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The Economics of Biomass Collection and Transportation and Its Supply to Indiana Cellulosic and Electric Utility Facilities

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Introduction

Biomass is poised to become an important energy source in the United States due to concerns regarding oil imports and the environment. Federal and state policies are beginning to mandate the use of renewable energy, some of which must come from cellulosic sources. This likely will result in more research and development being devoted to cellulosic energy production, and it will be important to know how much these feedstocks will cost to obtain. The development of cellulosic bioenergy will require finding an economically and environmentally sustainable method for obtaining large quantities of biomass feedstock (Hettenhaus, 2006).

The primary objective of this analysis is to determine up-to-date cost estimates for the production, collection, and transportation of corn stover and switchgrass from Indiana farms of different sizes that are located at various distances from an electric utility plant or biofuels plant looking to purchase biomass. Results from this analysis only consider costs from the field to the plant door and do not consider costs associated with adapting boilers to be able to burn biomass or capital expenditures on future cellulose conversion facilities. This analysis also creates information on biomass feedstock supplies for three specific Indiana electric utility plants and estimates CO_2 breakeven prices that equate the cost of using biomass for 10 percent of heat production to the cost when using 100 percent coal.

Parameters and Assumptions

With a number of studies arriving at similar aggregate conclusions for the cost of biomass collection, it is important to understand the parameters and assumptions behind these total cost figures and what might make one result different from another. Table 1 outlines the parameters used in this analysis and their sources. Table 2 outlines the input cost assumptions.

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Biomass Harvest, Collections, and Transportation Cost Analysis

Corn Stover

Collection scenarios include baling only from a windrow, raking and baling, and shredding, raking and baling. Each scenario removes 38, 52.5, or 70 percent of available stover on the ground respectively. With each increase in the amount of stover that is removed, the field is subject to more soil compaction, soil erosion, and water erosion. Agronomic effects from stover removal must be balanced with the economic question of how much stover is too little when it comes to ensuring that revenue from stover exceeds the additional costs of collection. Overall, different soils and locations will need to be treated differently with respect to how much stover can be safely collected and removed.

For each ton of stover removed, additional nutrients are applied during the annual fertilizer application. Table 3 outlines the per ton cost of additional nitrogen, phosphorus, and potassium.

Switchgrass

Establishment costs incurred during one year are amortized at an interest rate of 8 percent over the 10 year life of the stand. Field preparation includes mowing the field and spraying glyphosate to kill existing grasses. Production year costs include those incurred during the maintenance and harvest of switchgrass. Specific parameters of interest are in Table 1.

Collection and Harvest

Harvest with traditional hay equipment is either custom hired or done with owned equipment. While new harvesting technologies that collect both corn grain and corn stover in one pass are being used on a trial basis, these technologies are not widespread and considering the use of hay equipment (after corn grain harvest is complete) seems more appropriate for producers deciding to collect corn stover in the short run. Per ton custom rates for each activity are calculated by dividing the average custom rate by the amount of biomass removed

