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## Section 1 – Corn Stover Options and Pricing

As presented in the earlier corn stover feasibility report, the two most common product forms for packaging corn stover are bales and pellets. Baling corn stover involves using traditional hay equipment or biomass balers to create either round or square bales. Pelletizing corn stover involves using a grinder, hammer mill and a pellet mill to extrude pellets. Each product form has handling and storage limitations that need to be understood when marketing to potential buyers. Exhibit 1.1 has a detailed comparison of these two products.

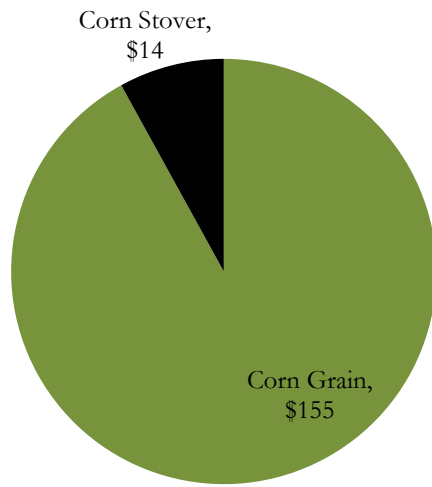
**Exhibit 1.1 Comparison between Corn Stover Bales and Pellets**

Component	Corn Stover Bales (Round or Square)	Corn Stover Pellets
Bulk density	5-10 lb./ft <sup>3</sup> (low)	37-44 lb./ft <sup>3</sup> (comparable to coal)
Handling	Requires hay collection and other specialized equipment for handling	Auger systems
Truck transportation	Flatbed trucks	Hopper bottom trucks
Storage	With a low bulk density, storage space represents a challenge both at collection points and destination markets	Less storage space than bales and will typically fit in traditional storage systems
Cost of delivered and sized product (excluding premium to farmer)	\$50 to \$65 per ton	\$65 to \$80 per ton
Proximity	Most of the research has centered on moving bales within a 50-mile radius of the end destination to minimize transportation costs	Pellets can flow much like the grain market, even to export markets

Farmers have to gain an economic reward (profit) for making the decision to remove corn stover. This would be the payment to a farmer for their participation and risks in serving as a corn stover supplier. Most of the academic research has estimated that producer payments must be around the 10-20% of total product cost before they are willing to participate. This profit premium would need to be added on top of the cost of production indicated earlier. Based on a 15% farmer premium, bales would need to be sold for approximately \$58 to \$75 per ton and pellets for \$75 to \$92 per ton.

A key point to understand is the relationship of grain and stover to the farming enterprise. Selling corn stover has the potential to increase the overall value created on a farm, but corn grain will still be the major profit center. Based on the latest University of Missouri dryland corn budget (FAPRI, 2010), income over total costs/acre was estimated at \$155 per acre. If one assumes an estimated corn stover removal rate of 1.5 tons per acre and assume the harvest is done in big bales, then farmer premiums of \$13 to \$15 per acre could be potentially captured. Exhibit 1.2 depicts the relatively minor impact that corn stover harvesting sales have upon the profitability of the corn production enterprise.

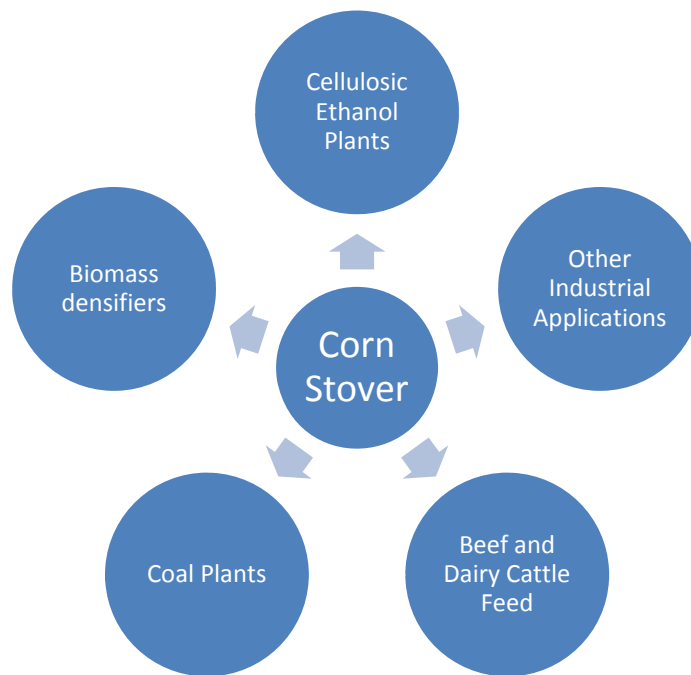
**Exhibit 1.2 Profitability Sectors from a Corn Grain and Stover Enterprise (per acre)**



## Section 2 – Potential Corn Stover Markets

Corn stover is currently being used on a limited basis in various industrial uses and in livestock production. Most of the markets are currently under development and may evolve in the future if certain market conditions are met. Markets for corn stover feedstock include coal fired electrical generation plants, cellulosic ethanol plants, livestock feed industry, biomass densification businesses, and other industrial applications in Missouri. Each of these industries will be discussed further in this section.

**Exhibit 2.1 Corn Stover Markets**



### **Option #1 - Coal Fired Electrical Generation Plants**

Coal is used to generate a significant portion of Missouri’s electricity generation. More than 80% of electricity generation for Missouri’s residential and commercial electricity consumers comes from coal fired generators. There are currently 23 operational coal fired electrical generation plants in Missouri. Co-firing is a practice that involves substituting biomass (such as agriculture residue or wood waste) for a portion of coal in an existing furnace. It is also a method for reducing CO<sub>2</sub> emissions for power plants. Corn stover is a potential feedstock that can be blended with coal for electricity production. Below is an analysis of this market that details the strengths, weaknesses, opportunities and threats for using corn stover in coal plants.

**Exhibit 2.2 Corn Stover Market Analysis for Coal Fired Electrical Generation Plants**

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Heat value of combusted corn stover can reasonably compare to some of the western coals</li> <li>• Biomass co-firing is environmentally sound, is sustainable, and provides regional economic benefit by buying local biomass versus out of state coal or gas</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Biomass co-firing is not a common practice in Missouri plants, site specific empirical testing will be needed by each plant</li> <li>• High alkaline content in the stover ash will increase slagging and fouling in most boilers</li> <li>• Further investments may be needed in a separate fuel feed and/or burner system</li> <li>• Utilities prefer to enter long term fixed price contracts for fuel with financially solid, long term suppliers</li> </ul>
<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• MU power plant is implementing a biomass boiler will utilize biomass and serve as a market outlet</li> <li>• Missouri’s renewable portfolio standard that was passed in 2008 will increase pressure on investor-owned plants (10) to use biomass feedstocks or other renewable sources</li> <li>• Consumer demand for a green energy power programs could grow over time</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Non-investor owned plants have no incentive to substitute low-cost coal with biomass</li> <li>• Woody biomass may be a lower cost solution for plants that are required to lower emissions or comply with the renewable portfolio standard</li> <li>• Plantation grown energy crops like miscanthus or poplar may eventually reach a scale allowing them to supply renewable energy needs cheaper</li> </ul>

The most likely coal plants that will buy biomass (including corn stover) in the future are the investor-owned plants (see Exhibit 2.3). Missouri is one of 32 states with a Renewable Portfolio Standard. In November 2008, Missouri voters passed Proposition C, which requires investor-owned utilities to increase renewable energy sources to 2% by 2011, 4% by 2012, 8% by 2015, 11% by 2020 and 15% by 2021. Bonus credits are awarded whenever the renewable sources are produced in the state. Renewable energy certificates will be used to document renewable energy that is delivered to the electric grid and document compliance with renewable standards. Current challenges have occurred in the implementation of Proposition C. One of the key points of disagreement is the geographic-sourcing of the credits and the process is currently tied up in courts. Missouri investor owned electric utilities that would need to comply with this standard include Ameren, Kansas City Power & Light Company and the Empire District Electric Company.

### Exhibit 2.3 Missouri Coal Plants, Operating Companies and Types

Operating Company	Plant Name	County	Type of Utility Provider
Ameren	Labadie	Franklin	Investor-Owned
Ameren	Meramec	St Louis	Investor-Owned
Ameren	Rush Island	Jefferson	Investor-Owned
Ameren	Sioux	St Charles	Investor-Owned
Anheuser-Busch Inc	Anheuser Busch St Louis	St Louis City	N/A
Ashland Inc	Ashland Inc	Pike	N/A
Associated Electric Coop, Inc	New Madrid	New Madrid	Cooperative
Associated Electric Coop, Inc	Thomas Hill	Randolph	Cooperative
Central Electric Power Coop	Chamois	Osage	Cooperative
City of Columbia	Columbia	Boone	Public
City of Marshall	Marshall	Saline	Public
City of Sikeston	Sikeston Power Station	Scott	Public
City Utilities of Springfield	James River Power Station	Greene	Public
City Utilities of Springfield	Southwest Power Station	Greene	Public
Empire District Electric Co	Asbury	Jasper	Investor-Owned
Independence City of	Blue Valley	Jackson	Public
Independence City of	Missouri City	Clay	Public
Kansas City Power & Light Co	Hawthorn	Jackson	Investor-Owned
Kansas City Power & Light Co	Iatan	Platte	Investor-Owned
Kansas City Power & Light Co	Montrose	Henry	Investor-Owned
Kansas City Power & Light Co	Lake Road	Buchanan	Investor-Owned
Kansas City Power & Light Co Co	Sibley	Jackson	Investor-Owned
University of Missouri-Columbia	University of Missouri	Boone	N/A

Associated Electric Cooperative, Inc. (AECI) corresponded with the project team about their stance on biomass co-firing. “Any biomass co-firing must stand alone on the economics of the project. A good target would be approximately 5 cents per kWh. At this point AECI does not see any value in renewable energy credits generated by biomass due to their current renewable portfolio, existing REC balance and the uncertainty of biomass’s classification as a renewable resource. In addition AECI has sufficient capacity for the foreseeable future and is presently not interested in any capacity additions (i.e. purchases from a biomass facility) unless it can meet the aforementioned hurdle rate.”

