Biomass Resource Assessment Final Report

University of Illinois Urbana Champaign

Contract Reference: 30.021

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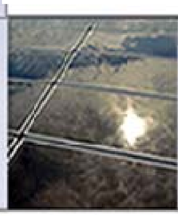
Date: 10/26/2010



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1. INTRODUCTION

The University of Illinois at Urbana-Champaign contracted with Antares Group Inc. (ANTARES) to conduct a biomass resource assessment for potential biomass cofiring and boiler conversion options at Plant Abbott, the on-site combined heat and power (CHP) facility on the campus. This report documents the results of the analysis, which included the following efforts:

- Site visit to assess boiler characteristics and operating history, biomass receiving and storage options and preliminary evaluation of biomass cofiring/repowering options
- Assessment of biomass resource availability
- Evaluation of biomass fuel contracting requirements and
- Summary of barriers and opportunities for project implementation.

The subsections in this chapter provide a description of Plant Abbott and estimated biomass use at Plant Abbott for several broad biomass cofiring and/or repowering scenarios. Following this introductory chapter are sections on agricultural, urban and forest biomass resource availability and contracting, delivery and storage logistics related to biomass use at Plant Abbott. A summary and conclusions chapter provides conclusions regarding barriers and opportunities for biomass utilization at the Plant Abbott facility.

This project did not include a technical evaluation of the energy needs; boiler condition and configuration; boiler fuel specifications and requirements; air emissions issues or requirements and other environmental conditions; biomass cofiring or repowering project economics; detailed biomass fuel receiving, storage, processing and conveyance system design and layout within the context of the overall plant configuration and operations; impacts of biomass fuel cofiring or repowering on plant operations or efficiency, or local testing and evaluation of biomass fuel quality characteristics. Each of these alone or in combination could significantly impact the technical feasibility, operational reliability and project economics for any biomass cofiring or repowering project. Prior to decision-making related to any biomass project, these factors need to be evaluated in detail to ensure that any proposed project will be technically and economically viable.

1.1. Plant Abbott Description

Plant Abbott (Exhibit 1) has three coal boilers that were originally installed circa 1956 to 1962. The plant uses Detroit spreader stoker grates and Babcock & Wilcox boilers. Boiler number 5 and 6 have a nominal capacity of 150 thousand pounds per hour (pph) and boiler number 7 has a nominal capacity of 200 thousand pph. The facility air permits limit the combined firing rate of the boilers to 350 pph. The facility operates year round for heating and cooling loads and also provides process steam to dining halls and laundry facilities. The facility beyond the boiler plant grounds are handled by the Building Maintenance Group, which is separate from the maintenance and staffing responsibilities at the plant.

The current fuel is a Southern Illinois coal that necessitates boiler de-slagging every five to six months. Coal is trucked up from the St. Louis region approximately 200 miles one way. Approximately 3.15 gallons of diesel is used per ton to transport fuel to the plant. The plant uses approximately 350 tons of coal each day; the summer firing rate for the plant is similar to the winter use due to use of steam driven chillers and dehumidification. Current total fuel use is approximately 100,000 tons per year.

Exhibit 1 Plant Abbott

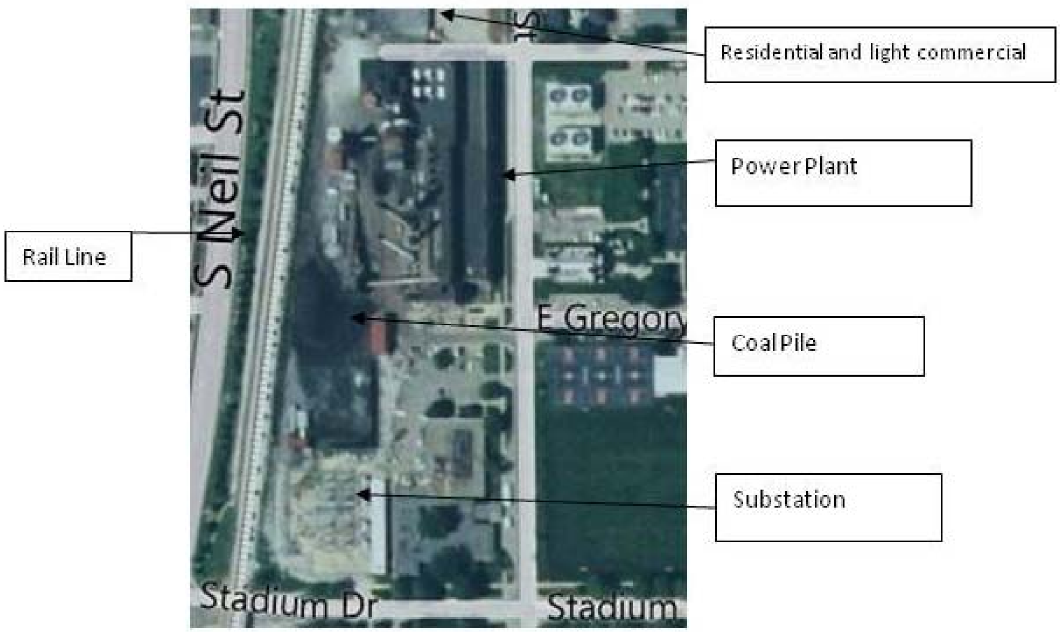
Fuel is delivered by truck to the plant and is unloaded from dump trailers into a below-ground hopper. The in plant bunker stores approximately 18 to 24 hours of fuel. Exhibit 2 shows the fuel receiving location. An under-pile reclaim system transfers coal to the conveyor system to the boilers.

Exhibit 2 Plant Abbott Coal Unloading into Below Grade Pit; Conveyor to Fuel Hopper on Left

In addition to fuel delivery into the below ground hopper, approximately 1.5 to 2 days of surplus fuel is stored in an uncovered pile that is handled using front end loaders.

The Plant Abbott location is bounded on the north by residential and light commercial; cooling towers and university parking and athletic facilities are located on the east (Exhibit 3). A rail line is located to the west but rail access is not available to Plant Abbott. Just east of the rail line is the coal fuel surplus pile. The entire land area from the northern tip of the coal pile south to the substation, bounded on the east by the parking area is approximately one acre in area. This would be the likely location for outdoor or partially covered biomass fuel storage; a biomass fuel storage bin system with a potentially smaller overall footprint could be located at a variety of locations to the west or southwest of the power plant. Section 3 discusses the range of potential storage options within the context of the different biomass cofiring or repowering scenarios.

Exhibit 3 Aerial view of Plant Abbott



There is limited availability of additional land area for biomass fuel storage at Plant Abbott without repurposing parking or other neighboring parcels. There are plans under investigation to install solid fuel storage bins near where the existing outdoor coal storage is currently located. This will increase solid fuel storage capabilities on-site. This project would likely improve biomass fuel storage options depending on the final design for the fuel storage system. There is an opportunity to integrate biomass fuel storage into this project, but a final determination of how this would work depends on a more detailed engineering and design analysis.

1.2. Biomass Utilization Options at Plant Abbott

Biomass options under consideration include cofiring 10 to 20 percent of capacity across all boilers or converting one boiler to biomass. Exhibit 4 summarizes estimated coal and biomass use for each of these scenarios. These estimates are preliminary and must be verified through detailed engineering and performance analysis, but are sufficient for a first-order of magnitude study to determine overall biomass resource requirements. Fuel use estimates are based on boiler capacity. A value lower than total capacity was used due to permit terms that limit firing of boilers to a maximum of 350,000 pph.