Table 1. Parameter Assumptions

Parameter			Sources
Corn Stover			
Corn Stover Yield	4.25 tons/acre		Atchison and Hettenhaus, (2003); Glassner, Hettenhaus, and Schechinger, (1998); Lang, (2002); Quick, (2003); Sokhansanj and Turhollow, (2002)
Removal Rates	Scenario 1	38%	Glassner, Hettenhaus, and Schechinger, (1998) ; Lang, (2002); Montross et al., (2003); Perlack and Turhollow, (2002); Petrolia, (2006); Richey, Lechtenberg, and Liljedahl, (1982); Schechinger and Hettenhaus, (2004); Sheehan et al., (2003); Shinners, Binversie, and Savoie, (2003)
	Scenario 2	52.5%	
	Scenario 3	70%	
Nutrient Replacement	Nitrogen	15.9 lbs/ton of stover removed	Fixen, (2007); Lang, (2002); Nielsen, (1995); Petrolia, (2006); Schechinger and Hettenhaus, (2004)
	Phosphorous	5.9 lbs/ton of stover removed	
	Potassium	30 lbs/ton of stover removed	
Switchgrass			
Switchgrass Yield	5 tons/acre		Brummer et al., (2002); Duffy and Nanhou, (2001); Kszoz, McLaughlin, and Walsh, (2002); Perrin et al., (2003); Popp and Hogan, (2007); Tiffany et al., (2006); Walsh, Becker, and Graham, (1996)
Land Rent	$70 per acre		Dobbins and Cook, (2007); Duffy and Nanhou, (2001); Popp and Hogan, (2007)
Seeding	7 lbs of pure live seed/acre		Duffy and Nanhou, (2001); Lawrence et al., (2006); USDA-NRCS, (1986); Rinehart, (2006); Teel, Barnhart, and Miller, (2003); Tiffany et al., (2006); Walsh, (2007)
Establishment Year	Phosphorous	30 lbs/acre	Duffy and Nanhou, (2001); Popp and Hogan, (2007); Tiffany et al., (2006)
	Potassium	37 lbs/acre	
	Lime	2 tons/acre	
	Glycophosate	2 qts/acre	
	Atrazine	1.25 qts/acre	
	2,4-D	1.25 pts/acre	
Production Year	Nitrogen	80 lbs/acre	Duffy and Nanhou, (2001); Gibson and Barnhart, (2007); Kszos, McLaughlin, and Walsh, (2002); Lawrence et al., (2006); Popp and Hogan, (2007); Rinehart, (2006); Teel, Barnhart, and Miller, (2003); Tiffany et al., (2006); Walsh, (2007)
	Phosphorous	3.15 lbs/ton of switchgrass removed	
	Potassium	13.25 lbs/ton of switchgrass removed	
	Atrazine	1.25 qts/acre	
	2,4-D	1.25 pts/acre	
Baling and Transportation			
Dry Matter Loss (in 6 months)	Twine	18.80%	Collins et al., (1997); I-FARM, (2007); Shinners, Binversie, and Savoie, (2003)
	Net Wrap	8.40%	
	Plastic Wrap	6.15%	

Table 1. Parameter Assumptions (Continued)

Parameter			Assumptions
Baling and Transportation			
Bale Dimensions	Weight	1000 lbs	Popp and Hogan (2007)
	Diameter	5 feet	
	Width	5.5 feet	
Transportation	Load Capacity	26 bales or 13 tons	Popp and Hogan (2007)
	Gas Mileage	6.73 miles/gallon	Berwick and Farooq (2003)
	Average Speed	50 miles/hour	Tiffany et al., (2006)

per acre. These decrease as the corn stover removal rate increases and are lower for switchgrass due to higher yields.

Under the owned equipment condition, an annual per ton payment is calculated for farm sizes including 500 acres, 1000 acres, 1500 acres, and 2000 acres. Total owned equipment costs are based on amortized equipment cost at 8 percent interest, fuel requirements, and labor requirements. These decrease as the corn stover removal rate increases and are even lower for switchgrass. Per ton owned equipment costs also decrease as the farm size increases.

Baling Options, Handling, and Storage

Baling options included in this analysis are twine, net wrap, and plastic wrap. Dry matter loss is highly dependent on the length of time in storage and the baling option chosen. An associated dry matter loss as a percentage of the total per ton product cost is added to account for an assumed six months of on the ground storage at the edge of the field. An extended storage premium is used to offset lost crop production. The extended storage premium is equal to half of the net revenue lost due to land being used as storage. This accounts for half of producers not losing the production area while the other half suffer a loss. Each producer is paid a per ton profit of 15 percent of the product cost to offer an incentive to producers beyond covered costs to participate in biomass production. For corn stover and switchgrass, this net profit averages $4.55 and $7.22 per dry ton respectively. For an acre under the assumptions of this analysis, net profit from corn stover averages $10.25 per acre and net profit from switchgrass averages $36.11 per acre. Exact decisions on profit payments will vary from plant to plant.

Transportation

The one way distance from the field to the plant ranges between 5 and 50 miles at intervals of 5 miles. As with harvest, transportation can be either custom hired or owned, and the associated costs are calculated in the same manner.

Results Analysis

A set of cost averages for corn stover and switchgrass served as a preliminary benchmark for comparison and serves to highlight the differences in cost for various farm sizes and management decisions (Tables 4 and 5). These cost averages include all removal rates and bale packaging options considered in this analysis for each farm size and equipment decision.