Ameren corresponded with the project team about their position on biomass co-firing. Ameren is exploring the potential of adding biomass into their plants. They indicated that their most viable plant is the Sioux plant because it has a cyclone boiler capable of handling fuel in larger chunks. Ameren also suggested that technical issues with slagging were not considered to be major and could be overcome. Their biggest issue is finding a credible source for long term contract that can meet their credit requirements. They do not want to invest money in handling/storage if they cannot find a supplier that is reliable and meets their credit standards.

**Option #2 – Biomass Densification Companies**

Biomass densification businesses compress corn stover and/or a mix of other biomass feedstocks into pellet or briquette form. While pellet mills exist in various areas of Missouri, only one is currently producing biomass pellets (Show-Me Energy). Other densification businesses could be created in the future to process and market corn stover or other biomass pellets.

Show Me Energy Cooperative (SMEC) is a non-profit and producer-owned cooperative located in Centerview, Missouri. It is the first producer-owned biomass cooperative in the US and is a certified Biomass Crop Assistance Program (BCAP) facility. SMEC currently produces biomass energy pellets from biomass delivered to the plant by local producers. The SMEC facility has a capacity of 100,000 tons per year. The facility processes 26 different feedstocks, including corn stover. They purchase crop residue in large round bales based on weight, moisture content and BTU content of the residue. The biomass undergoes a densification process that reduces the volume of the material by one-third. SMEC also dilutes silica, potassium and magnesium in their proprietary process to eliminate burning problems. Pellets currently contain 8,000 Btu per lb. SMEC plans to have a pellet product that will achieve 15,000 Btu per lb. by 2012. Market outlets include poultry farms, power plants and industrial and retail markets. SMEC has worked closely with the Kansas City Power and Light plant in Sibley, Missouri (located within 40 miles of the pellet production facility) to co-fire the biomass pellets along with coal.

**Exhibit 2.4 Corn Stover Market Analysis for Biomass Densifiers**

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Corn stover is a suitable feedstock for biomass densification</li> <li>• Logistically, pellets can be moved to far destinations efficiently</li> <li>• A commodity biomass pellet industry is emerging in the US and Europe deepening potential market for biomass</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• High cost of production for pellets</li> <li>• Only one current location (Show-Me Energy) is currently buying biomass for pellets</li> <li>• Pellet mills must be located relatively close to biomass sources (~35 miles) to minimize transport costs</li> </ul>
<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Growing market for pellet furnaces for consumer’s homes and livestock operations</li> <li>• Emission reductions could be met for industrial manufactures (cement, etc.) by using pellets</li> <li>• European export markets for U.S. pellets is growing due to their move toward renewables</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Other biomass feedstocks may be sourced cheaper than corn stover</li> <li>• Federal incentives for biomass collection may disappear which could slow the development of this market</li> </ul>



### **Option #3 – Beef and Dairy Cattle Feed Industry**

An older concept receiving new interest by Monsanto is alkali treating and ensiling of corn stover to increase intake and digestibility as a low cost replacement feed/forage for growing beef cattle. A meeting with Monsanto representatives was held to discuss this opportunity. Corn stover is a source of carbohydrates, but one challenge that exists is that the fiber-lignin matrix reduces its overall energy feeding value. Adding water and lime or sodium hydroxide (NaOH) to corn stover during ensiling is one way of increasing the feed value. Feeding trials date back to the 1960s but have received renewed interest due to the rising costs of all feeds and forages. Monsanto is assisting with beef feedlot trials in corn stover areas to demonstrate this low cost method of developing higher value feed from corn stover. This is one market for turning corn stover into feed and generating a profit near the farm of origin with the use of existing equipment and infrastructure.

#### **Exhibit 2.5 Corn Stover Market Analysis for the Beef and Dairy Cattle Feed Industry**

<b>Strengths</b> <ul style="list-style-type: none"><li>• Treated corn stover can be used as a corn replacement in ruminant feeds</li><li>• This practice could be done on farm with existing equipment</li><li>• Market for cattle feed will tend to be in close proximity to corn stover production areas</li></ul>	<b>Weaknesses</b> <ul style="list-style-type: none"><li>• Large scale feeding trials are now being conducted with treated corn stover to reinforce earlier results</li><li>• Beef feedlots are not a major enterprise in Missouri and many cow calf producers lack the equipment and facilities necessary to store and feed this product.</li></ul>
<b>Opportunities</b> <ul style="list-style-type: none"><li>• Cattle need another low cost substitute for corn in rations</li><li>• Rising feed and forage prices are driving cattle feeders to grow calves on farms for longer periods before sending to feedlots</li><li>• Rising crop, fertilizer, and land rental prices are driving farmers to plant former hay and pasture fields into cash crops thus necessitating finding replacement forages like treated corn stover</li></ul>	<b>Threats</b> <ul style="list-style-type: none"><li>• Beef producers tend to be resistant to change from traditional practices</li><li>• Other low-cost feeding solutions may be created more cost effectively in many parts of Missouri</li><li>• If other markets develop for stover and biomass, fescue hay could remain a cheaper feed than treated corn stover</li></ul>

**Option #4 – Cellulosic Ethanol Industry**

There are a number of companies pursuing various cellulosic ethanol technologies that will have future impact on agriculture. ICM's Plant in St. Joseph, Missouri (Lifeline Foods) is developing a pilot plant that will process corn fiber, corn stover, switchgrass and sorghum. Gevo in St. Joseph is developing a demonstration plant for biobutanol. Cellulosic ethanol plants in Missouri are in pilot/demonstration phases, but these plants or new ventures could develop in the future to utilize corn stover as a feedstock. Challenges of the cellulosic ethanol industry include reducing high operating and capital costs, and establishing reliable feedstock supply networks.

**Exhibit 2.6 Corn Stover Market Analysis for the Cellulosic Ethanol Industry**

<b>Strengths</b> <ul style="list-style-type: none"><li>• Corn stover is being used as a feedstock in various cellulosic demonstration plants in the US</li><li>• Pilot plants are working to commercialize creating cellulosic ethanol</li></ul>	<b>Weaknesses</b> <ul style="list-style-type: none"><li>• High operating and capital costs maybe not be overcome in the next 3-5 years to make cellulosic ethanol a cost effective fuel.</li><li>• Only two plants in Missouri are in demonstration or pilot stages</li></ul>
<b>Opportunities</b> <ul style="list-style-type: none"><li>• Federal government is pouring dollars into research to enhance the industry</li><li>• RSF2 mandates for cellulosic bio refineries</li><li>• Cellulosic ethanol plants may coincide with existing Missouri ethanol plants in close proximity to crop production areas</li></ul>	<b>Threats</b> <ul style="list-style-type: none"><li>• Most likely, cellulosic industry is 3-5 years away from being commercially viable</li><li>• Other feedstocks (sorghum, miscanthus, etc.) may prove to create more ethanol output than corn stover</li></ul>

### **Option #5 – Other Industrial Applications**

Gasification is another method of converting corn feedstock to a natural gas replacement. Chippewa Valley Ethanol Plant is a cooperative-owned ethanol plant located in Benson, Minnesota. The plant broke ground on a commercial-size biomass gasifier that uses corn cobs as its primary feedstock in 2006. The gas generated from corn cobs by the biomass gasification system displaces the use of natural gas for plant operations. The plant hopes to replace as much as 90 percent of its natural gas consumption by using the gas generated from the gasifier system. Other companies are investigating using gasification and will need biomass feedstock to create natural gas from these systems. One example is ICM, Inc., they began operating a commercial scale gasifier (Newton, KS) in 2009 and tested various feedstocks (including corn stover) that were successful. Ethanol plants or other manufacturing plants could use this syngas for their industrial power and heating applications. Recent declines in long term natural gas prices due to rising shale gas production have diminished some of the appeal of using corn stover for gasification.

Additionally, corn stover has historically found some uses in the industrial sector. Examples would include fiberboard, pulp and paper and chemicals. There are new markets emerging for the use of corn stover and/or corn cobs, according to Biorefining Magazine (Sims, 2010). MCG BioComposites based in Iowa is manufacturing garden markers, made of 20% corn cob flour mixture. Their company focuses on the sales, marketing and distribution of green bio materials. Recovery I Inc., an environmental company that specializes in handling oil spills, is using corn cobs as an absorbing agent in their oil reclamation applications. More uses for corn residue will evolve in the future as other industries develop practical applications that can use this residue in a cost effective manner.

### **Exhibit 2.7 Corn Stover Market Analysis for Other Industrial Applications**

<b>Strengths</b> <ul style="list-style-type: none"><li>• New markets may evolve that produce a high value product that will allow companies to pay a higher price for corn stover.</li></ul>	<b>Weaknesses</b> <ul style="list-style-type: none"><li>• Historically, existing commercial users typically expect corn stover to be a low cost input.</li></ul>
<b>Opportunities</b> <ul style="list-style-type: none"><li>• Companies may evolve with gasification applications which would stimulate demand for corn stover.</li></ul>	<b>Threats</b> <ul style="list-style-type: none"><li>• Natural gas prices remaining low will keep the gasification market from evolving</li></ul>

## Section 3 – Supply, Demand and Proximity to Markets

The form of corn stover (bales, pellets) will play an important role in understanding the logistics. Markets that are located in close proximity to corn production regions will have a competitive advantage in sourcing lower cost biomass. For bales, it has been suggested by research that markets should exist within 50 miles to justify the transportation expense.