Exhibit 4 Estimated fuel uses by boiler repowering and cofiring option

	100% replacement by boiler unit			10% cofiring by boiler unit			20% cofiring by boiler unit		
Variable	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**
Firing rate (000 pph)	105	140	350	10.5	14.0	35.0	21.0	28.0	70.0
Coal	29,239	38,985	97,463	2,924	2,924	3,899	5,848	7,797	19,493
Ag residue	53,993	71,991	179,977	5,399	7,199	17,998	10,799	14,398	35,995
Switchgrass	53,993	71,991	179,977	5,399	7,199	17,998	10,799	14,398	35,995
Urban wood	64,859	86,479	216,198	6,486	8,648	21,620	12,972	17,296	43,240
Mill residue	70,264	93,686	234,214	7,026	9,369	23,421	14,053	18,737	46,843
Corn stover pellets	50,993	67,991	169,978	5,099	6,799	16,998	10,199	13,598	33,996
Wood pellets	46,843	62,457	156,143	4,684	6,246	15,614	9,369	12,491	31,229

Note: Assumed combustion efficiency 80 percent and operation 65 percent of hours in year used to calculate fuel use by boiler.

Exhibit 5 provides fuel heat content assumptions that were used to derive the fuel use in Exhibit 4. Wood pellets have the highest heat content of any of the fuels, and therefore represent the lowest quantity of biomass fuel required. Because agricultural residues have lower moisture than green wood, a smaller quantity of agricultural residues (in this case, corn stover) is required .

Exhibit 5 Fuel moisture and higher heating value (HHV) assumptions

Heat content of fuel	As-received moisture (% wet basis)	HHV (MMBtu/ dry ton)	HHV (MMBtu/ as received ton)
Coal	3%	25.6	24.8
Agricultural residues	15%	15.8	13.4
Switchgrass	15%	15.8	13.4
Urban wood	35%	17.2	11.2
Mill residues	40%	17.2	10.3
Corn stover pellets	10%	15.8	14.2
Wood pellets	10%	17.2	15.5

Plant Abbott is evaluating a conceptual design for upgrades to the solid fuel storage. That design concept consists of six silos (bins) that each have a storage capacity of 18,700 cubic feet for a total capacity of 112,000 cubic feet. The proposed configuration of the silos is not suitable for storage of wood chips, ground wood, or ground agricultural residues and energy crops. These biomass fuels have a tendency to bridge and will not feed in or out of the silos reliably. Pellets and briquettes have better flow characteristics and bridging is not a problem for these more processed forms of biomass fuels.

Exhibit 6 provides reported density for biomass fuels and Illinois coal. This information is needed to determine how much fuel can be stored in the proposed storage facility and how biomass use would affect fuel volume throughput in the system. On a per volume basis, biomass fuels range from less than 10% of that for Illinois bituminous coal for ground agricultural residues[1] to 75% for wood pellets.

[1] This includes corn stover, wheat straw, and herbaceous energy crops.

Exhibit 6 Solid fuel bulk density, energy content, and moisture content

Biomass	Bulk Density (lbs/ft^3)	Energy Content (Btu/lbs)	Moisture (%)
Round Bale Ag Residues	10	6,700	15
Chopped Ag Residues	4	6,700	15
Saw Dust	17	4,730	45
Bark	22	5,000	45
Ground Wood (Hog Fuel)	18	5,590	35
Wood Chips	18	4,730	45
Wood Briquettes	25	7,750	10
Wood Pellets	38	7,750	10
Switch grass Pellets	28	7,100	10
Corn Stover Pellets	28	7,100	10
Wheat Straw Pellets	28	6,880	10
Illinois Bituminous Coal	51	12,400	3

Estimates of the increase in the fuel volume throughput in the boilers at Plant Abbott are feasible using the published bulk density values in Exhibit 6 and the estimated fuel mass values for various cofiring or repowering scenarios in Exhibit 4. Exhibit 7 provides a preliminary estimate of the current fuel volume using coal and additional fuel volumes that would be used for the various scenarios. Biomass use represents a significant increase in fuel throughput for all scenarios.

Exhibit 7 Estimated increase in fuel volume throughput at Plant Abbott based on cofiring/repowering scenarios

	100% replacement			10% cofiring			20% cofiring		
Variable	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**
Current fuel volume (thousand ft3/year)									
Coal	1,147	1,529	3,822	115	153	382	229	306	764
Change in fuel volume (thousand ft3/year) with biomass use. Note: red bar indicates size of increase									
Ag residue	25,850	34,467	86,166	2,585	3,447	8,617	5,170	6,893	17,233
Switchgrass	25,850	34,467	86,166	2,585	3,447	8,617	5,170	6,893	17,233
Urban wood	6,060	8,080	20,200	606	808	2,020	1,212	1,616	4,040
Mill residue	6,661	8,881	22,202	666	888	2,220	1,332	1,776	4,440
pellets	2,496	3,328	8,319	250	333	832	499	666	1,664
Wood pellets	1,319	1,758	4,396	132	176	440	264	352	879

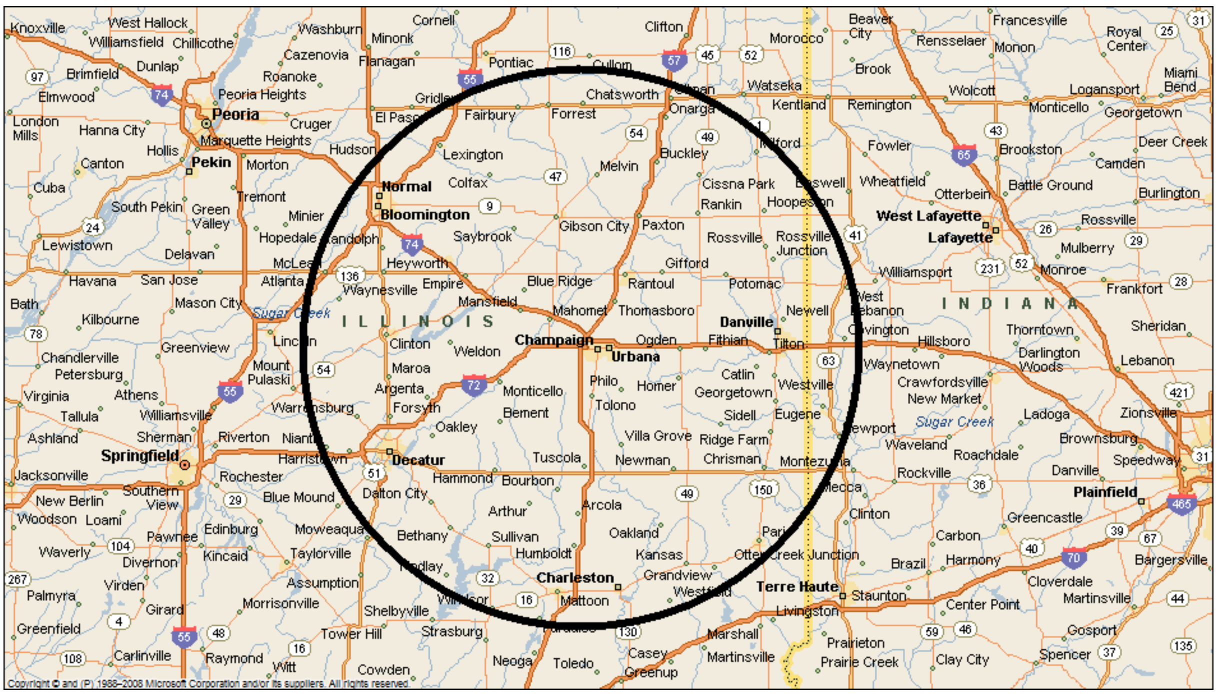
This project did not include a detailed analysis of the impacts of biomass cofiring or repowering at any of the boilers. The compatibility of biomass fuels with the conveyance, combustion and other system components needs to be evaluated as part of a more detailed engineering analysis. Some issues that could be encountered with wood fuel include bridging in conveyor and other handling components and proportion of fines in the fuel supply. A potentially more significant issue is whether corn stover or wheat straw will be compatible with the existing stoker grate system. Pellets have better flow characteristics, but they need to be kept dry to maintain cohesion and as with all fuels, ash and other chemical and physical traits are important. Appendix A provides published biomass composition data.

