ESTABLISHING BIOMASS MARKET STANDARDS AND PRICING
FY 2010

The Renewable Fuel Standard program as expanded under the Energy Independence and Security Act of 2007 (RFS2) mandates the blending of 36 billion gallons of renewable fuel, including 16 billion gallons of cellulosic biofuel, by 2022. Achieving this obligation will require massive amounts of biomass to complement traditional corn-based ethanol and biodiesel. A recent study found several knowledge gaps among farmers and ranchers who would potentially supply biomass as a feedstock for processing. Many producers are not aware of biomass market opportunities, pricing, preferred biomass harvest timing, product quality standards, or methods to reduce environmental impact. A larger void at the national level is the lack of quality standards as well as ensuing premiums and discounts which facilitate market activity. Further, biomass is primarily secured by private contracts at present and the industry lacks transparent pricing information.

The purpose of the project was to address these shortcomings by identifying key biomass quality standards, valuing premiums and discounts based on those standards, and devising a biomass price reporting series. A review of biomass conversion pathways, biomass characteristics and standards was conducted. Bioenergy companies approaching commercial production were surveyed to identify biomass quality characteristics. Finally biomass standards and a biomass price index were developed.

FINAL REPORT

Contact:
Dr. David Ripplinger
Bioenergy & Bioproducts Specialist
Department of Agribusiness & Applied Economics
North Dakota State University
701-231-5265
David.Ripplinger@ndsu.edu

Cellulosic Bioenergy Feedstocks:

Prices and Standards

Final Report

to the

USDA Federal State Marketing Improvement Program

David Ripplinger, Cole Gustafson, and Thein Maung

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Department of Agribusiness and Applied Economics

North Dakota State University

Contact:

David Ripplinger
North Dakota State University
701-231-5265
david.ripplinger@ndsu.edu

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1. The Emergence of Cellulosic Biomass Markets

The Renewable Fuel Standard program as expanded under the Energy Independence and Security Act of 2007 (RFS2) mandates the blending of 36 billion gallons of renewable fuel, including 16 billion gallons of cellulosic biofuel by 2022. Achieving this obligation will require massive amounts of biomass to complement traditional corn-based ethanol and biodiesel.

A recent study found several knowledge gaps among farmers and ranchers who would potentially supply biomass as a feedstock for processing (Broekema 2009). Producers were not aware of biomass market opportunities, pricing, preferred biomass harvest timing, product quality standards, or methods to reduce environmental impact. A larger void at the national level is the lack of quality standards as well as ensuing premiums and discounts which facilitate market activity. Further, biomass is primarily secured by private contracts at present and the industry lacks transparent pricing information.

Background

The federal government, California, Minnesota, eleven New England states, and Walmart are all placing greater attention on carbon emissions which is expected to result in rising demand for biomass renewable energy feedstocks, especially among coal-fired heating plants in the north central region. These feedstocks will either replace coal directly, or be gasified, to meet impending carbon regulations and/or generate carbon credits. Co-firing with biomass also generates renewable energy credits that enable utilities to meet state renewable energy mandates. Cellulosic biofuel production as mandated by RFS2 has accelerated demand for biomass feedstock.

North Dakota is a potential leading supplier of biomass renewable energy feedstock (US DOE 2011). Numerous counties have the potential to supply over 500,000 tons annually. National interest in North Dakota feedstock supply availability is especially keen given the perception that large portions of the state's land are of marginal quality. Collection of biomass from these lands is perceived to have less impact on food production for human consumption.

However, lack of biomass quality standards and market price information is stymieing biomass trading and industry development. Two emerging North Dakota biomass projects illustrate the problem's importance.

Spiritwood Station

Great River Energy, a wholesale electric cooperative, is proactively preparing for increased carbon regulation with a new combined heat and power facility, Spiritwood Station, near Jamestown, North Dakota. The facility has the infrastructure to co-fire up to 10% biomass. In addition, GRE has partnered with Inbicon, a Danish bioenergy company, to develop a cellulosic biofuel facility on the site which would be an additional market for biomass. To move forward, GRE completed a Biomass Co-firing Feasibility Assessment to determine whether or not a sustainable biomass business model can be developed in the Jamestown area. As a potential purchaser of biomass, GRE finds itself in a classic chicken and egg situation. Industry is reluctant to invest in a biomass processing plant without the existence of a reliable feedstock supply. Likewise no biomass supply chain exists because market prices and quality standards for such a product have not yet been established.