The Center for Applied Research and Environmental Systems (CARES) at the University of Missouri conducted some analysis that approximated sustainable corn stover tonnage and location in the state of Missouri. These calculations were based on cropland data layers, slopes, corn acreage, and grain yields.

Additionally, environmental constraints such as soil erosion, soil organic carbon, and soil organic matter are important when considering corn stover harvest. The following evaluation method based upon cropland slopes may be used to provide an initial estimate of sustainable corn stover removal rates in Missouri includes:

- Fields with land slopes less than 2%, less than 50% of corn stover would be harvested
- Fields with land slopes of 2% to 5%, less than 25% removal would be harvested
- Fields with land slopes greater than 5%, 0% of the corn stover removed

Estimated corn acres were calculated from the ratio of the latest five-year average (2005-2009) county harvested corn acres and total row crop acres. Missouri, as a whole, averaged 137 bushels per acre and had a yearly average of 2,956,000 harvested corn acres. Estimated corn stover tons were calculated by taking the county grain yields (bushels per acre) and using a dry weight of corn grain to residue ratio as 1:1 to estimate tonnage.

The next step in the analysis was to introduce the slope classifications of all cropland acres. The slope factor was introduced by multiplying estimated tons available for removal by 50% for the corn acres with a slope of less than 2%, and 25% for the corn acres with a slope of 2% to 5%. CARES determined the acreage of cropland that falls into each slope classification (see Exhibit 3.1). Missouri was estimated to have 31.5% of its cropland acres in corn. Based on their methodology, acres of corn and tonnage available for the state of Missouri can be found in Exhibit 3.2.

**Exhibit 3.1 Missouri Cropland and Slope Classifications**

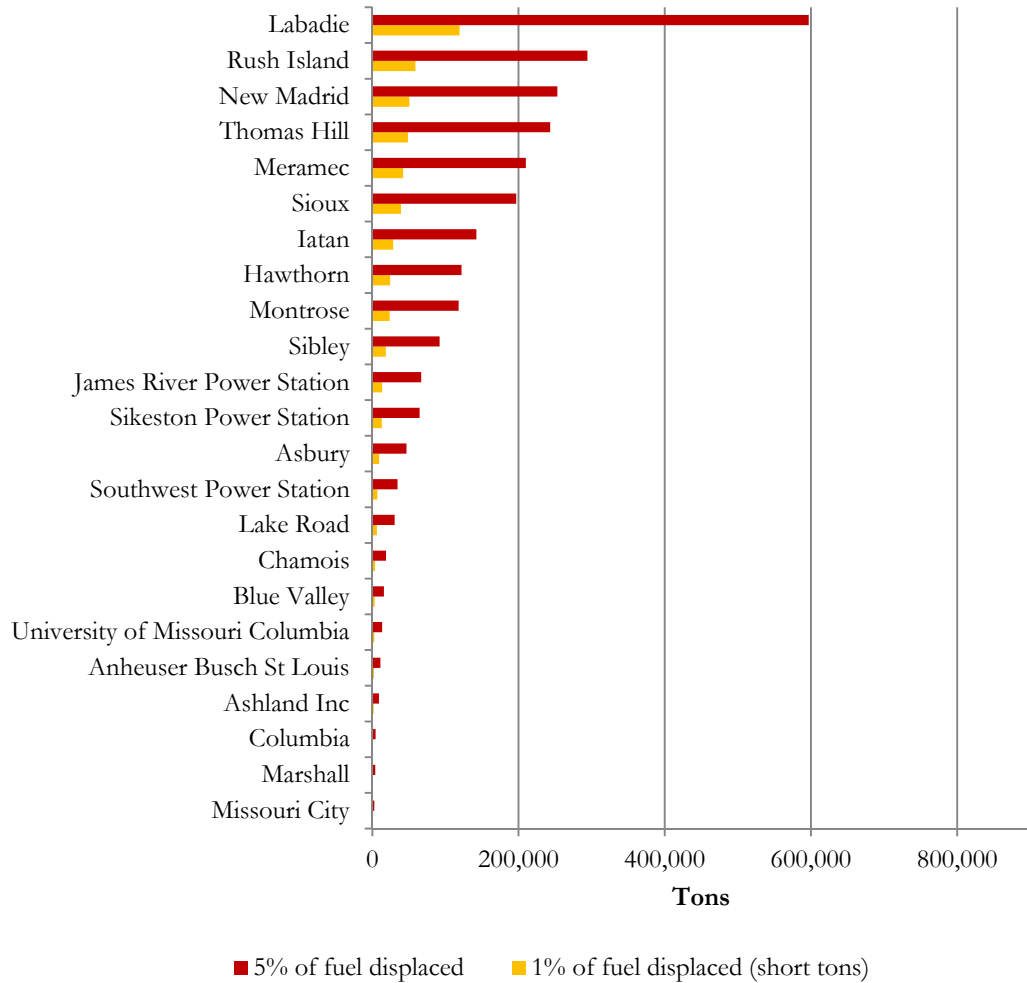
Category	Acres
Total cropland	9,370,495
Cropland less than 2% slope	5,331,639
Cropland, 2-5% slope	2,256,124

**Exhibit 3.2 Estimated Missouri Corn Acreage and Tons per Slope Classification**

Category	Total
Estimated acres in corn, slope less than 2%	1,679,466
Estimated acres in corn, slope 2% to 5%	710,679
Estimate of corn stover tons available for removal, slope less than 2%	2,721,928
Estimate of corn stover tons available for removal, slope 2% to 5%	575,902

Potential demand for biomass at the Missouri coal plants is estimated in Exhibit 3.3, based on one and five percent inclusion rates. Demand estimates for other market outlets were not estimated due to uncertainty in how the other markets would evolve and their potential demands.

**Exhibit 3.3 Potential Demand for Biomass at Coal-Fired Power Plants**



CARES also looked at the spatial aspects of corn stover supply around coal power plants. Any location or market in the state of Missouri can determine potential corn stover supply available within a certain distance of a facility based on their data set. To illustrate this concept, we looked at all existing coal plants in the state of Missouri and developed a data set that shows corn acres and corn stover tons per slope classification and proximity by road network (Exhibit 3.4-3.26).

**Exhibit 3.4 Ameren (Labadie Plant)**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	891	131	1,450	108
5 to 10	352	172	578	143
10 to 15	1,925	638	3,151	524
15 to 20	4,136	1,236	6,614	1,005
20 to 25	3,346	1,747	5,111	1,396
25 to 30	3,698	2,387	5,804	1,937
30 to 35	6,592	3,208	11,016	2,639
35 to 40	3,589	2,453	5,772	1,971
40 to 45	5,838	3,149	8,477	2,303
45 to 50	3,159	1,644	4,485	1,156
<b>Total</b>	<b>33,526</b>	<b>16,765</b>	<b>52,458</b>	<b>13,182</b>

**Exhibit 3.5 Ameren (Meramec Plant)**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	0	0	0	0
5 to 10	161	27	258	20
10 to 15	1,090	215	1,774	173
15 to 20	7,154	2,501	11,750	2,042
20 to 25	7,692	3,465	12,463	2,840
25 to 30	14,400	5,906	23,668	4,864
30 to 35	23,629	7,397	39,092	6,116
35 to 40	32,727	9,221	54,623	7,614
40 to 45	48,355	13,571	80,300	11,168
45 to 50	43,385	11,373	71,603	9,423
<b>Total</b>	<b>178,593</b>	<b>53,676</b>	<b>295,531</b>	<b>44,260</b>

**Exhibit 3.6 Ameren (Rush Island Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	3	3	4	2
5 to 10	18	30	26	22
10 to 15	166	158	252	124
15 to 20	125	134	175	98
20 to 25	967	681	1,519	536
25 to 30	8,593	2,379	13,430	1,875
30 to 35	7,453	2,885	11,606	2,245
35 to 40	8,643	3,988	13,648	3,127
40 to 45	5,955	2,921	9,446	2,304
45 to 50	3,994	3,038	6,359	2,422
<b>Total</b>	<b>35,917</b>	<b>16,217</b>	<b>56,465</b>	<b>12,755</b>

**Exhibit 3.7 Ameren (Sioux Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	2,617	373	4,526	324
5 to 10	6,867	890	11,874	772
10 to 15	7,421	667	12,803	573
15 to 20	9,080	2,243	15,195	1,882
20 to 25	18,906	6,312	32,494	5,532
25 to 30	42,194	11,695	74,491	10,448
30 to 35	53,906	15,416	94,724	13,631
35 to 40	60,157	17,150	104,148	14,884
40 to 45	80,046	22,781	139,710	19,546
45 to 50	66,064	16,558	115,767	14,196
<b>Total</b>	<b>347,258</b>	<b>94,085</b>	<b>605,732</b>	<b>81,788</b>

**Exhibit 3.8 Anheuser-Busch (St. Louis)**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	8	3	13	3
5 to 10	2,239	215	3,746	179
10 to 15	6,548	1,286	10,852	1,076
15 to 20	14,920	4,318	24,706	3,596
20 to 25	22,080	9,045	36,883	7,522
25 to 30	44,156	12,527	73,856	10,393
30 to 35	53,172	12,636	88,937	10,561
35 to 40	62,455	16,345	105,874	14,037
40 to 45	74,889	16,445	128,389	14,250
45 to 50	58,403	13,290	100,691	11,479
<b>Total</b>	<b>338,870</b>	<b>86,110</b>	<b>573,947</b>	<b>73,096</b>