2. BIOMASS RESOURCE AVAILABILITY AND PRICING

2.1. Description of Fuel Supply Shed

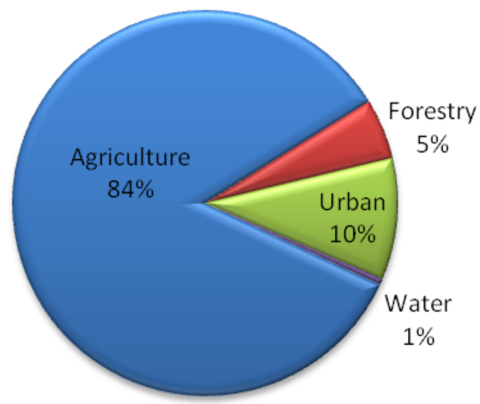
The biomass fuel supply shed around the University of Illinois at Champaign-Urbana is defined by a 50-mile radius which includes 21 counties in two states (Exhibit 8). The area has excellent state and interstate highway systems and is dotted with many small farming communities and three mid size cities (Champaign, Decatur and Bloomington, IL).

Exhibit 8 Map of biomass supply shed for Plant Abbott



The primary land use in the supply shed is agriculture with approximately 84% of the area under cultivation or in pasture (Exhibit 9). Forest makes up another 5% and less than 1% is covered by water. The rest of the land area is urban or transportation corridors.

Exhibit 9 Summary of land use in counties intersecting 50 mile radius around Plant Abbott



The availability of the biomass resource reflects the predominant land use in the region. The following subsections discuss agricultural, forest and urban biomass fuel resources in more detail.

2.2. Agricultural Crop Residue

There is approximately 6,833,756 farmed acres in the 21 county biomass fuel supply shed. This includes all acres within counties that intersect the 50 mile radius surrounding Plant Abbott. The total farmed acreage represents 84 percent of the total land area. Of this acreage 3,473,068 acres are in corn and wheat.[2] Most of the remaining agricultural land is in soy beans with small percentages in small grains, special crops, pasture, and the Conservation Reserve Program. Corn and wheat are of interest because after grain harvest both crops leave collectable amounts of stalks and leaves in the field, known as residues. Corn and wheat residues can be collected in large bales using standard farming equipment.

The amount of collectable corn stover generated each year is approximately 4,321,460 tons per year and for wheat straw is 173,830 tons per year[3]. Currently, there is limited or no collection of corn stover and wheat straw in the region. Total annual collectable agriculture residue production for the biomass supply shed is 4.5[4] million tons. Average corn stover residue production per acre is 4.16 tons, but assuming a 30%[5] collection rate the yield is lowered to 1.25 tons per acre. There is 3.4 million acres harvested for corn in the biomass supply shed. The average wheat straw production per acre is 2.66 tons. Using the same 30% collection rate as for corn stover the per acre wheat straw yield is 0.8 tons. There are approximately 67,000 acres of wheat harvested each year in the biomass supply shed.

It is anticipated that corn stover can be harvested over a 4 month period after grain harvest in late October through January. Land currently in constant corn (corn-corn rotation), production best suits

[2] Acres are based on 10-year averages of NASS data

[3] Based on 10-year average of production data from NASS. Corn is assumed to produce 1:1 by weight of residue to grain and wheat 1.5:1 (Wiselogel, Tyson, & Johnson, 1996).

[4] Tons are "as received" which is 15% moisture for stover and straw.

[5] The 30% residue recovery rate is based on (Lindstrom, 16 (1986) that shows 30% removal of residues is a sustainable practice that minimizes runoff and soil erosion.

this harvest window. Double cropped rotations such as corn-wheat will require a quicker harvest turnaround to allow for in-field planting operations. These double cropped production fields will require a 4 to 10 day corn stover harvest window in late October to mid November and a similar harvest window for wheat straw during the late June to mid July time frame.

Offsite storage and processing will be required because fuel will be required year-round, but can only be harvested during a limited harvest window. From 1 to 6 satellite storage depots in strategically located areas would be needed to minimize transportation costs and optimizes access to the processing facility and Plant Abbott. These depots will each hold 5,000-10,000 tons of baled material depending on the biomass needs, site acreage and topography. In addition it is anticipated that the feedstock processing facility will be contractually obligated to maintain a minimum operational reserve of up to 14 days worth of residue.

There is limited or no commercial operating experience that can provide local agricultural residue collection and transportation costs because corn stover and wheat straw are not currently collected in the area. The estimated cost of delivered residues[6] to a processing facility is expected to range from $44.50 to $68.50 a dry ton (Brechbill & Tyner, 2008). This cost is made up of harvesting, transportation, storage, equipment lease or operation, and profit. Most of the variation in cost is due to residue collection methods. On top of the delivered cost is the cost of processing. Tub grinding typically cost between $4 and $5 a ton while pelletizing (drying, milling, pelletizing), storage and delivery will add approximately $70 a dry ton to the fuel (Haase, 2009).

There will also be additional costs for storage of processed agricultural residues. Depending on processing logistics and the location of satellite storage of unprocessed agricultural residues approximately 14 to 21 days of processed storage should be located in conjunction with the processing site. This is only an approximate range; the amount of processed agricultural residue storage required for the Plant Abbott would need to be the focus of a more detailed assessment.

A concern for the use of crop residues is the development of contractual agreements with biomass suppliers, supply logistics, and processing. If the University is unable to develop long-term contracts with a feedstock processor and biomass suppliers it will be very difficult to establish a reliable supply of biomass that meets technical and delivery specifications. Without a guaranteed market for product most biomass processors will be hesitant or unable to put in a new processing facility or purchase new equipment and land. Biomass suppliers will also be hesitant or unable to develop a network of producers and satellite storage that is necessary to provide a consistent biomass supply.

2.3. Energy Crop Potential

University of Illinois

University of Illinois has conducted research on giant miscanthus and switchgrass on a 320-acre Energy Farm at South Farms. Based on field trials in 2005 and 2006, Dr. Frank Dohleman has shown switchgrass dry matter yields of about 5 tons/acre and miscanthus yields of 14 tons/acre. Current research emphasizes miscanthus because of its greater yield potential than other crops. Much of the research on miscanthus focuses on reducing the cost of regeneration. Miscanthus that produces large quantities of biomass is currently regenerated through rhizomes which are much more expensive to use than seeds. One approach is to develop equipment that increases the efficiency of regeneration with rhizomes and the other is to develop high yielding miscanthus that can be regenerated with seed.

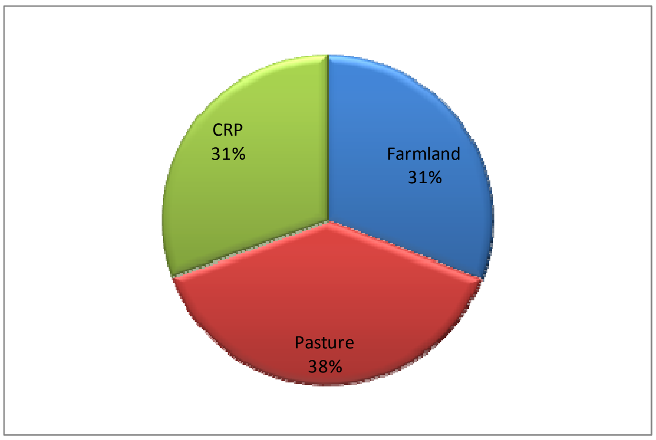
[6] Assumes a 50 mile one-way transportation distance.

Near-term Warm Season Grasses and Switchgrass

Warm season grasses and switchgrass can be used now to generate herbaceous biomass. These grasses are native to Illinois and Indiana and high biomass yielding varieties have been developed that grow well in the Plant Abbott biomass supply shed. Establishment and harvesting of switchgrass uses standard farm equipment and is similar to the establishment of typical pasture grasses.

In the 50-mile radius biomass supply shed there is approximately 522,000 acres of land suitable for conversion to warm season grasses and switchgrass. This acreage is either in low productive farm land, pasture, or the Conservation Reserve Program (CRP) (Exhibit 10). The type of land and the amount that farmers will convert to the production of energy crops is dependent on the financial return on energy crops vs. current use.

