AVAILABILITY OF POULTRY LITTER AS AN ALTERNATIVE ENERGY FEEDSTOCK: THE CASE OF MISSISSIPPI

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Introduction

The recent increase in energy costs has invigorated the search for alternative energy from sources other than fossil fuels. Biomass has received much of the attention as an alternative to fossil fuels. Biomass is plant and plant derived material or animal waste that can be converted into fuels (EERE). Currently, corn grain is used to produce the vast majority of ethanol in the U. S.; however it appears inevitable that cellulose and hemicellulose based energy will be used extensively in the future. One of the major problems faced with energy from biomass is transportation costs. Cellulosic feedstocks typically generate fewer Btu's (British thermal units) of energy per ton that fossil fuels. The lower energy values increase the amount of feedstock necessary to generate the same amount of energy.

One of the biomass feedstocks generating interest is poultry litter. Poultry litter is the bedding material and waste from poultry houses. The bedding material is primarily wood shavings; however rice hulls and peanut shells may also be used (Atul and English). Poultry litter is currently used as a fertilizer for hay, pasture, and forestry or as a livestock feed. As a fertilizer, poultry litter is estimated to contain approximately 60 pounds of nitrogen (N), 60 pounds of phosphorus (P), and 40 pounds of potassium (K) per ton. While the feeding of litter is not illegal, its use in this manner has declined significantly due to health concerns. Problems associated with poultry litter stem from the high level of concentration of poultry production in an area. There is a limited amount of area to apply waste litter, the grasses and forest do not utilize all of the phosphorus and potassium, and transportation costs of transporting litter to areas of major agricultural production are too high. The high concentration of nutrients remaining in the soil can lead to contaminated surface and ground waters. Therefore, alternative methods of disposal are needed for waste litter to avoid further environmental regulation.

One alternative disposal method gaining interest is producing energy from poultry litter by combustion. A process utilized by Fibrowatt, LLC is burning litter in a broiler lined with wall-water tubes, and using the steam to drive energy producing turbines (Fibrowatt, LLC). This process is currently used in their three United Kingdom facilities and their new facility, Fibrominn, in Benson, MN. Another process, used by Bioengineering Resources for Renewable Energy (BRI), involves a two-stage process (either gasification or plasma arc) to decompose organic materials into their basic gaseous forms at temperatures of up to 2,350˚ F. The synthesis gases (CO, CO_2, H_2) are scrubbed and cooled to approximately 98˚ F. This process generates an enormous amount of waste heat that can be used to create high temperature steam to drive electric turbines. An added process, known as the biocatalytic step, involves feeding the syngas to bacteria, which ingest the syngas and emit water and ethanol. The water can be distilled away to produce an ethanol that is 99.5% pure (Stewart, 2006). While it is possible to produce ethanol from litter, the high cost of the organisms makes it infeasible at this time. The benefit of the gasification process is that the ash contains nutrients, such as phosphorus and potassium, from the litter and is a highly valuable by-product fertilizer.

Methodology

Poultry production has been the top agricultural income producer in Mississippi for the past 12 years, with broiler production accounting for over 90% of the value

(Morgan and Murray). Mississippi produced approximately 750 million broilers in 2002, (NASS). According to Chamblee and Todd, litter production is estimated to be approximately 1.6 tons/1000 birds (2002). They determined the total volume of litter in broiler houses on three separate farms. Each load of litter removed from a single house on each farm was weighed as it was removed. They also measured the depth of the litter at 25 random locations in a broiler house, to calculate the volume of litter in the house in terms of cubic feet. The total volume in cubic feet was then multiplied by a known weight for a cubic foot of litter to provide the total predicted weight of the litter. Using this conversion factor, litter production in Mississippi is estimated to be approximately 1.2 million tons.

In 2002, Fibrowatt contracted for a pre-feasibility in the state of Mississippi for a 40-50 MW poultry litter fueled power generation facility to be conducted. They estimate that a 40 MW energy plant will require approximately 400,000 ton of litter to operate at full capacity. Previous studies by BRI estimate the potential ethanol yield of poultry litter to be 75 gallons per ton. The 400,000 tons of litter would produce approximately 30 million gallons of ethanol; which is considered to be a small to average size ethanol plant. Using the values for feedstock use and energy production, estimated by the two companies, this study examines the optimal placement of an energy/ethanol facility based on litter availability and transportation costs (McCallum Sweeny Cons.2002, Stewart, 2006).