**Exhibit 3.9 Ashland, Inc**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	925	287	1,627	214
5 to 10	10,321	1,701	18,670	1,362
10 to 15	12,047	3,967	20,987	3,267
15 to 20	14,999	10,545	24,896	8,685
20 to 25	23,921	14,642	40,260	12,295
25 to 30	27,885	18,210	46,477	15,411
30 to 35	40,113	20,267	65,228	16,807
35 to 40	44,319	21,719	73,203	17,914
40 to 45	61,156	24,372	103,330	20,006
45 to 50	66,501	23,501	115,163	19,576
<b>Total</b>	<b>302,187</b>	<b>139,211</b>	<b>509,841</b>	<b>115,537</b>



**Exhibit 3.10 Associated Electric Cooperative, Inc. (Chamois)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	662	113	1,014	87
5 to 10	447	279	685	214
10 to 15	459	420	697	320
15 to 20	529	336	800	254
20 to 25	876	421	1,327	321
25 to 30	2,625	943	3,718	687
30 to 35	3,769	1,535	5,416	1,128
35 to 40	1,888	1,368	2,722	1,016
40 to 45	5,670	5,715	7,937	3,941
45 to 50	6,404	5,043	8,878	3,478
<b>Total</b>	<b>23,329</b>	<b>16,173</b>	<b>33,194</b>	<b>11,446</b>

**Exhibit 3.11 Associated Electric Cooperative, Inc (New Madrid)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	1,244	76	2,435	74
5 to 10	8,353	367	16,352	360
10 to 15	14,150	596	27,569	581
15 to 20	19,708	790	38,308	767
20 to 25	30,687	1,129	59,656	1,097
25 to 30	42,578	1,540	83,079	1,498
30 to 35	52,262	2,492	101,413	2,388
35 to 40	58,918	5,972	113,108	5,555
40 to 45	53,997	9,481	102,287	8,677
45 to 50	36,767	9,868	68,473	8,912
<b>Total</b>	<b>318,664</b>	<b>32,311</b>	<b>612,680</b>	<b>29,909</b>

**Exhibit 3.12 Associated Electric Cooperative, Inc (Thomas Hill)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	126	206	180	147
5 to 10	1,988	1,325	3,106	1,017
10 to 15	6,174	2,025	9,853	1,609
15 to 20	8,243	3,798	13,186	3,010
20 to 25	8,290	5,796	13,305	4,663
25 to 30	11,325	6,656	17,681	5,270
30 to 35	22,588	10,186	35,125	7,855
35 to 40	27,344	11,906	42,348	9,126
40 to 45	26,685	14,853	40,726	11,583
45 to 50	21,517	16,003	33,044	12,866
<b>Total</b>	<b>134,280</b>	<b>72,754</b>	<b>208,554</b>	<b>57,146</b>

**Exhibit 3.13 City of Columbia**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	69	99	98	71
5 to 10	1,237	1,331	1,762	948
10 to 15	3,883	2,749	5,581	1,973
15 to 20	8,500	4,449	12,508	3,250
20 to 25	14,424	6,462	21,085	4,758
25 to 30	16,216	9,092	23,826	6,725
30 to 35	19,091	11,256	27,796	8,291
35 to 40	18,645	12,585	27,134	9,312
40 to 45	23,119	15,429	34,395	11,610
45 to 50	22,279	14,596	32,879	11,028
<b>Total</b>	<b>127,463</b>	<b>78,048</b>	<b>187,064</b>	<b>57,966</b>

**Exhibit 3.14 City of Independence (Blue Valley)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	567	366	922	298
5 to 10	1,511	1,042	2,458	843
10 to 15	4,342	2,302	7,106	1,887
15 to 20	2,701	3,828	4,573	3,247
20 to 25	5,785	5,093	9,744	4,258
25 to 30	8,090	8,648	13,566	7,222
30 to 35	16,275	13,813	27,296	11,349
35 to 40	18,288	18,956	29,443	15,021
40 to 45	19,353	24,745	30,757	19,554
45 to 50	16,970	20,000	26,779	15,756
<b>Total</b>	<b>93,882</b>	<b>98,793</b>	<b>152,644</b>	<b>79,435</b>

**Exhibit 3.15 City of Independence (Missouri City)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	836	85	1,381	70
5 to 10	2,651	473	4,475	397
10 to 15	3,400	889	5,813	749
15 to 20	5,678	2,707	9,646	2,267
20 to 25	5,915	2,136	10,227	1,818
25 to 30	8,611	6,722	14,731	5,623
30 to 35	7,401	6,041	12,701	5,111
35 to 40	9,889	8,046	16,877	6,827
40 to 45	10,240	8,560	17,473	7,292
45 to 50	10,646	9,350	18,080	7,889
<b>Total</b>	<b>65,267</b>	<b>45,009</b>	<b>111,404</b>	<b>38,043</b>

**Exhibit 3.16 City of Marshall**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	1,838	3,347	3,321	3,023
5 to 10	7,627	14,201	13,780	12,828
10 to 15	13,649	19,375	24,637	17,479
15 to 20	12,930	15,942	22,702	13,835
20 to 25	21,306	15,676	35,894	12,560
25 to 30	26,183	16,006	43,421	12,816
30 to 35	26,323	19,791	43,299	15,811
35 to 40	30,549	24,051	49,745	19,206
40 to 45	30,218	23,305	48,417	18,479
45 to 50	20,953	17,168	33,034	13,523
<b>Total</b>	<b>191,576</b>	<b>168,862</b>	<b>318,250</b>	<b>139,560</b>

**Exhibit 3.17 City of Sikeston (Sikeston Power Station)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	5,337	182	10,482	179
5 to 10	20,001	1,063	38,974	1,035
10 to 15	38,265	1,809	74,657	1,766
15 to 20	47,772	2,790	93,313	2,712
20 to 25	51,250	3,772	100,122	3,668
25 to 30	57,823	5,387	110,753	5,153
30 to 35	51,190	4,217	96,439	3,849
35 to 40	33,114	4,073	61,704	3,674
40 to 45	25,648	5,718	47,156	5,178
45 to 50	21,904	7,682	40,024	6,997
<b>Total</b>	<b>352,304</b>	<b>36,693</b>	<b>673,624</b>	<b>34,211</b>

**Exhibit 3.18 City Utilities of Springfield (James River Power Station)**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	0	0	0	0
5 to 10	0	0	0	0
10 to 15	0	0	0	0
15 to 20	0	0	0	0
20 to 25	19	16	26	11
25 to 30	200	149	277	104
30 to 35	133	133	184	92
35 to 40	625	289	866	199
40 to 45	1,648	999	2,279	691
45 to 50	1,040	424	1,437	294
<b>Total</b>	<b>3,665</b>	<b>2,010</b>	<b>5,069</b>	<b>1,391</b>

**Exhibit 3.19 City Utilities of Springfield (Southwest Power Station)**

Distance from Facility in Miles	Est. Corn Acres where slope is less than 2%	Est. Corn Acres where slope is 2% to 5%	Est. Corn Stover Tons Available for Removal where slope is less than 2%	Est. Corn Stover Tons Available for Removal where slope is 2% to 5%
0 to 5	0	0	0	0
5 to 10	0	0	0	0
10 to 15	0	0	0	0
15 to 20	98	76	135	53
20 to 25	189	180	261	125
25 to 30	382	120	529	83
30 to 35	1,199	764	1,660	528
35 to 40	1,533	810	2,120	561
40 to 45	3,108	720	4,286	498
45 to 50	3,815	885	5,236	608
<b>Total</b>	<b>10,324</b>	<b>3,555</b>	<b>14,227</b>	<b>2,456</b>

**Exhibit 3.20 Empire District Electric Co (Asbury Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	3,255	490	4,411	332
5 to 10	8,674	1,680	11,534	1,139
10 to 15	13,738	3,507	18,242	2,393
15 to 20	18,239	4,242	23,922	2,818
20 to 25	20,756	5,049	27,293	3,385
25 to 30	21,885	6,352	28,454	4,274
30 to 35	25,232	6,350	33,045	4,253
35 to 40	23,534	5,960	30,716	4,003
40 to 45	21,912	5,671	27,653	3,719
45 to 50	15,497	3,875	19,401	2,556
<b>Total</b>	<b>172,722</b>	<b>43,176</b>	<b>224,671</b>	<b>28,872</b>

**Exhibit 3.21 Kansas City Power & Light Co (Hawthorn Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	102	32	167	28
5 to 10	795	150	1,312	127
10 to 15	961	293	1,539	239
15 to 20	1,566	825	2,581	687
20 to 25	3,886	4,928	6,303	4,005
25 to 30	4,534	4,990	7,236	3,706
30 to 35	6,970	8,095	10,446	6,080
35 to 40	5,286	7,644	7,367	5,415
40 to 45	9,966	10,642	14,087	7,797
45 to 50	8,971	7,399	12,601	5,261
<b>Total</b>	<b>43,037</b>	<b>44,998</b>	<b>63,639</b>	<b>33,345</b>

**Exhibit 3.22 Kansas City Power & Light Co (Iatan Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	719	63	1,223	55
5 to 10	3,414	526	5,796	449
10 to 15	5,171	1,883	8,799	1,608
15 to 20	10,483	5,377	17,409	4,396
20 to 25	10,477	9,900	17,000	7,903
25 to 30	7,775	14,531	12,233	11,849
30 to 35	9,838	18,213	16,346	15,055
35 to 40	15,440	19,647	25,057	15,989
40 to 45	17,386	20,226	28,111	16,425
45 to 50	14,780	18,084	23,028	14,492
<b>Total</b>	<b>95,483</b>	<b>108,450</b>	<b>155,002</b>	<b>88,221</b>