Exhibit 10 Current usage of land suitable for the production of herbaceous energy crops



A study by Purdue University estimates delivered prices for switchgrass between \$62.50 and \$68.50[7] (Brechbill & Tyner, 2008). This price includes profit, establishment and cultivation cost, harvesting, baling, storage and transportation. The amount of biomass that can be produced from warm season grasses or switchgrass is presented in Exhibit 11. Even at low land conversion rates and production levels it is possible that the biomass required from any of the Plant Abbott firing scenarios can be met with herbaceous energy crops.

There is an incentive program that may help encourage farmers to produce herbaceous energy crops for us in biomass power applications. The 2008 Farm Bill contains provisions for the Biomass Crop Assistance Program (BCAP) which is implemented through the Farm Service Agency (FSC) by the Commodity Credit Corporation (CCC). There are two provisions in BCAP. The first provision provides matching payments to certain persons or entities for the collection, harvest, storage, and transportation (CHST) of eligible material delivered to qualified biomass conversion facilities. The second provision is intended to assist agricultural and forest land owners and operators with the establishment and production of eligible crops including woody biomass in selected project areas for conversion to bioenergy.

[7] Assumes a 50-mile one way transportation distance.

The CHST provision was suspended by the CCC due to concerns about the provision's implementation and budget. New rules have been proposed, reviewed and the CCC has received comments. The disclosure and implementation of the new CHST rules is expected to occur by the end of September 2010. Farmers providing crop residues and dedicated energy crops should benefit from the CHST provision and receive additional payments above what is paid by the qualifying biomass facility. The second provision is specific for producers of dedicated energy crops. It provides crop establishment funding for producers in specific area approved for the production of energy crops. Approval primarily requires the development or existence of an approved bioenergy facility.

Exhibit 11 Potential production rates of biomass from energy crops in the biomass supply shed

% Land Converted	Tons per acre		
	3	4	5
10%	156,555	208,740	260,925
25%	391,388	521,850	652,313
50%	782,775	1,043,700	1,304,625
75%	1,174,163	1,565,550	1,956,938
100%	1,565,550	2,087,400	2,609,250

Qualifying for BCAP provisions requires some organization and effort by the biomass power facility, and biomass producers, suppliers, and processors. A local champion must sell the participation in the BCAP program to farmers (producers). Such a champion can come from Plant Abbott or the University, but the chances of a champion coming from the private sector is minimal without the incentive of a long-term contract to provide services or feedstocks.

2.4. Wood Biomass

Local Biomass Supply Shed

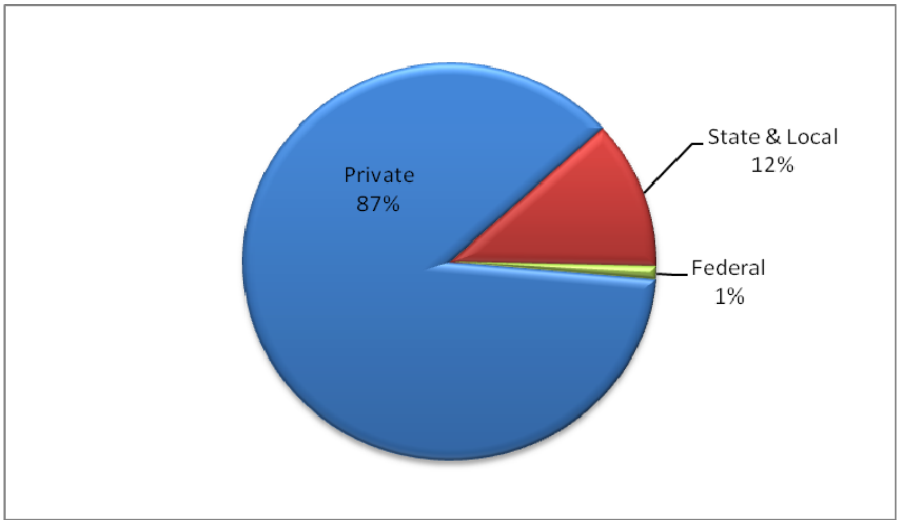
Only 412,000 acres of the biomass supply shed is covered in forest which represents about 5% of the area. Most of this forest is owned by private landowners with small percentages managed by federal, state, and local governments (Exhibit 12). These forests have value to their owners for wind rows, soil protection, recreation and aesthetics, and are not typically considered as commercial forest. The forests in the biomass supply shed consist of 38.5 million green tons[8] of merchantable trees that are growing at a rate of 1.75% annually producing 529,000 green tons of collectable wood that can be harvested sustainably each year[9]. This quantity includes commercially valuable, low-grade and noncommercial trees. This material is not currently harvested and would take additional investment in logging capacity and equipment to procure and an active effort to enlist forest landowners to actively manage their land.

[8] A green ton is assumed to be 45% moisture by weight.

[9] This is above the 386,000 tons that are commercially harvested each year from the supply shed.

Forest harvest in the area is 386,000 green tons a year which produces 44,400 green tons of collectable harvest residues suitable for use as fuel wood. In addition, 90,000 green tons of collectable wood from land clearing activities is produced annually. Currently these potential sources of fuel wood are piled and burned or left on the ground to decompose because of a lack of market and local loggers do not have the resources to economically collect and process the wood.

Exhibit 12 Forestland ownership in the biomass supply shed



There is little forest industry in the biomass supply shed and at best only two or three small saw mills were in operation during the collection of the latest US Forest Service Timber Production Output (TPO) data in 2008. The severe economic down turn in the forest products industry may have caused these mills to close or drastically reduce production. In 2008 there was 85,000 green tons of mill residues produced in the supply shed. These mill residues consist of chips, scraps, saw dust, and bark. All mill residues currently have markets and are sold as pulp chips, biomass fuel, and to produce mulch. Saw mills sell their residues on the open market or short-term contracts. It is possible the Plant Abbott can compete for mill residues by paying competitive prices and offering other attractive contract terms.

Exhibit 13 Potential forest and mill biomass resources in the biomass supply shed

Forest and Mill Resource	Production (Green tons/year)
Currently Produced	
Harvest Residues	44,400
Land Clearing	90,000
Mill Residues	85,000
Subtotal	219,400
Potential for Expansion	
Sustainable Forest Harvest	529,000
Total	748,400

At the present time fuel wood harvest is limited due to existing markets and lack of technical and equipment resources of local loggers necessary to economically collect and process potential fuel wood. In addition, land owners in the fuel supply shed may have limited interest in harvesting their forest because of how they value the resource. However, with the creation of a viable market for fuel wood in the biomass supply shed the current market, technical and equipment barriers can be easily over come. Landowner preferences for managing land for recreational and uses other than commercial timber production are more difficult to overcome; and logging operators may want a multi-year contract to invest in new harvest and chipping equipment to support a new fuel wood demand.

Cost estimates for harvest residues and land clearing (expressed as dirty chips) and mill residues are presented in Exhibit 14. These cost estimates are based on the results of a telephone survey of 22 forest product facilities in southern Indiana, Illinois, and Kentucky conducted the third quarter of 2009, and include transportation for a 40-mile one-way delivery. The actual cost paid by Plant Abbott for fuel wood from these resources will reflect an increase in demand caused by Plant Abbott entering the local fuel wood market.

The available of fuel wood expressed in Exhibit 14 reflects the total potential annual amounts of wood resource in Exhibit 13. In practice it is highly unlikely that all the collectable forest residues and wood from land clearing will be collected, but it does provide an upper limit on the potentially available forest derived fuel wood resource.