This study examines location analysis using a sample area of poultry production in Mississippi. The area is comprised of nine counties located in east central Mississippi. The area was chosen based on broiler production and their geographical relationship to one another. Figure 1 shows the nine county area in central Mississippi considered for this study. The counties, broiler production, and litter production are shown in Table 1. The number of broilers per county comes from the 2002 Census of Agriculture. The tons of litter per county are calculated by multiplying 1.6 tons per 1,000 birds (Chamblee and Todd, 2000).

Table 1. Broiler and Litter Production in the Nine County Sample Area

County	No. Broilers	Tons/litter
Covington	21,836,656	34,938.65
Jasper	21,865,240	34,984.38
Jones	56,632,899	90,612.64
Leake	59,820,959	95,713.53
Neshoba	66,871,029	10,6993.6
Newton	38,513,838	61,622.14
Scott	93,686,885	149,899
Simpson	62,396,188	99,833.9
Smith	87,181,123	139,489.8
Total	508,804,817	814,087.7

The objective of this study is to locate an energy/ethanol gasification facility, within the subject area, that is supplied poultry litter at the minimum transportation cost. This analysis uses an X, Y coordinate model to determine the location of the plant. An X, Y coordinate model uses a point, or points, in each county and each point is assigned an X value and a Y value. The model was run in Premium Excel Solver, subject to the model constraints, and an optimal X, Y coordinate was calculated. The point in the subject area that corresponded with these coordinates, meets the feedstock requirements at the least transportation costs.

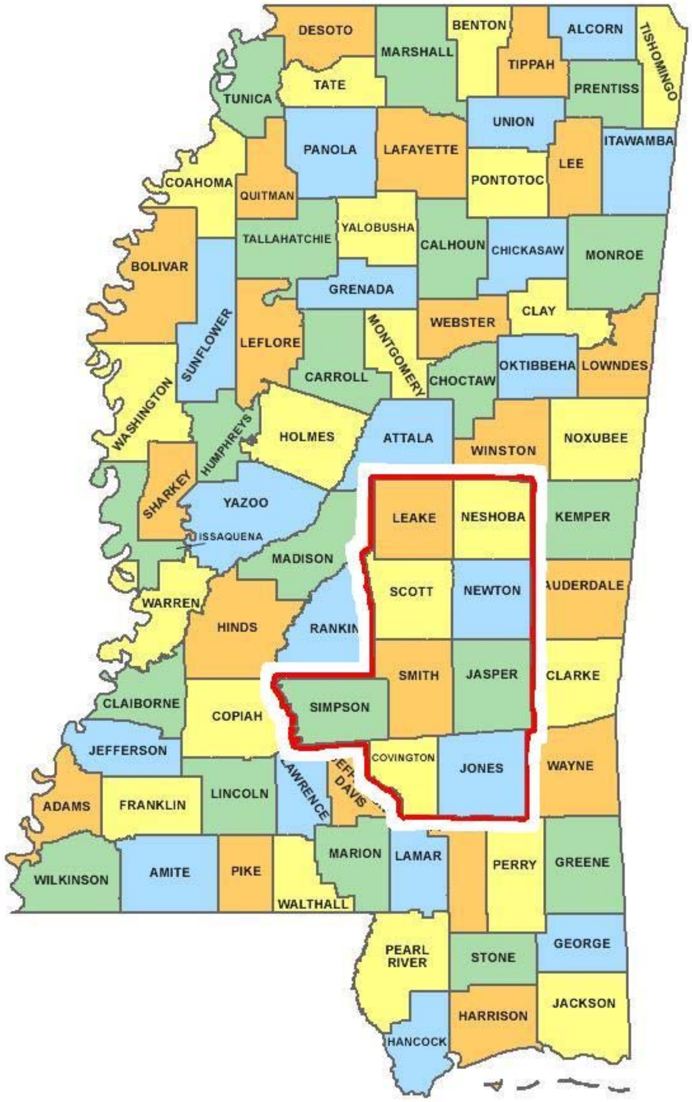

Figure 1. Nine County Sample Area in Central Mississippi

Poultry litter is delivered, assuming a truck load capacity of 25 tons, at $50/load for trips less than 30 miles, $75/load for trips between 40-50 miles, and $2.69/mile for trips over 40 miles. One hauler stated that, for simplicity and variation in load weights, he charges $3.00 per mile for all deliveries. Load weights may vary significantly, depending on the moisture content of the litter. Therefore, costs are generally in $/load as opposed to costs/ton/mile (Barrett and Murray, 2003). However, for modeling purposes, a per/ton/mile basis was chosen. The values mentioned above were used to estimate a per ton mile cost of transportation model to be used in the analysis:

$$C_M = 0.1 + 0.002D$$

Where C_M is the costs per ton mile of transportation, and D is the distant traveled. The assumption is made that the capacity of each truck load is 25 tons per trip. As stated before, the weight of the litter will vary considerably, based on moisture content. If the assumption is also made that all litter in the area averages the same moisture content, then no county would have an advantage over another based on weight; therefore, varying the capacity of the truck per trip will not affect the location of the plant.

It is safe to assume that not all poultry litter will be available to the plant. There will still be litter used for land applications, some livestock feeding, and some composting. There may also be some inefficiency in litter collection that prevents total litter production from being used. This analysis examines two potential litter availability scenarios. The first assumes that 50 percent of all litter in the area will be available to the plant. The second scenario will assume that 70 percent of the litter will be available. The model is constrained in each scenario such that the amount available is equal to 400,000 tons. The number of trips required to deliver the litter is determined by the amount of litter shipped divided by the capacity per trip. Total distance is equal to the number of trips required, multiplied by the distance from the plant determined within the model. The total cost of transportation is the amount shipped, multiplied by the distance to the plant, multiplied by the cost per mile/ton. The model is therefore to minimize:

$$C_T = AS * D * C_M$$

where, C_T is the total costs of transportation, AS is the amount of litter shipped in a county, D is distance to the plant, and C_M is the per ton mile costs of transportation.

The X, Y coordinates represent a specific location in each county. The coordinates are in miles, and represent the number of miles from the point of origin. The point of origin (0,0), is the extreme lower left corner of the subject area. The X axis is miles, East and West while the Y axis is miles, North and South. A point, or town, was chosen in each county to estimate mileage. The towns, and their corresponding X,Y coordinates, chosen for analysis are listed in Table 2.

Table 2: Towns and X,Y Coordinates used in Study

County	Town	X Coordinate	Y Coordinate
Covington	Seminary, MS	48	8
Jones	Ovett, MS	72	4
Simpson	Georgetown, MS	8	30
Smith	Taylorsville, MS	48	24
Jasper	Bay Springs, MS	56	36
Scott	Morton, MS	34	60
Newton	Decatur, MS	66	60
Leake	Carthage, MS	42	92
Neshoba	Philadelphia, MS	60	92

Results

The results from the first scenario, based on the ability to obtain 50 percent of the poultry litter in the subject area, are presented in Table 3. At 50 percent availability, litter from all nine counties will be used, with only Jones County not supplying all of its available litter. The total cost of transportation of the feedstock is $2,403,251.

Table 3. X, Y Location of Energy Plant Based on 50% Availability of Litter

County Name	Capacity Per Trip	Amount Produced	Amount Available	Amount Shipped	Coordinates X	Y	Distance to Plant	Cost per Mile-Ton	Trips Required	Total Distance	Total Cost
Covington	25.00	34,938.65	17,469.33	17,469.33	48.00	8.00	49.78	$0.20	698.77	34,783.66	173,532.54
Jones	25.00	90,612.64	45,306.32	38,262.47	72.00	4.00	60.67	$0.22	1,530.50	92,850.76	513,775.80
Simpson	25.00	99,833.90	49,916.95	49,916.95	8.00	30.00	44.99	$0.19	1,996.68	89,823.39	426,600.10
Smith	25.00	139,489.80	69,744.90	69,744.90	48.00	24.00	33.87	$0.17	2,789.80	94,498.25	396,291.73
Jasper	25.00	34,984.38	17,492.19	17,492.19	56.00	36.00	24.92	$0.15	699.69	17,433.63	65,303.17
Scott	25.00	149,899.02	74,949.51	74,949.51	34.00	60.00	9.84	$0.12	2,997.98	29,513.32	88,310.33
Newton	25.00	61,622.14	30,811.07	30,811.07	66.00	60.00	22.59	$0.15	1,232.44	27,838.86	101,038.85
Leake	25.00	95,713.53	47,856.77	47,856.77	42.00	92.00	34.46	$0.17	1,914.27	65,958.79	278,531.96
Neshoba	25.00	106,993.65	53,496.83	53,496.83	60.00	92.00	38.15	$0.18	4,279.75	163,289.78	359,866.52
Plant		814,087.71	407,043.86	400,000.00	43.54	57.58	319.26		18,139.87	615,990.44	2,403,251.00