Bale Packaging

For both corn stover and switchgrass, baling with net wrap is always the cheapest option for a given farm size, distance to the plant, equipment choice, and removal scenario. The slightly higher cost of net wrap is offset by a lower dry matter loss. Plastic wrap, however, involves an added cost that is nearly twice as much as net wrap, but the additional dry matter loss savings is only about 2 percent.

For corn stover, plastic wrap is always the most expensive option, followed by twine and net wrap. However, for switchgrass, twine is always the most expensive option, followed by plastic wrap and net wrap. This is because the higher value per ton of switchgrass results in dry matter loss playing a relatively more important role in determining the total per ton product cost.

Equipment Choice Results

Removing stover increases the fuel, labor, and equipment costs, but it increases the collected stover yield per acre. Larger farms are able to remove any amount of stover at a less expensive per ton cost than smaller farms. Thus incurring a higher cost due to more passes through the field can be paid off by being able to spread the extra cost incurred for each acre over more collected tons of stover.

Small farm sizes likely will have higher costs by using owned equipment and will be forced to use custom hired equipment should they choose to harvest stover. Larger farm sizes will likely find owned equipment to be the lower cost option due to the large amount of acres over which to spread their costs. Limitations posed by weather on the window of time available for harvest have not been considered. Depending on the schedules and workloads of either producers or custom operators, adverse weather conditions could serve to shorten the harvest window.

Table 2. Input Cost Assumptions			
Input	Price	Units	Sources
Fertilizer:			
Anhydrous Ammonia	$536.00	Cost per ton	NASS, Agricultural Prices, 2007
Liquid Nitrogen	$270.00		
Urea	$450.00		
MAP	$421.00		
Potash	$277.00		
Lime (and application)	$13.76		Halich, 2007
Seed:			
Cave-In-Rock-Switchgrass	$9.50	Cost per lb	Sharp Brothers Seed Company
Herbicides:			
Glyphosate	$28.90	Cost per gallon	NASS, Agricultural Prices, 2007
Atrazine	$12.20		
2,4-D	$15.90		
Custom:			
Stalk Shredder	$8.56	Cost per acre	Halich, 2007
Rake	$5.40		
Bale	$8.52		
Mower	$10.03		
Fertilizer/Seed Application	$5.13		
Herbicide Application	$5.41		
Owned:			
Stalk Shredder (14' wide, 10 year lifespan)	$10,277	Cost per unit	Laughlin and Spurlock, 2007
Rake (8.5' wide, 8 year lifespan)	$4,105		
Baler (large round, 8 year lifespan)	$24,579		
Rotary Mower (15' wide, 10 year lifespan)	$12,547		
Packaging:			
Twine	$20.75	Cost per roll	Montana Custom Hay
Net Wrap	$200.00		
Plastic Wrap	$80.00		Tudor Ag
Labor:			
Field Worker Wage	$9.46	Cost per hour	NASS, Indiana Agriculture Report, 2006
Ag. Truck Driver Wage	$14.37		Bureau of Labor Statistics, 2006
Fuel:			
Highway Diesel	$3.93	Cost per gallon	Energy Information Administration, 2008
On-Farm Diesel	$3.53		

The switchgrass analysis does not have the same numerous combinations of management decisions as corn stover, because there is not a variable removal rate. However, the resulting equipment choices for farms of various sizes are similar to those for corn stover.

Transportation Results

The transportation results in Table 6 are averaged over custom and owned equipment. The difference between transportation costs for corn stover and switchgrass is be-

Table 3. Corn Stover Nutrient Replacement

	Fertilizer Used	Fertilizer Composition	Price Per Ton of Fertilizer	Price Per Pound of Nutrient	Pounds to Replace Per Ton of Stover Removed	Nutrient Replacement Cost Per Ton of Stover Removed
N	Anhydrous Ammonia	82-0-0	$536.00	$0.327	15.9	$5.20
N	Liquid Nitrogen	28-0-0	$270.00	$0.482	15.9	$7.67
N	Average					$6.44
P2O5	MAP	11-52-0	$421.00	$0.404	5.9	$2.39
K2O	Potash	0-0-61	$277.00	$0.227	30	$6.81
Total						$15.64

Table 4. Average Product Only Per Ton Costs by Farm Size/Equipment Decision

Farm Size	Corn Stover Cost	Switchgrass Cost
	Dollars per ton	
Custom	$33.95	$55.92
500 acres	$38.10	$57.26
1000 acres	$35.03	$55.11
1500 acres	$34.01	$54.40
2000 acres	$33.50	$54.04

cause capital transportation costs are spread over more tons in the case of switchgrass due to its higher yield. The average marginal transportation cost per mile is $0.20.