**Exhibit 3.23 Kansas City Power & Light Co (Lake Road Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	2,558	448	4,472	390
5 to 10	6,804	1,811	12,046	1,582
10 to 15	9,161	4,688	15,906	4,085
15 to 20	8,673	8,050	15,307	7,001
20 to 25	13,702	13,687	23,463	11,758
25 to 30	18,167	23,539	30,949	19,868
30 to 35	18,176	25,594	30,351	21,061
35 to 40	19,162	27,582	31,738	22,052
40 to 45	22,594	27,863	37,589	22,380
45 to 50	19,725	21,278	32,428	17,220
<b>Total</b>	<b>138,722</b>	<b>154,540</b>	<b>234,249</b>	<b>127,397</b>

**Exhibit 3.24 Kansas City Power & Light Co (Monstrose Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	675	390	802	232
5 to 10	2,584	1,517	3,082	906
10 to 15	2,397	2,110	3,062	1,364
15 to 20	4,033	4,176	5,431	2,866
20 to 25	6,629	5,829	9,336	4,051
25 to 30	7,710	7,360	11,123	5,256
30 to 35	12,222	10,535	17,713	7,620
35 to 40	17,690	10,001	25,294	7,172
40 to 45	15,786	10,569	22,496	7,506
45 to 50	10,566	8,017	14,933	5,660
<b>Total</b>	<b>80,292</b>	<b>60,504</b>	<b>113,272</b>	<b>42,633</b>

**Exhibit 3.25 Kansas City Power & Light Co (Sibley Plant)**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	633	665	1,028	540
5 to 10	2,286	1,423	3,719	1,169
10 to 15	2,905	2,293	4,921	1,959
15 to 20	3,535	3,046	5,975	2,637
20 to 25	4,592	5,239	7,910	4,531
25 to 30	12,349	8,995	21,342	7,741
30 to 35	16,439	12,137	27,880	10,258
35 to 40	14,970	15,053	24,993	12,454
40 to 45	18,806	20,576	31,186	16,892
45 to 50	20,897	20,543	35,003	16,720
<b>Total</b>	<b>97,412</b>	<b>89,970</b>	<b>163,957</b>	<b>74,901</b>



**Exhibit 3.26 University of Missouri-Columbia**

<b>Distance from Facility in Miles</b>	<b>Est. Corn Acres where slope is less than 2%</b>	<b>Est. Corn Acres where slope is 2% to 5%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is less than 2%</b>	<b>Est. Corn Stover Tons Available for Removal where slope is 2% to 5%</b>
0 to 5	46	76	65	55
5 to 10	1,153	1,263	1,643	899
10 to 15	3,194	2,390	4,574	1,712
15 to 20	6,814	3,729	10,092	2,730
20 to 25	14,023	6,323	20,528	4,660
25 to 30	15,299	8,443	22,495	6,245
30 to 35	19,681	11,296	28,718	8,346
35 to 40	17,780	12,523	25,910	9,266
40 to 45	22,101	15,152	32,882	11,413
45 to 50	21,112	13,227	31,454	10,072
<b>Total</b>	<b>121,203</b>	<b>74,422</b>	<b>178,361</b>	<b>55,398</b>

## Section 4 – Biomass Competitor Analysis and Supply

Missouri’s diverse agricultural landscape has produced an array of commodities that can potentially be used for producing sustainable energy beyond corn stover. From crop residues through the north-central region, to switchgrass on CRP land and ginning residues in the southeast region, options for biomass feedstocks are accessible across the state. A key component of understanding how corn stover relates to other biomass feedstocks is by looking at energy and potential costs. Exhibit 4.1 demonstrates biomass characteristics and costs that are important for potential biomass purchasers.

**Exhibit 4.1 Biomass Fuel Characteristics and Costs**

Resource	Energy Content, Wet (Btu/lb)	Energy Content, Dry (Btu/lb)	Cost (\$/ton)	Cost (\$/MMBtu)
Forest residue	5,140	8,570	15-30	1.50-2.95
Forest thinnings	5,140	8,570	15-30	1.50-2.95
Mill residue		8,570	8-50	0.50-2.95
Corn stover	5,290	7,560	20-40	1.90-3.80
Wheat straw	5,470	6,840	40-50	4.00-5.00
Hybrid poplar/willow	4,100	8,200	30-60	4.75-7.50
Switchgrass	6,060	8,670	35-50	2.90-4.25
Urban wood waste	4,600	6,150	3-24	0.50-2.80

Source: Energy and Environmental Analysis, Inc. (2007)

As the demand for biomass grows, the smaller quantities of low cost biomass will quickly be committed and buyers may begin paying more to pull in larger quantities of other types of biomass. All biomass sources are not interchangeable. Chemical and physical characteristics of woody biomass may restrict the value further below other sources, depending upon the specifications demanded by the buyers.

Urban wood residues and mill residues are currently the lowest cost sources of biomass. However, according to Dr. Hank Stelzer, University of Missouri State Extension Forestry Specialist, 93% of mill residue is already committed to buyers. Forest residues are the next cheapest source of biomass for consumers who can use this product.

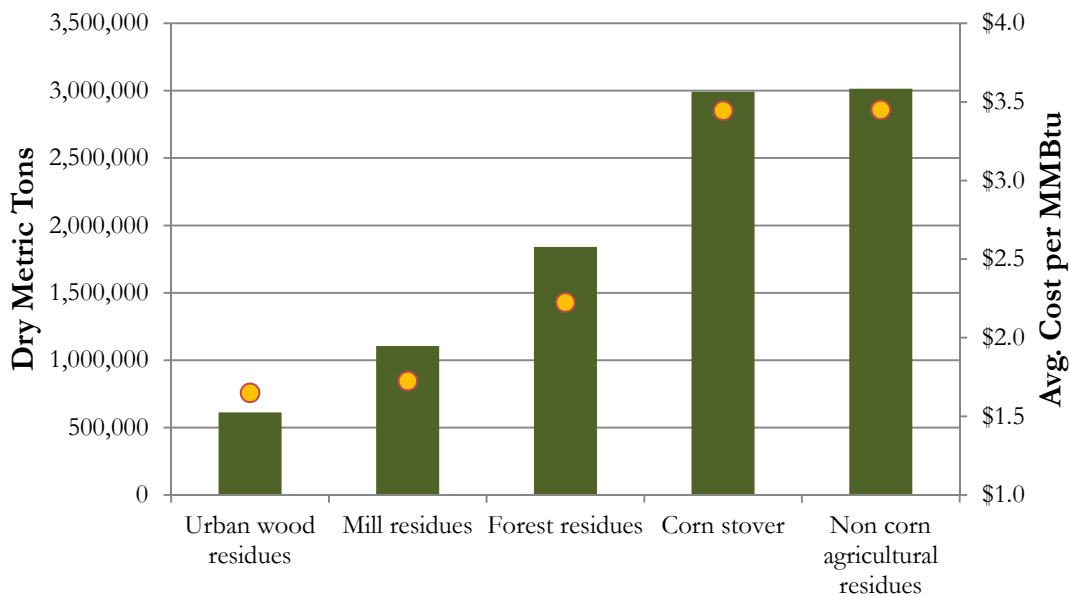
While Missouri annually grows three times the amount of timber that is harvested, an industry has not yet developed to harvest timber specifically for biomass chipping. Co-harvesting of low quality timber during regular harvests is currently supplying the existing demand for forest residues. In preparation for the development of a woody biomass industry, the Missouri Department of Conservation (MDC) has defined and published “Guidelines for Woody Biomass Harvest in Missouri” in cooperation with industry partners. The guidelines suggest logging practices and chain of custody standards for the industry.

According to MDC, “Biomass harvesting is a developing industry in its infancy. As world petroleum prices rise, alternative energy sources, such as biomass from our forests, will become more and more utilized. It will not be much different, however, from harvesting pulpwood. We

expect new equipment and methods to be developed as demand grows, but in the beginning most harvesting will occur with equipment such as we now use. And, in the beginning, we can only envision biomass harvesting to be economically feasible if it is combined with saw timber harvest.” Hardwood pulpwood prices for green pulpwood have averaged approximately \$10 per ton on the stump in Missouri in recent years and \$35 per green ton delivered to the mill. At least four major projects at various stages of development exist in southern Missouri to create electricity from woody biomass. Typically those projects will need 10,000 tons of biomass per year per megawatt of capacity. If and when those projects actually start using woody biomass, demand for woody biomass could easily reach one million additional tons per year. This kind of demand will likely create a supply network of woody biomass loggers built around a new type of timber harvest industry.