Exhibit 14 Price estimates for potential forest derived fuel wood resources in the biomass supply shed

Woody Biomass Type	Available Tons/ Month	Available MMBtu/ Month	Delivered Cost ($/Ton)			Delivered Cost ($/MMBtu)		
			High	Low	Weighted Average	High	Low	Weighted Average
Mill Residues	7,083	60,208	$40.00	$7.64	$15.42	$4.71	$0.90	$1.81
Dirty Chips	11,200	95,200	$26.50	$10.00	$13.13	$3.12	$1.18	$1.54
Total/*average*	18,283	155,408	$31.73	$9.09	$14.02	$3.73	$1.07	$1.65

With the small forest industry in the biomass supply shed most of the potential woody resource is from urban wood from tree service and wood products such as pallet recycling. Based on per capita wood waste generation and disposal factors, the estimated local urban wood resource generated each year within the 50 mile radius surrounding Plant Abbott is 52,250 tons. Almost half, 25,000 tons, of the urban wood is taken to private facilities that convert a majority of it into mulch. Of the material taken to county landfills around 21,400 is processed and the remaining 5,850 tons goes into the landfills (Wiltsee, 1998) . Most urban wood processing consist turning the wood into a mulch using a tub grinder or vertical wood hog. The wood mulch is used as mulch, bulking agent for compost, land fill topping material, and is suitable for use as fuel wood. The processed urban wood generally has a market and sells for $55 to $60 a ton FOB. Transportation cost for wood mulch typically is around 12¢ ton/mile with a minimal charge of $4.80[10] a ton.

Local mulch producers from urban wood are the area landfills within the biomass supply shed. Mulch is the primary product and most is sold or given away on a first come first serve basis or short-term contracts. Other sources of wood chips are local tree services and arborists. By paying

[10] Typical minimal transportation charge for wood fuel is a 40-mile one way delivery. At 12¢ ton/mile that is $4.80 a ton.

competitive prices and offering attractive contract terms the University should be able to secure some of its biomass supply from local urban wood processors.

Exhibit 15 Landfills near Champaign/Urbana

Facility	Location	County
Landscape Recycling Center	1210 E. University Ave. Urbana IL	Champaign
Rantoul Landfill	331 S. Tanner, Rantoul	Champaign
Livingston Landfill	Pontiac, IL	Livingston
McClean County Landfill	Bloomington, IL	McClean
Illinois Landfill Inc.	CR4100, North Hoopeston, IL	Vermillion
Thomas Landfill #1	55 Greenwood Cemetery, Danville	Vermillion
H&L Disposal Landfill #3	Brickyard Rd., Danville	Vermillion

A regulatory issue that will affect suppliers of wood biomass within the Plant Abbott supply shed but also in the greater region is the identification of Emerald Ash Borer infestations in Illinois, Indiana and surrounding areas. Emerald Ash Borer (EAB) is a small, (1/2-inch long, 1/8-inch wide) metallic green beetle native to Asia. Discovered in Illinois in 2006, it has since spread throughout the Midwest US. EAB feeds only on members of the Fraxinus genus or true Ash trees. If trees go untreated, the death rate is 100 percent. Currently, Federal regulations restrict the movement of untreated hardwood in several states including Illinois and Indiana. Untreated hardwood[11] quarantines are enforced by the USDA through the Animal and Plant Health Inspection Service (APHIS) with assistance from the US Forest Service (USFS) in conjunction with state agencies. In Illinois, the lead agency for EAB is the Department of Agriculture and in Indiana it is the Department of Natural Resources.

Quarantines are placed on a county level and movement of untreated hardwood within the state is regulated by the appropriate state agency with oversight from APHIS. Movement of hardwood across state lines is regulated by APHIS with the assistance of USFS. Within Illinois most of the northern part of the state is under EAB quarantine (Exhibit 16). This includes wood from the Chicago metropolitan area. EAB was discovered in Champaign County September 2010. Champaign County and will be under EAB quarantine by November 2010. There are no restrictions to bring fuel wood in from outside the EAB quarantine area[12].

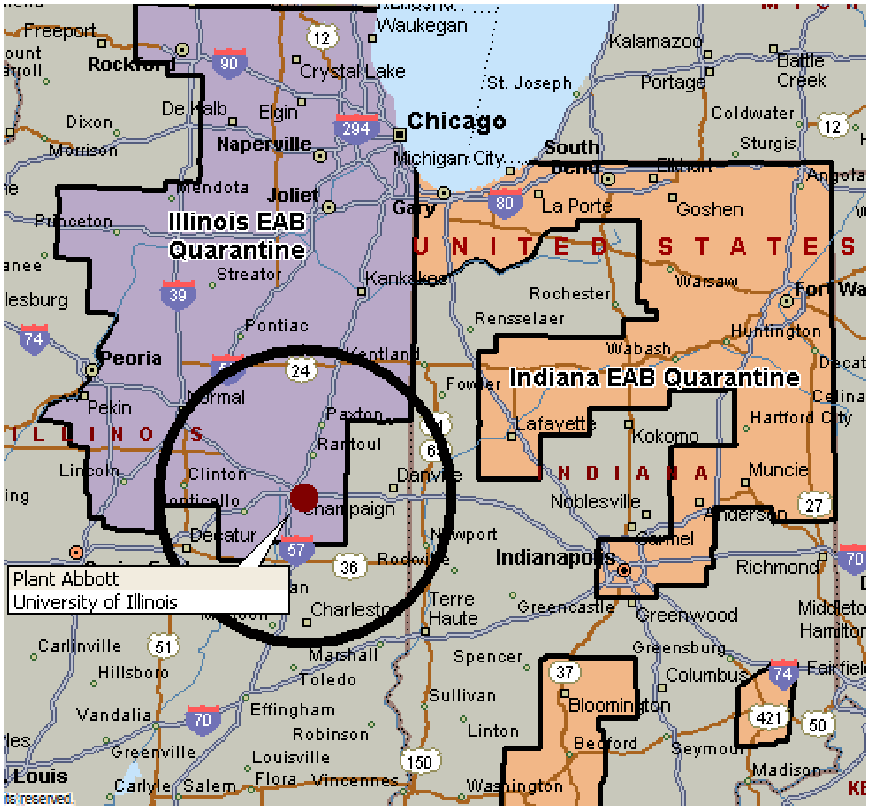
While preferring for wood use to be local, the state of Illinois allows the movement of wood within quarantined areas[13]. This means that wood resources within the EAB Illinois quarantine area can be transported to Plant Abbott and used as fuel. To transport wood within Illinois it is advisable to develop a compliance agreement with the Department of Agriculture to insure that all transportation, storage, and wood handling requirements are understood and up held.

[11] All ash logs and all hardwood fuel wood/firewood from EAB quarantine areas are required to undergo treatment T314-a, specifically, heat treatment at 71.1ºC for 75 minutes.

[12] Personal communications with Jeff Cath APHIS Illinois EAB 847 699-2400 x3

[13] Personal communications with Juliann Heminghouse of the Illinois Dept. of Ag. 217 785-5575

Exhibit 16 Emerald ash borer quarantine locations



To import wood from Indiana requires the wood to be certified by or have a special “limited material” permit from APHIS in Indiana. Wood can be certified for import throughout the year if it is less than 1” in two dimensions. To be certified the wood processing facility need to pass a quarterly inspection to verify fuel wood meets the size requirement based on a sieve test. Another option is for the fuel wood provider to obtain a limited material permit from the APHIS office in Indiana which allows wood to be imported into Illinois between October 1st and March 31st based on a compliance agreement between Plant Abbott and the Illinois Department of Agriculture on the use, storage, and handling of the wood. Wood imported from Indiana under the limited material permit does not have to meet the particle size constraints for certified wood[14].

[14] Personal communications with Christopher Degdan APHIS Indiana EAB 765 497-2446

Regional

There is a forest products industry in southern Illinois and Indiana which is dominated by small specialty saw mills. There are a few large saw mills in Indiana and the Domtar pulp mill in Hawesville, KY. The forest products industry generates $2.5 billion annually in Indiana and $2 billion per year in Illinois. A summary of the results of a telephone survey of 22 forest product facilities in southern Indiana, Illinois, and Kentucky conducted the third quarter of 2009 is presented in Exhibit 17. An additional transportation cost of $12/ton for delivery provides an indication of the price of fuel wood from this area. Delivered costs range from $38 to $23 per ton for fuel wood with a weighted average of $28 per ton. Fuel wood prices have varied little since the survey and these prices are within reason.