Biomass Supply

To apply these costs to the situation of a particular coal power plant, supply curves are generated based on the location of the plant and the available supply of biomass in the area. Data for biomass supply is available from a recent study by Oak Ridge National Laboratory sponsored by the Department of Energy and the Department of Agriculture that determines the total biomass availability for the United States (Perlack *et al*., 2005). Supply for both corn stover and switchgrass are given separately, and it is assumed that supply from both sources can be produced and used at the same time. Since data are available for Indiana only, supply that might potentially come from neighboring states is assumed to be similar to the supply from Indiana. It is assumed that 53.5 percent (or an average of the removal rates used in this analysis) of corn stover is feasibly and sustainably collected. Land participation rates of 50 and 75 percent are assumed for both corn stover and switchgrass to account for the expected percentage of potential land that will actually have biomass collected or harvested from it.

Using Figure 1 shows each plants location and their concentric supply circles (Figure 1), and assuming that the biomass in each county is evenly distributed, the fraction of county area within each circle is used to determine the fraction of available biomass from each county that is located within a given circle. The total amount from all counties within a given circle corresponds to the x-axis of the supply curve, which therefore is measured in both miles and tons. The Knox county plant in southern Indiana has a smaller available amount of corn stover at all distances relative to the other two plants. The Marion county plant is located in a metropolitan area, which makes its overall supplies of either biomass source less abundant until the rural surrounding counties are reached. The Tippecanoe county plant is located in a highly agricultural area and has large potential supplies of both corn stover and switchgrass.

Supply Costs

A set of average costs that are a function of one-way distance to the plant serve as the costs associated with the available supply. Table 7 indicates these costs in both dry ton units and MMBTU units. These biomass costs per MMBTU can be compared to a coal cost per MMBTU of $1.56. These biomass costs per MMBTU can be compared to a coal cost per MMBTU of $1.44 for Illinois Basin coal with heat content of 11,800 BTU per pound or a coal cost per MMBTU of $1.56 if the heat contents of the three plants considered in this analysis are averaged (10,994 BTU per pound). Either way the coal price is calculated, the biomass cost per MMBTU is always lower. This coal cost is calculated from the assumed price of coal per ton of $34.31 based on EIA market prices as of January 2008 and an average of the high heat values for the plants included in this analysis.

Table 5. Average Product and Transportation Cost Per Ton by Farm Size/Equipment Decision					
Biomass Type and Distance from Plant	Custom	500 acres	1000 acres	1500 acres	2000 acres
			Dollars per ton		
Corn Stover:					
5 miles	$36.49	$42.80	$38.48	$37.04	$36.32
10 miles	$37.87	$43.47	$39.15	$37.71	$36.99
15 miles	$39.26	$44.14	$39.82	$38.38	$37.66
20 miles	$40.64	$44.81	$40.49	$39.05	$38.33
25 miles	$42.03	$45.48	$41.16	$39.72	$39.00
30 miles	$43.41	$46.15	$41.83	$40.39	$39.67
35 miles	$44.80	$46.82	$42.50	$41.06	$40.34
40 miles	$46.18	$47.49	$43.17	$41.73	$41.01
45 miles	$47.57	$48.16	$43.84	$42.40	$41.68
50 miles	$48.95	$48.83	$44.51	$43.07	$42.35
Switchgrass:					
5 miles	$58.45	$60.52	$57.84	$56.94	$56.50
10 miles	$59.84	$61.19	$58.51	$57.61	$57.17
15 miles	$61.22	$61.86	$59.18	$58.28	$57.84
20 miles	$62.61	$62.53	$59.85	$58.95	$58.51
25 miles	$63.99	$63.20	$60.52	$59.62	$59.18
30 miles	$65.38	$63.87	$61.19	$60.29	$59.85
35 miles	$66.76	$64.54	$61.86	$60.96	$60.52
40 miles	$68.15	$65.21	$62.53	$61.63	$61.19
45 miles	$69.53	$65.88	$63.20	$62.31	$61.86
50 miles	$70.92	$66.55	$63.87	$62.98	$62.53

Biomass Demanded

The amount of biomass demanded depends upon the size of each plant and the amount of heat production that is to come from biomass. For this analysis, biomass makes up from 1 to 10 percent of total heat production. Information regarding the demand for fuel inputs from the coal plants comes from the 2005 Coal Power Plant Database by National Energy Technology Laboratory and the Environmental Protection Agency Clean Air Markets Data.