The results indicate that the optimal location to locate the plant is at coordinates X = 43.54 and Y = 57.58. The point associate with the results of the optimization model places the plant location just south of Forest, MS. The coordinates are plotted on a map of the area in Figure 2.

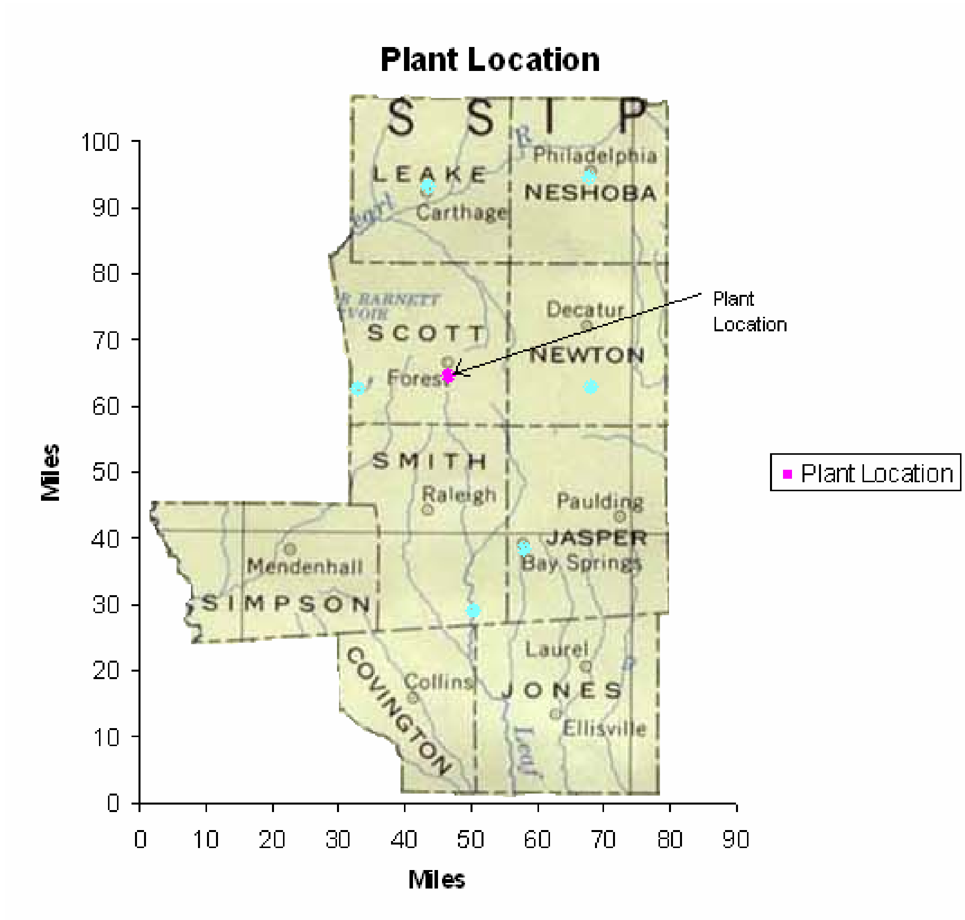

Figure 2. Plot of Plant Location with 50% litter availability

Results from the second scenario, when 70% of the litter in the area is available for use as a feedstock for energy/ethanol, are listed in Table 4. When efficiency in collection, or participation by producers increases, to allow 70% of the litter to become available, transportation costs are reduced greatly. The necessary amount of litter supplied is achieved without participation from Covington, Jones, or Simpson County and only limited participation from Smith County. When the availability of litter increases from 50% to 70%, transportation costs are reduced by $706,054.70 from $2,403,251 to $1,697,196. The total number of trips required to supply the feedstock is also reduced, from 18,140 to 17,284. The average distance to the plant also decreases, from 35.47 miles in the 50% scenario, to 26.90 miles in the 70% scenario. The number of trips required to deliver the feedstock decreases from 18,187 to 17,263, or by 924 trips. The reduction in the number of trips decreases the risk of accidents, chance of contamination between farms, and wear and tear on roadways.