Exhibit 17 Wood fuel pricing in southern Indiana and Illinois third quarter 2009

Woody Biomass Type	Available Tons/ Month	Available MMBtu/ Month	Delivered Cost			Delivered Cost		
			High $/Ton	Low $/Ton	Weighted Average	High $ /MMBtu	Low $ /MMBtu	Weighted Average
Clean Chips	1,062	9,028	$52.00	$32.00	$35.51	$6.12	$3.76	$5.35
Saw Dust	2,623	22,292	$38.00	$17.00	$26.53	$4.47	$2.00	$3.12
Scraps	2,174	29,561	$32.00	NA	$21.83	$2.35	NA	$1.60
Dirty Chips	5,302	45,067	$38.50	$24.00	$30.98	$4.53	$2.82	$3.64
Bark	5,654	48,059	$37.00	$22.00	$25.13	$4.35	$2.59	$2.97
Total/*average*	16,815	154,007	$37.93	$19.64	$27.42	$4.14	$2.14	$3.07
Summary by fuel quality category (bark and dirty chips are fuel wood)								
Pellet Quality	5,859	60,881	$38.31	$21.32	$27.96	$3.69	$2.51	$3.36
Fuel Wood	10,956	93,126	$37.73	$22.97	$28.06	$4.44	$2.70	$3.31
Total/*average*	16,815	154,007	$37.93	$19.64	$27.42	$4.14	$2.14	$3.07

All mill residues in the region are currently sold. However, mill residues tend to be sold on short-term contracts or on the open market, so much of the fuel quality mill residues can be obtained for competitive pricing and purchase terms.

There are two large cities in the region. Chicago is 140 miles from Champaign/Urbana and Indianapolis is 120 miles. Other cities of note are:

- Danville, IL – 34 miles
- Decatur, IL – 53 miles
- Bloomington/Normal, IL - 57 miles
- Terre Haute, IN – 88 miles
- Springfield, IL – 90 miles
- Lafayette, IN – 90 miles
- Peoria, IL – 93 miles

All these cities/metropolitan areas produce urban wood waste. The smaller cities produce comparable amounts of urban wood waste as Champaign/Urbana. Chicago produces approximately 2 million tons/year of urban wood waste and Indianapolis 360,000 tons/year. The demand and FOB cost of this urban wood is similar to that in Champaign/Urbana. Assuming similar transportation cost and delivered price for regional urban wood waste derived fuel wood is $61.36/ton from Decatur to $70.60/ton from Chicago.

All regional wood should be transported after processing, so there will be a need for screening, processing, and storage at a location in the Champaign/Urbana area to reduce supply interruption risk. This storage, screening, and any additional processing will add to the cost to these biomass resources. Storage, screening, and local transportation add additional cost to the delivered biomass fuel supply depending on the configuration, scale and duration of off-site storage and processing needs.

2.5. Pellet Fuels

Wood pellets are a highly processed biomass fuel. Densifying (pelletizing) affords a higher energy density and flow characteristics similar to that of fluids. The production of wood pellets requires the use of dry wood (10% to 15% moisture content) that has been reduced to fine "saw dust" particles. The wood is either forced through an extruder or a die at very high pressures. In a typical processes, the friction and pressure creates heat which cause the lignin component of the wood to melt and bind the wood particles together without the need for any other binding or adhesive material. Most wood pellets produced in the U.S. are premium grade wood pellets for use in the residential market or export to Europe. Wood pellet grades are based on ash content. Premium grade pellets have less than 1% ash content, standard grade contains up to 3% ash, and industrial grade contains up to 5% ash.

There are some pellet fuels produced in the U.S. that are not made from wood. Pelletizing technologies have evolved to produce pellets from herbaceous materials and paper. These pellets have higher ash content than wood pellets and tend to be used in commercial, industrial, or specialized applications.

There is no pellet production within the Plant Abbott biomass supply shed. The closest pelletizing facility is American Pellet Supply (APS) located a 125 miles away in Carlisle, IN. APS makes a non-wood fuel pellet along with animal food and bedding pellets. According the President of APS, Mike Myers, the composition of the fuel pellets can be altered to match the client's need. Their stock fuel pellet consists of cellulosic material from soy bean stubble, corn stover and paper mixed with about 20% coal. Wood pellets or pellets consisting of corn stover or other herbaceous material can be produced if that is what the customer requires. APS ships fuel pellets in bulk by truck and Mr. Myers claims to have produced customized fuel pellets for use in utility co-fire tests. In addition, APS is looking for opportunities to expand their operation, so there may be opportunity to develop a pelletizing operation closer to Champaign/Urbana. All other operational pellet facilities are at least 240 miles[15] away and were not considered for this study.

It is anticipated that the Btu content of herbaceous pellets will be approximately 10% lower than that for wood pellets[16]. APS did not provide a price for pellets because it will depend on the specifications provided by Plant Abbott. However, the pelletizing process cost around $70/ton and by adding feedstock cost ($4 for corn stover) an estimated price of $115/ton FOB at the plant is calculated. Using 12¢ ton/mile for one-way delivery of 125 miles the potential delivered cost of corn stover pellets directly to Plant Abbott is $130/ton. Offsite storage that protects the pellets from the weather will add to the cost. Pellet storage in a modified grain elevator should be minimal.

An alternative that APS may be able to provide are briquettes. Mr. Myers mentioned that APS has the ability to produce briquettes that are suitable for use in grate boiler systems that are designed to take chunk coal. He claims that briquettes are cheaper to make and are an economical option for a commercial, industrial, or utility user of coal who is interested in converting to use biomass.

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[15] Pile Pellets in Griggsville, IL is closer, but this facility may be closed, the telephone number was disconnected.

[16] HHV of wood is generally 8,400 Btu/lbs while for corn stover and switchgrass it is around 7,600 Btu/lbs.

2.6. Biomass Resource Summary

Exhibit 18 summarizes the technical potential to recover biomass resources and delivered costs within the Champaign/Urbana area. Exhibit 18 costs do not include any additional storage and handling at a local processed storage location near Plant Abbott. All prices reflect prices currently received. For those fuels with markets, the University of Illinois may have to pay a higher price to secure the fuels from their current markets.

The least expensive fuel is saw mill residues from the local biomass supply shed followed by mill residues from southern Illinois and Indiana. The amount of regional mill residues reflects the production from the 22 small mills that were surveyed. To maintain a consistent supply of saw mill residues will either require the services of a wood fuel aggregator or much of the attention of a fuel supply expert at Plant Abbott to coordinate deliveries from numerous small mills. To capture a sufficient quantity of mill residues to supply all but the smallest Plant Abbott firing scenarios will be a challenge. This material is currently nearly completely utilized. Most is currently sold under short term contract or verbal agreement with the 22 sawmills identified in the region and sustainability of supply is always an issue.

The quantity of forest residues generated from the limited amount of commercial forest harvest, forest land clearing and thinning is hypothetical. Currently little or none of this material is collected or utilized. Current logging and land clearing companies are small and do not have the experience and equipment to collect and process harvest residues and land clearing wood. Reconfiguring logging operations to include residue collection and harvest may be feasible on a small scale in the region, but it would take a significant outreach effort to the logging community.

Additional wood resources can be procured from local and regional urban wood. Most urban wood in the area is processed for use as mulch. As with the saw mill residues that also have an existing market, it is possible for Plant Abbott to secure fuel from the urban wood resources. However, it will require paying competitive prices. Additional wood fuel can be also procured from the numerous urban areas, in particular Chicago and Indianapolis. Between mill residues and urban wood Plant Abbott should be able to secure sufficient wood fuel supply quantities for several biomass firing scenarios, but the numerous small suppliers will require a dedicated coordination effort to secure a reliable, high quality and economical fuel supply. This should be factored into any economic analysis for the project.