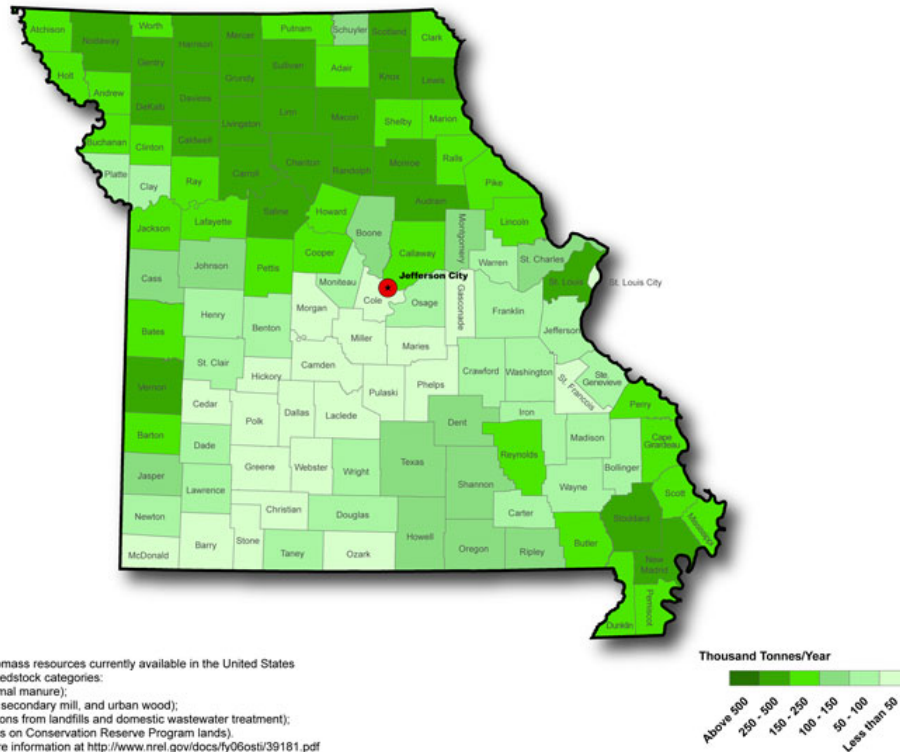
Exhibit 4.2 below depicts the potential supplies and costs of biomass in Missouri. As low cost forest residues are consumed, the next cheapest source of biomass will likely be crop residue, both corn stover and non-corn stover. Dedicated energy crops and a newly developed hardwood chipping industry would likely follow as demand would continue to grow and prices increase.

**Exhibit 4.2 Potential Supplies and Costs of Biomass in Missouri**



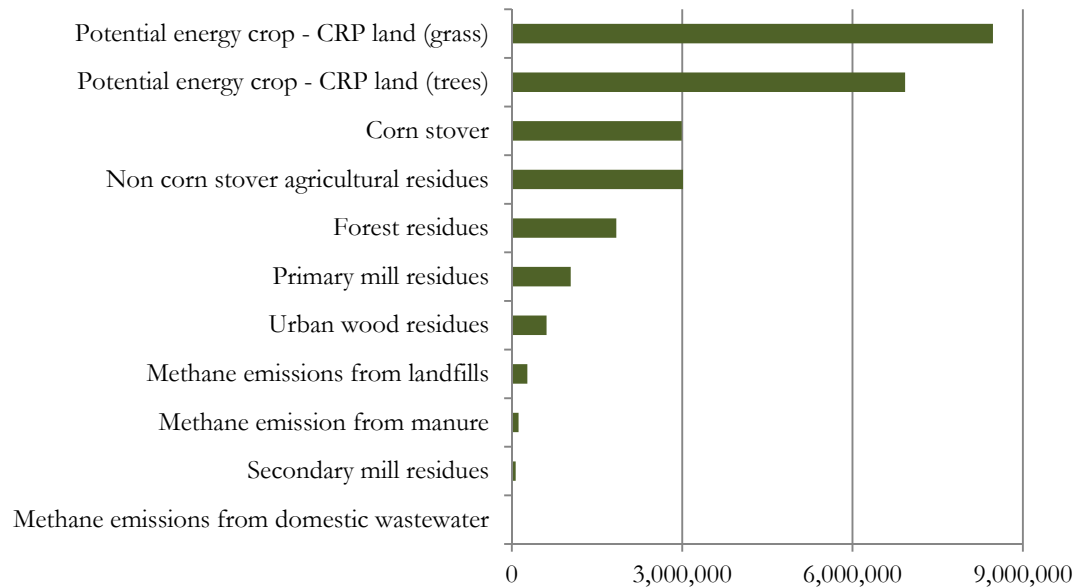
There has been much research in the area of assessing the potential resources that can be used for biomass purposes. A comprehensive study conducted by the National Renewable Energy Laboratory (NREL) looked at the availability of agricultural residues, wood residues, municipal discards and dedicated energy crops in Missouri. Exhibit 4.3 represents a roadmap of all biomass resources available in the state of Missouri. Darker green areas represent large accumulations (metric tons) of biomass available per year.

### Exhibit 4.3 Missouri Feedstock Availability (Metric Tons/Year)



All feedstock estimates were developed on various assumptions. For example, agricultural residues were estimated using total grain production, crop to residue ratio, moisture content, and factoring the amount of residue that should be left on the field for soil protection, grazing, and other agricultural activities. Similar methodology was used in the other respective feedstock categories. Based on the same NREL report, Missouri can be further examined per each feedstock category in Exhibit 4.4. Corn stover supply that was calculated earlier in this report was also included. Agricultural residues and forest products are currently some of the largest existing resources in Missouri. There is also great potential for energy crops to be grown on CRP acreage. Methane emissions from the livestock industry ranks low, as Missouri does not have a large abundance of concentrated animal feeding operations.

**Exhibit 4.4 Missouri Feedstock Availability per Category (Dry Metric Tons)**



Source: Milbrandt (2005) and University of Missouri

Another study prepared by Fink and Fink (2006) completed an assessment of the biomass feedstock availability in Missouri. This report evaluated and inventoried various biomass feedstocks by using assumptions on energy (Btu), supply (dry tons), and sustainable removal rates to determine Btu potential in feedstock. Exhibit 4.5 details these categories to estimate the potential for biomass energy in Missouri.

**Exhibit 4.5 Estimated Feedstock Energy Potential in Missouri**

Feedstock	Btu Rating (Per Ton)	Total Supply (Dry Tons)	Total Million Btu Supply Available	Sustainable Removal Rate	Sustainable Annual Million Btu
Hybrid poplars (5 tons/acre)	16,400,000	7,783,935	127,656,534	100%	127,656,534
Switchgrass (5 tons/acre)	14,934,000	7,783,935	116,245,285	100%	116,245,285
Corn residues	15,000,000	8,178,917	122,683,756	30%	36,805,127
Soybean crop residues	15,000,000	4,997,865	74,967,980	30%	22,490,394
Timber harvesting residues	17,100,000	871,552	14,740,393	100%	14,740,393
Winter wheat residues	15,000,000	2,237,479	33,562,184	30%	10,068,655
Grain sorghum residues	15,000,000	809,450	12,141,746	30%	3,642,524
Rice residues	13,622,000	711,783	9,695,911	30%	2,908,773
Cotton field waste residues	15,000,000	507,893	7,618,388	30%	2,285,516
Cotton gin waste residues	14,000,000	56,433	790,055	100%	790,055
Tall fescue seed screenings	16,000,000	8,099	129,580	100%	129,580

Source: Fink and Fink (2006)

The following sections provide a summarized analysis of Missouri biomass according to Finks' study.

#### *Corn Residues*

Collection of corn residues as a potential feedstock has been shown to be feasible throughout most of Missouri. Areas of the state that have high corn production and relatively low erosion include much of the flood plains along the Missouri and Mississippi rivers, as well as in the southeast region of the state where erosion is of low environmental impact. In these areas, wind erosion may be an issue, prompting careful collection methods to preserve the integrity of the soil.

#### *Soybean Crop Residues*

Soybean crop residue is simply the bean stalks that are left after soybean harvest. The ratio of straw to grain used to calculate the residue available after harvest was 1:1 (straw to grain), leaving sixty pounds of residue per bushel. Soybean crop residue can potentially account for seven percent of the total sustainable feedstocks in Missouri.

#### *Winter Wheat Residues*

Winter wheat residues are produced similarly to soybean crop residues. One limiting factor in the use of winter wheat residues is the use of wheat straw as cattle feed and use by other industries such as landscaping and gardening as a weed deterrent. This study assumes that collection of winter wheat residues will be primarily used as a biomass feedstock, representing three percent of the annual supply available.

#### *Grain Sorghum Residues*

Grain sorghum residues are produced as a co-product of harvesting in the same fashion as soybean harvesting. The stalks produced by harvest have not been used as a commodity to be manufactured into a marketable product; however, sorghum has experienced a recent increase in use for ethanol production. The Btu rating of grain sorghum is calculated based on corn residue formulas and represents only one percent of the total biomass feedstocks available in Missouri.

#### *Rice Residues*

The rice residue calculation involved a 1.7:1 ratio for residue produced compared to yield. With sixty pounds per bushel and the residue ratio, rice producers in the southeast portion of the state produce approximately 700 thousand tons of residues each year.

#### *Cotton Field Waste Residues*

Traditionally, cotton gin field residues have not had any residual market value. Use of field waste as a biomass feedstock can add value for cotton farmers in the southeast region of Missouri. As with other crops, cotton field waste residues are a source of nutrients for the next season's crop.

#### *Cotton Gin Waste Residues*

Cotton gin waste residues have been an operating cost for gins in the southeast region, not a source of additional income. Due to the residue being produced out of the field and at a gin, 100% of the residues would be available to be used for energy. Ginners have had to traditionally dispose of the waste themselves or pay to have the waste disposed of in the past. Using the waste as a feedstock has the potential to reduce costs for ginners and even provide a source of additional income.

### *Tall Fescue Seed Screenings*

Tall fescue seed screenings are produced when fescue seed is processed at seed plants. Screenings have a Btu rating of 8,000 Btu, but only produce 130 million Btu annually, which accounts for less than one percent of the total.

### *Timber Harvesting Residues*

Timber harvesting residues are all the branches, limbs, tops and other residues, excluding stumps, left after harvesting logs. Although Missouri has a somewhat strong logging industry in the south central area of the state, recovering the residues may be challenging from an economic standpoint.