Table 6. Average Per Ton Transportation Costs for Corn Stover and Switchgrass		
	Transportation Costs for:	
Distance	Corn Stover	Switchgrass
	Dollars per ton	
5 miles	$3.30	$2.70
10 miles	$4.12	$3.52
15 miles	$4.93	$4.33
20 miles	$5.74	$5.14
25 miles	$6.56	$5.96
30 miles	$7.37	$6.77
35 miles	$8.18	$7.58
40 miles	$9.00	$8.40
45 miles	$9.81	$9.21
50 miles	$10.62	$10.02

The tons of biomass required per year to produce a given percentage of heat production can be calculated with the following equation:

*total Btu/hour × fraction of heat from biomass × (Btu/lb of biomass / 2000) × operating hours/day × operating days/year = **tons of biomass/year***

Supply Curves

Supply curves for each biomass source are created for each plant at each land participation rate by plotting the amount of biomass available at each distance against the cost of collection and transport of the given distance. The vertical lines on these graphs represent the possible fractions of total heat production from biomass. Increases in the land participation

Figure 1. Plant Locations and their Concentric Supply Circles

rate simply make more biomass available at a lower cost and shift the vertical lines to the left. Where these vertical lines hit the x-axis, the amount of biomass required and the one-way distance from the plant to the furthest ton are indicated. At the point where the vertical line and the supply curve intersect, the associated value on the y-axis indicates the per ton delivered cost for the furthest ton required. The area below the supply curve up to each vertical line indicates the total cost associated with acquiring the amount of biomass needed to generate a particular percentage of heat assuming that the biomass and transportation costs are treated separately. Figure 2 is an example from the Knox county plant that shows the general structure of the supply curves. In this case, the plant uses corn stover up to 105 miles from the plant and then begins using switchgrass located near the plant. In other words, corn stover located 105 miles from the plant costs the same as switchgrass located next to the plant. Ten percent of heat production, however, can be produced from corn stover that is approximately 80 miles from the plant.

The Marion county plant is a larger plant and requires more biomass to meet requirements. For enough biomass to produce 10 percent of heat, the plant must go out between 35 and 45 miles. This increase in distance is accounted for by the proximity to a large metropolitan city and by the large size of the plant.

The Tippecanoe county plant is a small plant located in an area that is abundant in both corn stover and switchgrass. Regardless of the type of biomass or the land participation rate, 10 percent of heat production could be obtained by going less than 10 miles from the plant.

CO_2 Emissions Reductions

This use of biomass in place of coal will serve to reduce the greenhouse gas emissions. This analysis will consider the value of reductions of CO_2 emissions from using biomass in place of coal. While there are also reduction for other emissions such as SO_2, due to limited data regarding emissions

Table 7. Supply Analysis Costs by One-Way Distance

Distance	Corn Stover Cost		Switchgrass Cost	
	Dollars per ton	Dollars per MMBtu	Dollars per ton	Dollars per MMBtu
5 miles	$38.22	$2.52	$58.05	$3.99
10 miles	$39.04	$2.57	$58.86	$4.05
15 miles	$39.85	$2.62	$59.68	$4.11
20 miles	$40.66	$2.68	$60.49	$4.16
25 miles	$41.47	$2.73	$61.30	$4.22
30 miles	$42.29	$2.78	$62.12	$4.27
35 miles	$43.10	$2.84	$62.93	$4.33
40 miles	$43.91	$2.89	$63.74	$4.39
45 miles	$44.73	$2.95	$64.55	$4.44
50 miles	$45.54	$3.00	$65.37	$4.50

