer Farms in Mississippi has been processing its poultry litter in an anaerobic digester and recently found that the project would have a commercial payback period of 5 years. They are also producing more energy than they consume in litter handling, making it a net positive energy balance (Shafer, 2010).

6.2 Threats for energy from poultry litter

When considering poultry litter for energy generation, there are numerous technical, environmental, social, and policy factors that must be integrated beyond economic factors. According to the final report prepared for the SC energy department, following general issues have been identified (energy.sc.gov, 2010).

- Since poultry houses are cleared once a year, energy generating facilities need litter storage.
- General public has the impression that the facility will cause air pollution that would impact health and would deflate property values.
- Selling the energy into the power grid will be technically and economically problematic.
- Concerns about spreading poultry-related disease among farms

Converting the poultry litter into thermal energy is one of the realistic answers to lessen increasing pressures on poultry producers to embrace alternative management practices for surplus litter. On the other hand, energy form the poultry litter can be used for space heating, thereby displacing some of the fossil fuel typically used for this purpose. Eventually, current economic conditions associated with the poultry industry are likely to become more favorable and the industry will have to embrace strategies for recovering operating costs that are now being recognized as required for managing surplus poultry litter (thepoultrysite.com, 2010).

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