Exhibit 18 Biomass supply potential and delivered cost to a local storage facility in the Champaign/Urbana area

Biomass Feedstock	Amount (Tons)	MMBtu/ Truck	Low Price Estimate		High Price Estimate	
			$/ton	$/MMBtu	$/ton	$/MMBtu
Resources within counties intersecting 50-mile supply shed						
Agricultural Residues	4,321,460	335	$48.50	$3.62	$73.50	$5.49
Switchgrass	2,609,250	335	$66.50	$4.96	$73.50	$5.49
Forest Fuel Wood	219,400	280	$9.00	$1.07	$31.73	$1.65
Urban Wood Local	46,400	280	$59.80	$5.34	$64.80	$5.79
Biomass Supply Shed 50-mile radius [1]	7,196,510	316	$58.45	$4.66	$70.88	$5.61
Regional resources						
Urban Wood	2,360,000	280	$61.30	$5.47	$70.60	$6.30
Mill Residues - Fuel	132,000	258	$22.97	$2.70	$37.73	$4.44
Corn Stover Pellets	NA	355	$130.00	$9.15	$157.50	$11.09
Wood Pellets	NA	388	$109.80	$7.08	$129.80	$8.37

[1] MMBtu/truck and all price estimates for Biomass Supply Shed are weighted averages.

Agricultural residues represent the largest potential source of biomass fuel available to Plant Abbott. While there isn't an existing demand for agricultural residues the price to obtain it as a biomass fuel will depend on local collection costs, farm owner/operator revenue objectives and hauling, storage and processing requirements for the available supply.

There are multiple issues with using agricultural residues that must be factored into a final decision to develop a Bioenergy project at the site:

1. Local farmers will need to change their current farming practices to include residue collection. This will require marketing the idea to the local farm community and making it financially appealing. Very little if any of this material is currently utilized for energy. There are also technical issues associated with ensuring that the material is consistent and of sufficient quality to be used as a boiler fuel. Although outside the scope of this effort, these issues will need to be adequately addressed to protect fuel processing, handling and firing systems.
2. Another supply issue is the necessity to store the raw biomass and coordinate delivery and processing. Depending on space availability and on-site processing objectives, baled agricultural residues will need to be destringed, broken up, sized and stored for firing as needed. This will require either the processor to act as an aggregator and provide this service to Plant Abbott or for Plant Abbott to have personnel to provide agricultural residue delivery coordination.

Near-term dedicated energy crops have the second highest potential to provide locally produced biomass fuel. Many of the issues associated with agricultural residues will have to be addressed in the promotion of dedicated energy crop production. Local farmers will have to be convinced that conversion of land suitable for production of energy crops is worthwhile. This will take marketing and providing suitable financial incentives. Energy crops will also have the same raw biomass storage and logistical issues to address as does the use of agricultural residues. Recruiting suppliers and establishing crops on a scale sufficient to support most biomass options at Plant Abbott is a multi-year process.

Pelletized fuels are the most expensive fuel resource, but they have many advantages that may be worth the additional cost depending on the economic constraints that the University of Illinois may have for a biomass cofiring or repowering project. The pellet manufacturer assumes the raw biomass supply and delivery risk by contracting to deliver a final pellet fuel product. Pellet fuels have a higher energy content to weight ratio than other biomass fuels, pellet characteristics are more consistent from load to load[17], are stable in storage[18], easier to handle, and have fluid like flow characteristics. They can also be sized and shaped to be compatible with the end-users specific needs. The higher energy density also means less truck traffic to deliver fuel and potentially greater on site storage of fuel through the use of silos at the Plant Abbott location. In addition, dealing with one, or only a few, fuel providers make supply logistics easy. This option has the lowest overhead in terms of fuel supply procurement and management for Plant Abbott staff.

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[17] Energy content, moisture content, ash content, and particle (pellet size)

[18] Pellets a stable as long as moisture is minimized.

3. BIOMASS BARRIERS AND OPPORTUNITIES

There are several barriers and opportunities for biomass use based on the biomass availability and supply logistics, storage and processing options and the combustion technology at Plant Abbott.

3.1. Biomass Resource Availability

Biomass supply shed agricultural residue quantities are sufficient enough to provide adequate fuel for all firing scenarios. The land base suitable to produce herbaceous energy crops in the biomass fuel supply shed is large enough even at a 10% participation to produce enough fuel for all firing scenarios.

The only available wood resource within the fuel supply shed is urban wood. Published data indicate there may also be small quantities of sawmill residues available, but current mill operating status within the supply shed is not confirmed. The local production of mulch has competing markets and is only sufficient enough to provide fuel for the lowest biomass firing scenario. Regionally there are adequate supplies of urban wood and saw mill residues for all firing scenarios, but would require long trucking distances and competitive pricing/contract terms.

3.2. Feedstock Quality

While it is beyond the scope of this study to conduct a detailed local fuel supply composition analysis and evaluation of impacts on the Plant Abbott combustion systems, the compatibility of crop residues and herbaceous energy crops with stoker grate systems used at Plant Abbott needs to be further investigated (Appendix A provides published data on biomass feedstock traits that can affect boiler systems). Processed corn stover and wheat straw can be “fluffy” and particles could float over stoker grates, interfering with effective combustion. Also the proportion of fines in wood fuel sources needs to be evaluated for compatibility with stoker grate systems. Depending on the fuel specifications at Plant Abbott, pellet fuels and potentially briquettes would likely have favorable handling and combustion characteristics.

3.3. Feedstock Supply Logistics

Cofiring or repowering using agricultural residues such as corn stover and wheat straw or herbaceous energy crops such as switchgrass present the following challenges:

- Lead time required to recruit farm owner/operators, baling contractors and processing and storage contractors may be a multi-year process;
- Lack of local familiarity with baling, storage and processing practices for biomass fuels;
- Because University of Illinois cannot make multi-year supply contracts, it will be difficult to;
    - Convince farmers to collect residues or grow energy crops or
    - Attract suitable biomass processing/aggregators to the area that are needed due to limited current supplier network and need for satellite storage yards;
- Agricultural residues and/or herbaceous energy crops will require 6 to 9 months of satellite storage of baled material before processing due to the limited harvest window; and
- It may be difficult to organize local farmers to apply for benefits from the Biomass Crop Assistance Program without a local champion.

The fuel supply challenges for wood and pellet fuels are different and less significant:

- Wood and wood pellets as fuels are well understood and have a long history of use in boiler systems in the U.S.;
- Pelletized agricultural residues are not widely produced or used for fuel in the U.S. or elsewhere;
- Limited local availability of wood biomass or pellet fuels can add significantly to delivered fuel supply costs and long truck hauls increases risks of supply interruptions; and
- Requirements for satellite storage of processed fuels are more limited because these materials can be produced on a nearly year-round basis; cofiring rate can be turned down if there are short-term supply interruptions.
- EAB quarantine areas in the region will affect movement of hardwoods, but the State of Illinois permits movement of wood within quarantined areas. Therefore, resources within the EAB Illinois quarantine area can be transported to Plant Abbott and used as fuel. Champaign County will be an EAB quarantine area by November 2010. A compliance agreement may be needed with the Illinois Department of Agriculture. A special permit may be needed to import wood from the State of Indiana and although some seasonal restrictions apply, if wood is processed to 1 inch minus in all directions, those seasonal restrictions on imports can be avoided.

Common challenges to all biomass fuel sources include the limited local supply infrastructure. Due to the lack of current biomass fuel demand, few contractors have experience and equipment needed to supply biomass fuel at quantities needed for cofiring or repowering.

3.4. Biomass Fuel Storage and Delivery

The fuel storage and delivery issues differ significantly between agricultural residue, wood fuels and engineered fuels such as pellets and briquettes. These issues can be broken down into off-site and on-site storage issues, and truck delivery.