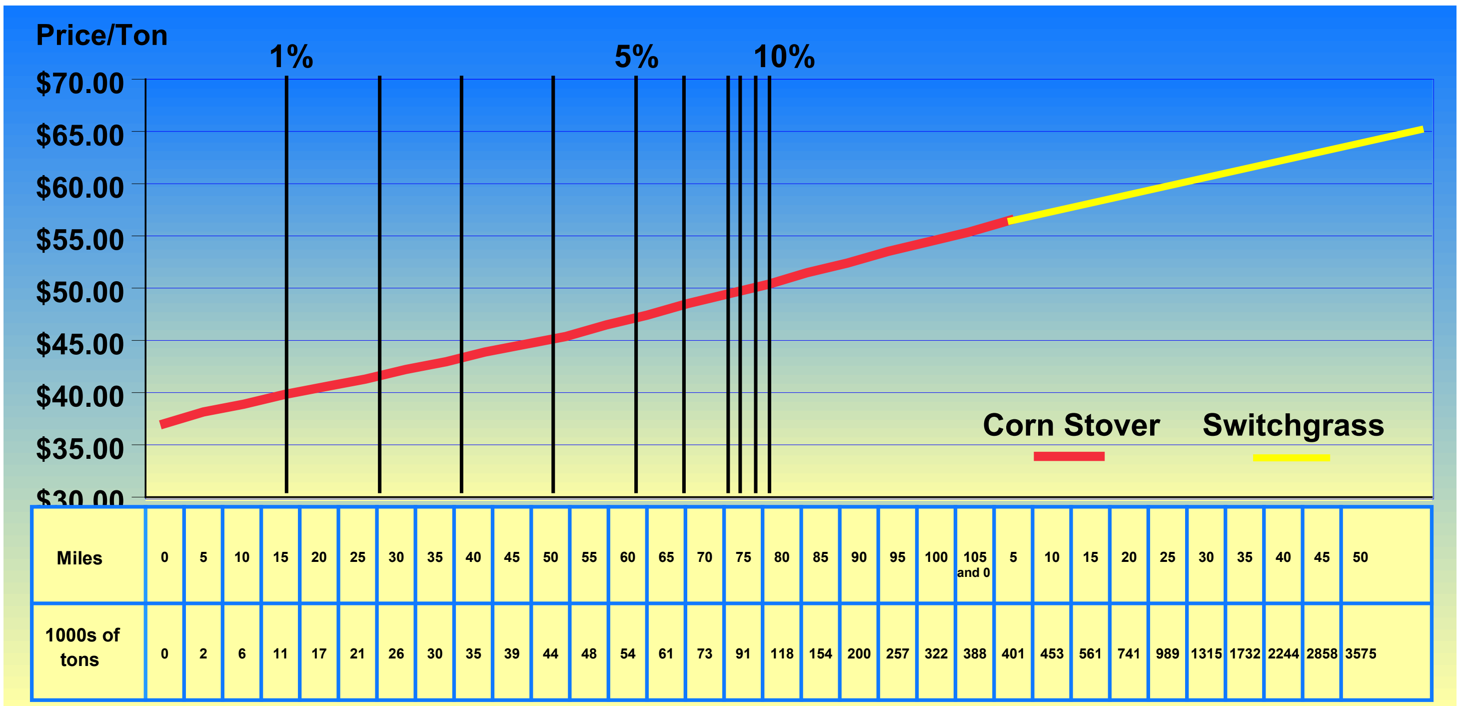

Figure 2. Knox County Biomass Supply Curve

and biomass combustion, only the value of reduction of CO_2 emissions is calculated. From Ney and Schnoor (2002) and Spatari, Zhang, and Maclean (2005), the net emission reductions in tons of CO_2 equivalent from using one ton of biomass instead of coal are 2.88 and 2.60 for corn stover and switchgrass respectively. In the case of switchgrass (but not for corn stover), an indirect leakage effect occurs when land is shifted into biomass production. This serves to negate a portion of the CO_2 sequestration from switchgrass. This analysis did not take that effect into account, but the net CO_2 reduction for switchgrass may be lower as a result. Total CO_2 emissions for each plant are calculated by assuming that a ton of coal generates 2.86 tons of CO_2 when completely combusted (Hong and Slatick, 1994).

Assuming a CO_2 per metric ton price of $5.75, the reduced costs from less coal and less CO_2 emissions can be calculated. The carbon credit price is from the market rate for Carbon Financial Instruments (CFIs) on the Chicago Climate Exchange. One CFI contract consists of 100 metric tons of CO_2 equivalent, and the market price as of March 2008 was $5.75 per metric ton of CO_2 (or $5.22 per short ton).