Table 4. X, Y Location of Energy Plant Based on 70% Availability of Litter

County Name	Capacity Per Trip	Amount Produced	Amount Available	Amount Shipped	Coordinates X	Y	Distance to Plant	Cost per Mile-Ton	Trips Required	Total Distance	Total Cost
Covington	25.00	34,938.65	24,457.06	0.00	48.00	8.00	54.32	$0.21	0.00	0.00	0.00
Jones	25.00	90,612.64	63,428.85	0.00	72.00	4.00	63.69	$0.23	0.00	0.00	0.00
Simpson	25.00	99,833.90	69,883.73	0.00	8.00	30.00	50.13	$0.20	0.00	0.00	0.00
Smith	25.00	139,489.80	97,642.86	85,551.10	48.00	24.00	38.33	$0.18	3,422.04	131,157.30	579,237.76
Jasper	25.00	34,984.38	24,489.07	24,489.07	56.00	36.00	28.01	$0.16	979.56	27,437.30	107,018.83
Scott	25.00	149,899.02	104,929.31	104,929.31	34.00	60.00	12.55	$0.13	4,197.17	52,677.84	164,752.02
Newton	25.00	61,622.14	43,135.50	43,135.50	66.00	60.00	19.79	$0.14	1,725.42	34,151.54	119,177.23
Leake	25.00	95,713.53	66,999.47	66,999.47	42.00	92.00	30.02	$0.16	2,679.98	80,463.95	321,952.77
Neshoba	25.00	106,993.65	74,895.56	74,895.56	60.00	92.00	32.70	$0.17	4,279.75	139,942.51	405,057.67
Plant		814,087.71	569,861.40	400,000.00	46.34	62.29	329.54		17,283.92	465,830.45	1,697,196.29

The results of the optimization model place the plant location at the coordinates X=46.34 and Y=62.29. This point is 3 miles east and 5 miles north of the location in the first scenario, however the change in location is relatively small and the plant would actually be placed closer to Forest, MS in the second scenario. This plant location is shown in Figure 3.