### *Hybrid Poplars*

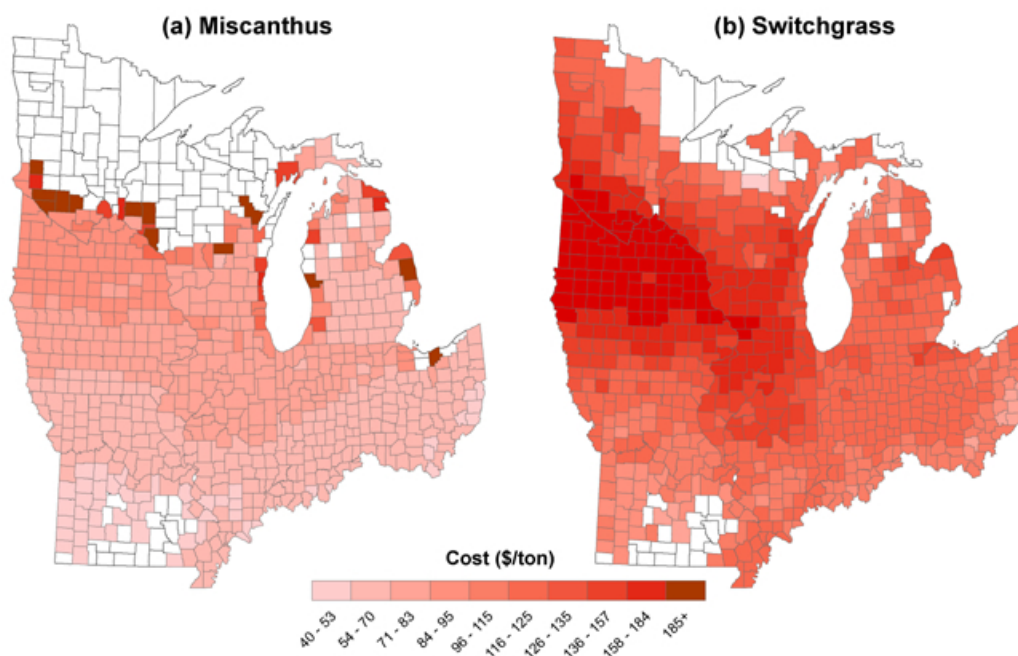
Hybrid poplars are not currently produced as a commodity in Missouri and it is assumed that their production would occur on CRP contracted land. However, utilizing CRP land to produce hybrid poplars may reduce or eliminate the payments landowners are currently receiving from enrollment in the program.

### *Energy Crops*

Switch grass was primarily researched in Finks' report. However, Miscanthus is another potentially viable energy crop that is generating interest. The University of Illinois (Khanna et al., 2011) has been extensively researching the use of these crops in the Midwest region.

According to their publication, the cost of the next-best alternative, growing corn and soybeans, is incorporated into the break-even price determinations due to those crops being the most prevalent in the Midwest. The analysis included costs for inputs, field operations, planting and harvesting, the costs of storage, and the cost of land. The costs were calculated for each crop in each state, with the break-even prices depicted in Exhibit 4.6.

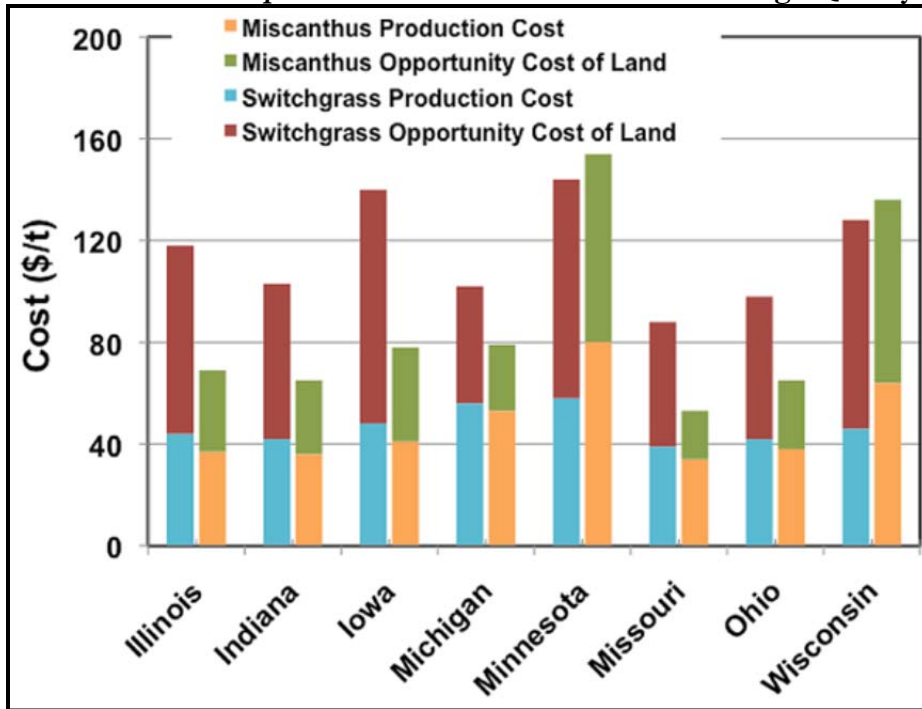
**Exhibit 4.6 Breakeven Prices on Average Quality Land**



Source: Khanna et al. (2011)

Production of Miscanthus in much of Missouri will result in a low breakeven cost, while switchgrass breakeven prices for the state are on average higher. Exhibit 4.7 identifies the components of the breakeven prices for each crop by state. Missouri has the lowest breakeven costs of any state for both Miscanthus and switchgrass.

**Exhibit 4.7 Components of Breakeven Prices on Average Quality Land in 2007 Prices**



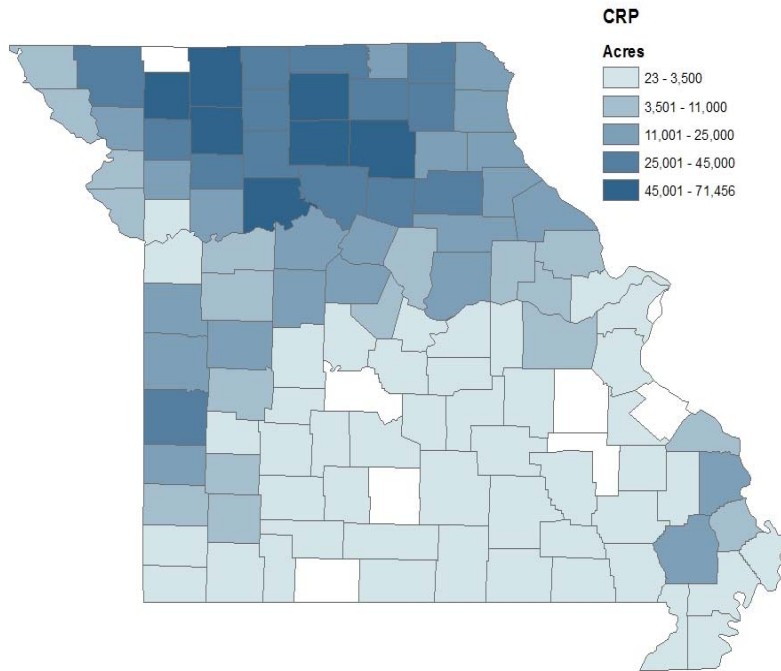
Source: Khanna et al. (2011)

The most challenging aspect of utilizing energy crops as a feedstock is the establishment timelines involved with each crop. Switchgrass can be established in one growing season, but may only yield as low as 30% of total available residue, with at least 67% harvested the second season and the full 100% harvested the third season. Miscanthus, however, has an establishment period of one season without any harvesting possible, followed by 40-50% the second year and 100% each year thereafter.

Like hybrid poplars, it is assumed in Finks' study that the crop would be produced on CRP enrolled land and its production may reduce or eliminate CRP payments. Marginal ground such as that enrolled in the Conservation Reserve Program (CRP), for example, can be used to produce biomass products that can be harvested without the negative result of erosion and run-off. Exhibit 4.8 shows the relative concentration for enrollment in CRP across the state.



**Exhibit 4.8 Missouri CRP Enrollment Concentrations (2010)**



Source: USDA – Farm Service Agency

The USDA-Farm Service Agency has made recent announcements about Biomass Crop Assistance Program (BCAP) project areas being developed in Missouri (USDA, 2011). MFA Oil Biomass LLC was the applicant of these two locations (Columbia and Aurora) and Show Me Energy in the other project area. Giant miscanthus is the warm-season grass that will be grown in the Missouri project areas for MFA Oil and yields are expected to be 10 to 12 tons of dry matter per acre. Show-Me Energy will include various feedstocks that are currently being utilized in their facility.

**Exhibit 4.9 BCAP Project Areas in Missouri**

Sponsor Location	Counties Included	FY2011 Acreage Targets
Centerview, Missouri	39 counties in central and western Missouri and eastern Kansas	20,000 acres
Columbia, Missouri	Audrain, Boone, Callaway, Cole, Cooper, Howard, Moniteau, Monroe, and Randolph	3,200 acres
Aurora, Missouri	Barry, Christian, Dade, Jasper, Lawrence, Newton, and Stone	5,600 acres

A project area will provide financial incentives to landowners and farmers that will establish and produce biomass crops. Financial incentives include establishment payments of 75 percent of the eligible costs of the plantings, annual payments for the land enrolled, and matching payments for up to two years for the collection, harvest, storage and transport of the biomass to a qualified biomass conversion facility.

## Section 5 – Suitable Target Markets

Corn stover markets will evolve and change over time. Markets that have few barriers to entry, simple in operation and pay the highest returns will generate the most interest for farmers. Based on markets for corn stover, a timeline for market development estimated by the authors can be found in Exhibit 5.1.