Table 8 estimates the percent difference in total input costs relative to the coal only case. In all cases, the use of biomass as it offsets some coal costs and CO_2 emissions is not enough to offset the costs incurred from purchasing the biomass. Total input costs when biomass is used are calculated by adding together the savings from less coal, the savings from reduced emissions, and the total amount spent on biomass. The sav-

Table 8. Percent Change in Total Feedstock Costs[a] to the Plant When Using Biomass, by Location and Proportion of Co-fire

Fraction of Heat from Biomass	Knox County, IN		Marion County, IN		Tippecanoe County, IN	
	Corn Stover	Switchgrass	Corn Stover	Switchgrass	Corn Stover	Switchgrass
0.05	1.67%	5.30%	0.32%	4.83%	0.41%	5.46%
0.10	5.98%	10.97%	1.26%	10.47%	0.81%	11.31%

[a]Total feedstock costs for 2006 is estimated at $25,938,360 for Knox County; $477,915,080 for Marion County; and $5,350,405 for Tippecanoe County

ings from sequestered carbon occurring from root establishment by switchgrass was not included in this analysis. Further information is needed to develop a firm estimate on the amount of carbon that would be sequestered during a 10-year perennial crop such as switchgrass.

This is information for plants to determine how much additional cost they are willing to incur in order to incorporate biomass or "go green." Table 9 provides breakeven per ton CO_2 prices for the case of producing 10 percent of total heat production from biomass. These can be compared to the current price from the Chicago Climate Exchange of $5.22 per ton of CO_2. Breakeven prices for the use of corn stover are much lower than those for switchgrass due to the extra feedstock costs that must be covered in the case of switchgrass. These breakeven prices also signal the level of carbon tax that would be necessary to induce firms to use biomass as a substitute for coal under a carbon tax system. Carbon (instead of CO_2) breakeven prices are 3.67 times the values in Table 9.

Conclusions

Corn Stover

Other than nutrient replacement and harvesting activities, there are no additional costs for collecting corn stover. This makes corn stover the less costly option compared to switchgrass without any consideration of transport distance. Management decisions such as removal rate and equipment decisions can also change corn stover per ton costs. Total costs per dry ton for transporting corn stover 25 miles range between $39 and $45.

Switchgrass

The decision to plant switchgrass is accompanied by the input and activity costs that relate to its establishment, production, and harvest. These additional costs make switchgrass the more expensive option compared to corn stover. Total costs per dry ton for transporting switchgrass 25 miles range between $59 and $64. A recent study by Perrin *et al.* (2008) determined switchgrass production costs on a commercial scale. The results were very similar to this analysis; however, yields and fertilizer rates varied among cooperating producers.

Table 9. CO2 Breakeven Per Ton Prices

	Corn Stover	Switchgrass
Knox County, IN	$10.03	$14.57
Marion County, IN	$6.35	$15.24
Tippecanoe County, IN	$5.79	$14.46

Supply Situations

Supply of biomass is far from uniform across the state of Indiana and the country as a whole, making location extremely important. Variations in supply are affected by the proximity to metropolitan areas and the density of agriculture near the plant. However, due to the delivered cost of switchgrass being higher than corn stover, plants will most likely choose to collect as much corn stover as possible at very far distances before they begin to collect any switchgrass.

The current resources of the individual producer are likely to dictate whether one decides to pursue biomass production or not. Therefore, from the perspective of the plant, there may be much uncertainty as to how much of the area supply might actually be brought in. This uncertainty may lead plants to contract their supply of raw material before making any plant investment.

Future Work

Future work on this topic would be to find ways to reduce the cost of producing and transporting biomass. Since both corn stover and switchgrass involve many inputs and activities for their production and transportation, large reductions in cost could be achieved by reducing the costs of numerous steps and components. Examples of ways to reduce costs might include further development of efficient commercial corn stover harvesters or research to increase switchgrass yields.

These results might also be used in exploring the potential for a cellulosic ethanol plant in Indiana and where the optimal plant location might be. Based on the results of this analysis and assuming 70 gallons of ethanol can be produced from one ton of biomass, Indiana corn stover could produce between 115 to 185 million gallons of ethanol annually, and Indiana switchgrass could produce between 175 to 280 million gallons of ethanol annually, depending upon the land participation rate. These projections are based on current conditions in the state and could be larger should land use and tillage changes be adopted.

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