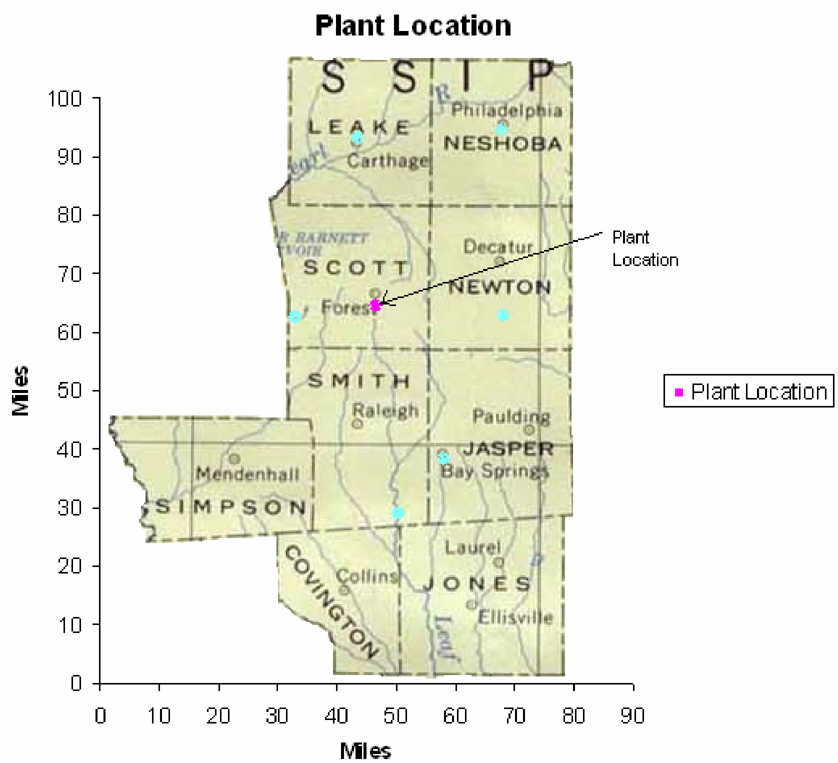

Figure 3. Plot of Plant Location with 70% litter availability

Forest, MS is centrally located in Scott County MS. From the 2000 census, Forest had a population of 5, 987, and Scott County had a population of 24,423. It is located 42 miles from Jackson, MS and has several towns with populations exceeding 10,000 within 45 miles. Forest is serviced by the Kansas City Southern railroad, and has access to Mississippi highways 21, 35, 501, U.S. Highway 80, and Interstate 20. Commercial forests make up approximately 66 percent of the land use; therefore, there should be numerous areas suitable for an energy plant (www.forestms.com). The aerial map in Figure 4 depicts the optimal area generated by the model.

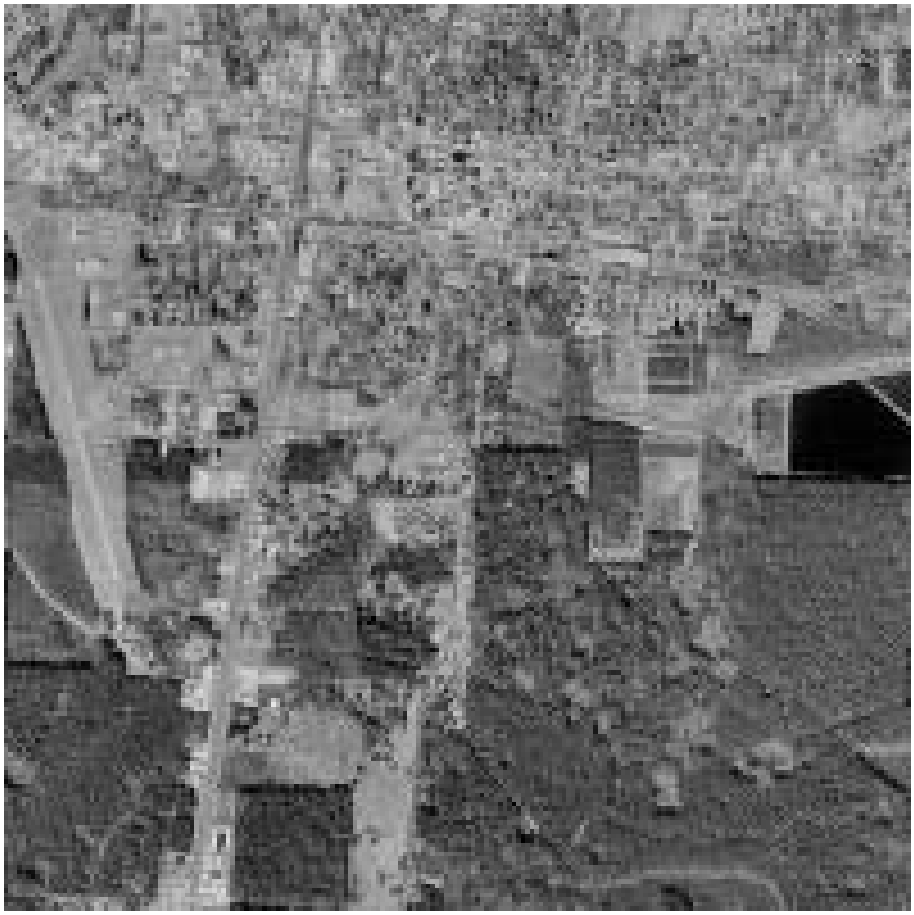

Figure 4. Aerial Photo of Forest, MS South of the Intersection of US 80 and MS Highway 35

Conclusion

Recent news reports and statements by both Republican and Democratic members of Congress suggest widening support for alternative energy research and development. Given the amount of funding and incentives alternative energy programs are projected to receive, it appears inevitable that energy from renewable sources will materialize. Among the alternatives are biofuels and agricultural waste. An important aspect of this research is to determine where reliable sources of these feedstocks can be obtained, in sufficient quantities, and at a feasible transportation costs. While there have been some successes in the form of power generation from combusting biomass, at this time no commercial scale biomass-to-ethanol plants exists.