**Exhibit 5.1 Timeline for Corn Stover Market Development**

Market	Speed of Market Creation	How to Participate in Market	Potential Size of Market	Potential Returns to Corn Stover Producers
Feed for beef and dairy cattle industry	Current	Individuals or as a collective business	Small	Medium
Biomass densifiers	1 operational plant, others may come in the future	Individuals or investor owners in densification business	Regional	Medium
Coal-fired power plants	3-5 years	Supply company only	Large	Low
Cellulosic ethanol plants	5-10 years	Dependent on plant; individual or supply company contracts	Large	Low
Other industrial applications	0-10 years	Dependent on volume needs	Small	?

Beef and dairy cattle industry appear to be the most viable market as of today. Farmers could utilize practices on farm to turn corn stover into a ruminant feedstuff that could replace some corn and/or forage in diets. Monsanto has been leading efforts at this technology and feeding trials have conducted to validate its effectiveness. With a small cattle feeding industry in Missouri, it appears that this will not develop into a large market for ensiled corn stover unless smaller beef cow/calf operations adopt using corn stover in place of fescue hay.

Biomass densification is another market that exists today, but only with farmers invested and located in close proximity to Show-Me Energy Cooperative. Show-Me Energy could decide to license its technology or build similar plants in other regional locations. Pelleting corn stover appears to have value if it can maintain a low cost of production, minimize capital investments and deliver a consistent quality product. Companies such as Pellet Technology in Omaha, Nebraska are working to reach these goals for corn stover.

Coal-fired power plants will face increasing pressure over time to add more renewables to their portfolio in the state of Missouri. These plants will look to the lowest cost alternatives for meeting these needs and corn stover/pellets currently are not the lowest cost solution when compared to other biomass sources. The University of Missouri combined power and heat plant is one market and Ameren has also indicated interest in their plants. But it is important to note that these plants could gobble up a lot of biomass with even minimal inclusions rates of one to five percent, so the

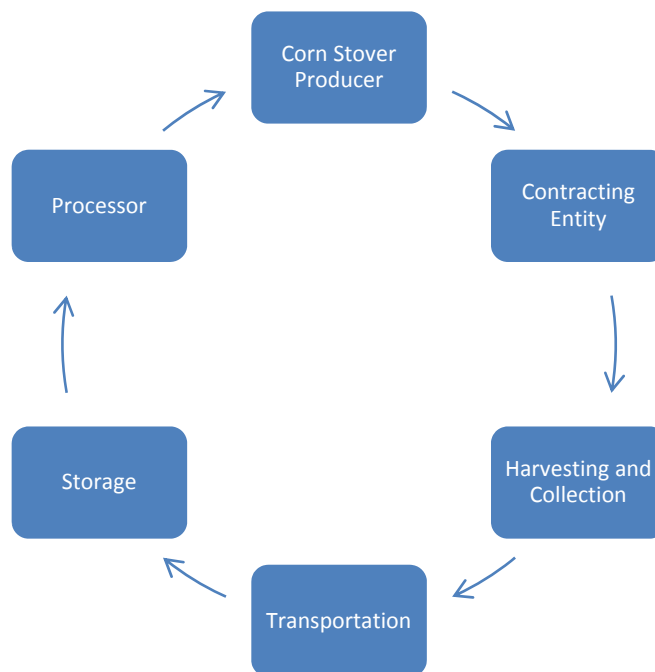
corn stover market could develop quickly if prices reach a satisfactory point for farmers to sell. A key driver in this market evolving is that plants will want a credible market supplier to handle all of the procurement, storage, transportation and quality control of corn stover and other biomass feedstocks. To minimize risk, they will seek the establishment of a long term contract to mitigate any feed and handling investments that a plant will make for biomass feedstocks. Developing an integrated supply chain network is not an easy task and will take diligent work with farmers and strong businesses to create an efficient and credible one-stop shop for biomass.

The cellulosic industry is evolving as many companies are investigating through demonstration and pilot plants. While two demonstration plants exist in Missouri today, no commercially viable plants are in operation in Missouri or planned in the near future. But there will come a date when a business will most likely decide to set up operations and look at various biomass feedstocks including corn stover to supply its needs. Other industrial applications for using corn stover could develop as well in the future, but it is impossible to predict at this point when, prices, and where they will develop.

## Section 6 – Business Models for Corn Stover Producers

There are a variety of ways that corn stover farmers can become involved in feedstock supply. Exhibit 6.1 details the segments of the value chain that could be used to capture more value. Corn stover will be the primary product supplied, unless the business decides to include handling other feedstocks demanded by the final targeted customer. The challenge for farmers is deciding which services to provide and which services to outsource to other entities. Corn stover business owners must decide how and what services that they wish to provide. Inventorying existing resources, understanding the end market's product needs and learning the farmers' willingness for providing services will dictate how a business should be formed.

**Exhibit 6.1 Options for Developing a Corn Stover Business**



### **Producers**

As grain producers, corn farmers will essentially be corn stover producers by default. Many farmers may prefer to end their active involvement in the stover supply chain in the field. These farmers will expect that all other stover collection, logistics, processing and marketing functions will be handled by others in the value chain. A contracting entity could handle all stover business activities after the farm gate and pay the farmer for biomass collected. A number of businesses in the US are currently contracting with individual farmers for corn stover.

### **Contracting Entity**

A contracting entity is a potential corn stover aggregator. Many potential end markets will prefer to deal with one credible business to provide all functions of the feedstock supply chain, under a long term supply agreement. Services provided by the contracting entity could include:

- Securing supply arrangements with local corn farmers that detail the quantity, form, and cost
- Determining if other biomass feedstocks will be provided beyond corn stover

- Arranging for collection and baling of all contracted corn stover
- Arranging storage- either through an off-field collection site or on-farm
- Ordering transportation and delivery to the processor or end facility
- Processing the product (either in house or outsourcing) according to buyer's specifications

### **Harvesting and Collection**

If harvesting or collection is not provided by the supply company, decisions will be needed on whether these functions are provided by the farmer or a custom-hire operator. Existing hay collection equipment and/or trucking units owned by farmers may be suitable for collecting and hauling corn stover. This approach would not require additional purchases, but farmers would need compensation for providing these services. Some producers might decide to "share" some of the equipment and reduce ownership expenses. But the business could prefer to outsource all harvesting and collection to a certain vendor who will provide a consistent.

### **Transportation**

Logistics are a critical key point in serving an end market. A corn stover business that provides baled corn stover to an end market or pellet facility would need to be within a certain radius of the end market due to the transportation and handling challenges of corn stover. Corn stover densification (i.e. ground/compacted or pelletized) would allow the final product to serve more distant end markets. Options for transportation would include farmers' providing transportation, contracting entity owning equipment, or outsourcing to a local transportation company.

### **Storage**

Unless an end market will handle all storage for product after collection, staging areas will be needed for corn stover or other biomass feedstocks. One option is to store the corn stover at the producer's farm until it is needed by the plant. The producer must allocate space for corn stover storage and provide all-weather access to the stover storage area. The producer would also be responsible for maintaining stover quality and be provided compensation for storage costs. Another stover storage solution is to transport the corn stover to a central or intermediate storage location. Increased costs are incurred when corn stover is stored at a central location because of the additional handling. However, these additional storage costs may be offset if transportation is more convenient for either or both the producer and the plant.

### **Processor**

End markets will dictate the needs of processing corn stover. They may want a pelleted product, densified corn stover or baled corn stover. Once a market is designated to supply, decisions have to be made whether these processing functions are provided or outsourced to a local facility. Densification equipment represents a significant capital investment so careful analysis should be mandatory before agreeing to a long term agreement with an end market.

### **Farmer Business Models (or combinations of each)**

- Corn Stover Producer Only
- Corn Stover Producer that Provides Collection, Handling, Storage and/or Transportation
- Producer-Owned Contracting Entity
- Producer-Owned Processing Entity

## Sources

Energy and Environmental Analysis, Inc. (2007). “Biomass Combined Heat and Power Catalog of Technologies”. ICF International Company, and Eastern Research Group, Inc. (ERG) for the U. S. Environmental Protection Agency, Combined Heat and Power Partnership.

Fink, R. J. and R. L. Fink. (2006). “An Assessment of Biomass Feedstock Availability in Missouri.” Prepared for University of Missouri and Missouri Department of Natural Resources under Contract No. SEBSRP-SSEB-2004XX-KLP-001. Sponsored by Southern States Energy Board.

Food and Agricultural Policy Research Institute (FAPRI). (2010). “2011 Dryland Corn Budget”. University of Missouri. Accessed at [http://www.fapri.missouri.edu/farmers\\_corner/budgets/](http://www.fapri.missouri.edu/farmers_corner/budgets/) July 12, 2011.

Khanna, M., A. Jain, and A. Oliver. (2011). “Production of Bioenergy Crops in the Midwest”. Farm Economics: Facts and Opinions, Farm Business Management. Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign. Accessed at [http://farmdoc.illinois.edu/manage/newsletters/fefo11\\_06/fefo11\\_06.html](http://farmdoc.illinois.edu/manage/newsletters/fefo11_06/fefo11_06.html). July 12, 2011.

Milbrandt, A. (2005). “A Geographic Perspective on the Current Biomass Resource Availability in the United States.” National Renewable Energy Laboratory, Golden, Colorado.

Sims, B. (2010). “Rethinking Ag Residue.” Biorefining Magazine. Accessed at <http://www.biorefiningmagazine.com/articles/150/rethinking-ag-residue> November 14, 2010.

United States Department of Agriculture (USDA). (2011). Biomass Crop Assistance Program (BCAP) Project Areas 2 through 5”. Farm Service Agency Fact Sheet. Accessed at [http://www.fsa.usda.gov/Internet/FSA\\_File/bcap\\_areas2\\_5\\_2011.pdf](http://www.fsa.usda.gov/Internet/FSA_File/bcap_areas2_5_2011.pdf). August 2, 2011.