Off-site storage and processing. The limited harvest window for harvesting crop residues or herbaceous energy crops will require off-site bale storage of between six and nine months of facilities at off-site satellite storage sites. This form of storage will be required regardless of the scale of the cofiring or repowering project. In addition, offsite processing and storage of approximately 14 to 21 days of processed fuel will be required at a location that will need to be reasonably close to Plant Abbott to reduce supply interruption risk. Local storage adds additional processing, screening, storage and local transport costs to the biomass supply delivered. Feedstock processing and supply could be located on University lands in the Champaign/Urbana area. This will likely require a multi-year planning process.

Wood fuel and pellet fuel off-site processing and storage is not required in the same quantities as agricultural residue if at all, because these materials are available on a year-round basis and are generally speaking ready to fire as they are produced, with the exception of requirements for screening and wood fuel grinding to reduce the presence of oversize particles for wood fuels.

The amount of off-site processed fuel storage needed depends in part on tolerance for supply interruptions; for a repowering project at Plant Abbott, where nearly all the available plant capacity is utilized and there is limited on-site fuel storage, off-site processed fuel storage is imperative. For a cofiring project where Plant Abbott could substitute coal for biomass fuels for short periods, the amount of off-site storage is less crucial.

On-site storage. The space available on-site at Plant Abbott restricts biomass firing options that are feasible. The challenges differ depending on the fuel type and level of biomass fuel use.

The conceptual design under consideration for additional solid fuel storage capacity at Plant Abbott currently includes the use of silos. Silo storage would not be advisable if green wood fuel or herbaceous wood fuels would be used due to issues with bridging. Pellet fuels may be stored in silos because they have appropriate flow characteristics. This is the case regardless of the level of cofiring or repowering.

Biomass cofiring at the 10 percent level for one or all boiler units should be feasible even with the limited amount of current storage space available, with appropriate engineering design and equipment specifications. Approximately 40 to 60 tons of biomass fuel would be required per day. Some form of separate on-site biomass storage bin would be advisable, even if less sophisticated than the plan under consideration at Plant Abbott. On-site solid fuel storage bins required to support 10 percent cofiring can occupy a relatively small footprint (pending a more detailed evaluation of the systems available from vendors) and unloading can be accomplished with self-unloading trailers into the solid fuel storage bin and a small reclaim system used to transfer the biomass fuel to a conveyor.

On-site storage would be a more significant issue that for 20 percent cofiring. Fuel demand for cofiring 20 percent cofiring at all units using unprocessed wood fuel approaches that for some repowering scenarios. While using agricultural residues for a 20 percent cofiring scenario would present less of an issue with storage, it still faces the issues with feedstock quality, supply and contracting logistics that make it a less likely fuel source than wood. There is a distinct advantage for this scenario over repowering however; plant operators could just cofire at a lower level in the event of supply interruptions or other logistical and cost issues.

Repowering one or more units presents challenges in terms of fuel supply reliability, contracting logistics, fuel supply costs and feasibility of on-site storage. Daily biomass fuel use for repowering would average from approximately 130 to 260 tons of fuel per day depending on the boiler unit and fuel used. The current receiving and on-site storage area required will present operational challenges. Walking floor trailers take time to unload and for high biomass firing scenarios there could be traffic flow issues due to the number of trucks that may have to unload at peak periods to deliver adequate fuel. One of the proposed silo-based solid fuel storage units would have enough total capacity to support one to two days of wood pellet fuel storage for conversion of one boiler unit to pellet fuels. Silos would not support use of unprocessed wood fuel, agricultural residues or energy crop-based fuels.

Repowering all units requires an average of approximately 430 to 640 tons of biomass per day depending on the fuel used. This presents significant logistical, technical and siting difficulties. Repowering at any unit at Plant Abbott would require nearly total system reliability with little margin for fuel supply interruption. Meeting this would likely significantly increase system and fuel supply costs. The proposed solid fuel storage silos, if constructed, would likely have enough total capacity to store several days of pellet fuel supply, if supply reliability, cost and receiving issues were resolved.

Truck Delivery. Due to the lower energy content of biomass fuels compared to coal currently being delivered to Plant Abbott, truck traffic will increase. Trucks can carry up to 25 tons of solid fuel. Using vans with walking floors will allow loads of biomass to be delivered using the current method used for coal[19]. The number of truck deliveries will depend on the firing scenario and biomass Fuel type.

[19] Assumption is the 80,000 tons is local weight limit on trucks.

Exhibit 19 provides an indication of annual truck traffic to deliver biomass fuels[20]. The Coal row provides an estimate of how many trucks it takes to deliver coal necessary to deliver the amount of coal proposed to be displaced by biomass. The biomass resource rows indicate the estimated increase in the number of trucks required to deliver the necessary biomass required to meet the fuel firing scenario (e.g., a 100% conversion of boiler unit #5 from coal to wood pellets results in an increase of 704 (1,874 truckloads of pellets minus 1,170 truckloads of coal) trucks per year.

Exhibit 19 Truck traffic for combinations of fuel firing scenarios at Plant Abbott

	100% conversion by boiler #			10% cofiring by boiler #			20% cofiring by boiler #		
Variable	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**	**#5 or #6**	**#7**	**Total**
Current estimated trucks/year									
Coal	1,170	1,559	3,899	117	156	390	234	312	780
Estimated increase in annual truck deliveries by biomass scenario									
Ag residue	990	1,320	3,301	99	132	330	198	264	660
Switchgrass	990	1,320	3,301	99	132	330	198	264	660
Urban wood	1,425	1,900	4,749	142	190	475	285	380	950
Mill residue	1,641	2,188	5,470	164	219	547	328	438	1,094
Corn stover pellets	870	1,160	2,901	87	116	290	174	232	580
Wood pellets	704	939	2,347	70	94	235	141	188	469

Biomass repowering would involve an increase in annual truck traffic; most cofiring scenarios involve a significantly lower increase, especially if pellet fuels are used.

3.5. Summary of Key Barriers and Opportunities

Cofiring at 10 percent for one or all three boilers at Plant Abbott using wood fuel, pellet fuels and potentially briquettes (if suitable supplies that meet feedstock specifications) appears to be the most likely biomass scenario. Demand can be met with relatively low risks due to supply interruption, there is familiarity with wood fuel use stoker grate systems, and the fuel storage and contracting logistics can be managed. Pellets or briquettes from local materials may limit capital investment requirements if the fuel costs and specifications are appropriate for Plant Abbott.

Agricultural residue or herbaceous energy crops appear to be a challenging feedstock for repowering or cofiring due to the characteristics of the fuel, supply contracting needs and the lack of familiarity with using herbaceous fuels in stoker grate systems (or any combustion facilities in the U.S.).

Repowering one or more units with biomass presents risks in terms of supply reliability and cost; obtaining fuel at these levels reliably will require a dedicated fuel manager (or most of the time of an existing staff member), will require obtaining fuel supplies from outside the local supply area, and will present challenges in terms of on-site storage and potentially truck traffic flow issues.

Cofiring at a 20 percent level at one or more units offers some potential to alleviate some of the reliability needs over a repowering scenario; however on-site storage and fuel cost will remain an issue if Plant Abbott desires to reliably maintain cofiring at the 20 percent level.

[20] Exhibit 17 is based on fuel usage estimates from Exhibit 4.

4. REFERENCES

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Wiltsee, G. (1998). *Urban Wood Waste Resources Assessment.* Golden: National Renewable Energy Laboratory NREL/SR-570-25918.

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Appendix A
Feedstock Property Table

Name	Ash %	C %	H %	O %	N %	S %	HHV MEAS kJ/g	HHV MEAS Btu/lb
Hickory	0.73	47.67	6.49	43.11	0	0	20.17	8,670
Maple	1.35	50.64	6.02	41.74	0.25	0	19.96	8,580
Poplar	0.65	51.64	6.26	41.45	0	0	20.75	8,920
White Oak	1.52	49.48	5.38	43.13	0.35	0.01	19.42	8,350
Wheat Straw	8.9	43.2	5	39.4	0.61	0.11	17.51	7,530
Corn Stover	5.58	43.65	5.56	43.31	0.61	0.01	17.65	7,590
Switchgrass	8.9	46.7	5.82	35.6	77	0.19	18.02	7,750