Poultry litter is an interesting biomass feedstock for several reasons. Poultry production, and therefore litter production, is generally highly concentrated in a region. The high levels of concentration suggest that energy plants can be located close to source of the feedstock and minimize transportation costs. The high level of concentration also means that nutrients under current disposal methods have the potential of creating adverse environmental effects. Energy production will give producers a safe and alternative litter disposal method, other than land application. The cleanout of poultry houses can also be scheduled in such a way as to minimize on-site feedstock storage for the energy plant. Biomass from annual crops, such as corn stover and cotton gin trash, will need to be stored for 8-12 months, and may also experience deterioration. Energy produced from poultry litter also qualifies as "Green Power" and may have positive social benefits as well as economic benefits. Another benefit is from the combustion or gasification process, whereby the phosphorus and potassium nutrients are captured in the processed ash. This creates a by-product fertilizer that has value and that is highly concentrated and easily transportable to crop production areas.

There are negative externalities associated with bioenergy from poultry litter. Among these are odor, noise, increased traffic, and potential cross contamination between farms. Systems have been developed to manage odor, such as Fibrowatt's enclosed system. Litter is delivered to an enclosed collection area, and air from the collection area is used as fuel for the furnace, where the odor containing particles are incinerated. A plant such as this would also create increased truck traffic and the noise that comes along with it. A plant requiring 400,000 tons, operating 350 days a year would require 46 25-ton truck loads of litter per day. It would be necessary that the trucks were covered in order to prevent the litter from blowing out of the truck, and to suppress the odor from the litter during transportation. It is also important to ensure that trucks are adequately washed before entering a new farm to prevent contamination across farms.

While this study examines the availability of poultry litter as an alternative energy feedstock, it does not examine the feasibility. Further study needs to be conducted to examine input costs, output revenues, and capital costs for these technologies. Another compelling study is comparing the net social benefit from using poultry litter for energy versus land application. It may be that the benefits to society from improved water quality, the benefits to the producer as reliable disposal method of poultry litter, and the benefits of using “Green Energy” outweigh the increase in production cost of using poultry litter as an alternative energy feedstock versus energy from fossil fuels.

REFERENCES

Atul, C.S. English, J. "Prelimenary Economic Analysis of Poultry Litter Gasification Option with a Simple Transportation Model." The University of Tennessee Space Institue, Tullahoma, TN. ISSN 1047-3289. *Journal of Air and Waste Management Association*. 55: 510-522.

Barrett, J., Murray, S. "The Economics of Transporting Poultry Litter in Mississippi from the Broiler Region to the Delta." Food and Fiber Center, Mississippi State University Extension Service. February 13, 2003.

Chamblee, T. N., Todd, R. L. "Mississippi Broiler Litter: Fertilizer Value and Quantity Produced." Mississippi State University Extension Service Research Report. June 2002 Vol. 23 No. 5.

Energy Efficiency and Renewable Energy. U. S. Department of Energy. "Biomass Gasification." Retrieved from http://www1.eere.energy.gov/biomass/gasification.html on August 29, 2006.

Fibrowatt, LLC. http://www.fibrowattusa.com/US-Corporate/OurTechnologyUS.html

Forest MS. "The Official Website of Forest, Mississippi." At http://www.forst-ms.com/ Accessed on January 15, 2007.

McCallum Sweeney Consulting. "Pre-Feasibility Study for 40-50 MW Poultry Litter Fueled Power Generation Facility." Prepared for the Mississippi Technology Alliance, Mississippi Alternative Energy Enterprise. September 2002.

Morgan, G.W., Murray, S. "Economic Impact of the Mississippi Poutry Industry at the Year 2002." Mississippi State University Extension Service. Information Bulletin 385. January 2002.

National Agricultural Statistical Service. 2202 Census of Agriculture. Available at http://www.nass.usda.gov/Census_of_Agriculture/index.asp

Stewart, J.L. "The Co-Production of Ethanol and Electricity From Carbon-based Wastes." Bioengineering Resources for Renewable Energy. www.brienergy.com. March 206.