The GRE study evaluated specific types of biomass that may readily exist or be established in the future, along with combustion characteristics, and expected delivered costs. Study results find great biomass supply potential within a 100 mile radius of Spiritwood as shown in Figure 1:

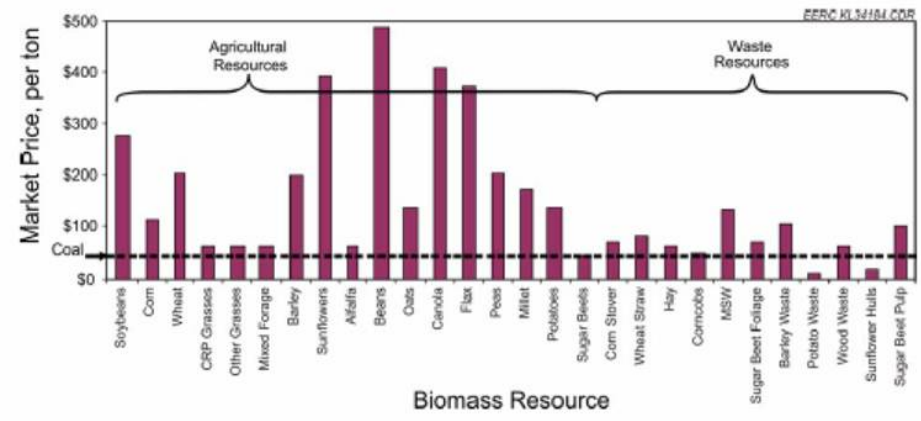

Figure 1. Waste Resources within 100 mile Radius of Spiritwood, North Dakota

Another dimension of the GRE study was to determine producer interest in supplying biomass and preferred participation in alternative supply chain network designs. Four focus groups were conducted in Spring 2009. A striking observation from these groups was that most producers were not aware of the Spiritwood project or the market opportunities for biomass, especially pricing, quality premiums, and discounts. To motivate producer interest, Steve Flick, manager of Show Me Energy, Missouri, participated and presented a detailed overview of their biomass purchasing and processing operation.

Producers were not aware of preferred biomass harvest timing, pricing, product quality standards or methods to reduce environmental impact. Attendees had expected biomass harvest to conflict with either summer or fall machinery operations. Mr. Flick stated the ideal biomass harvest time is late winter before spring field operations begin. He also noted that

preferred moisture was as low as possible. He indicated that biomass is purchased solely on the basis of BTU content, moisture and weight. One third of potential biomass is left unharvested to preserve environmental quality and soil health. While most biomass is sold in bulk to wholesale buyers (e.g. electric utilities), one fourth is bagged and sold retail at $150/ton. Show Me Energy pellets produce electricity at a cost of $0.03/kwh. Finally, producers were unaware of potential processing byproducts. Residual ash is high in potash and an excellent fertilizer with a cost of $2/ton. Having just experienced record high fertilizer prices, this caught the farmer's attention.

Mr. Flick proceeded to describe the two most important challenges facing the plant – silica and embedded metal which are highly corrosive and destructive to processing machinery. All feedstock is first ground in a specialized grinder and then pelleted to ¼″ size. Considerable discussion ensued with respect to preferred feedstock qualities, processing requirements, pricing and potential market opportunities.

The preceding Spiritwood discussion details the void in North Dakota biomass market and pricing information. However, biomass industries are beginning to form in other states and similar informational gaps are arising there as well. Moreover, sizeable retail markets exist for biomass, unbeknown to most individual farmers. Biomass pellets are currently for sale at $200/ton at both Home Depot and Tractor Supply Company in the Fargo/Moorhead area. Individual farmers could provide an affordable alternative to nationwide retailers.

Biomass Standards

Traditional commodity market pricing mechanisms and quality standards are not directly transferable to biomass and other processed crop residues. For example, No. 2 yellow corn has specific quality standards and market prices that readily exist in established USDA/AMS reporting markets. Sellers and buyers wishing to trade corn have reliable pricing information for decision making and planning. Such information does not exist for corn stover. Stover is a composite feedstock (mixtures of cob, leaves, and stalks), entail some degree of farmer processing (densification), have higher moisture, and are more likely to spoil. Importantly, the process goal for biomass is to preserve BTU's, not nutrient content for animal feed. At the moment, most biomass is contracted and information for decision making is proprietary and difficulty to obtain.

Poet, for example, has developed a proposed corn feedstock supply contract. The four-year agreement entails a 600 dry ton minimum commitment, $55/ton f.o.b. purchase price, no price escalator reflecting inflation, pricing based on dry matter equivalent, 25 percent maximum material other than cob (MOC) and no foreign material. Farmers interested in supplying biomass, or firms considering purchasing biomass in other regions would not have direct access to this proprietary market information and pricing.

The economic impact of improved biomass pricing for the nation has not been quantified, but is expected to be significant. Again, drawing upon the Spiritwood example, assume that 2/3 of the 3.5 million tons of biomass available in the 100 mile area surrounding Spiritwood are fully utilized for biomass (e.g. 1/3 is left undisturbed for environmental reasons). With a revenue

margin potential of $110/t ($150 retail pellet price less $40 payment to producers), biomass processing has the opportunity to provide an additional $385 million of economic expenditures to the area. In addition, farm profitability is enhanced and diversified, and local communities benefit from secondary economic impacts. If carbon emission legislation is implemented at the national level, perennial biomass renewable energy credits will increase in value. Finally, more informed producers (especially with respect to biomass quality attributes), greater price transparency, preferred processing technologies and flows, and economic premiums and discounts, will elevate business climate potential while minimizing investment risk in substandard technology or supplier organizations. Imperfect quality standards and pricing information will result in substantial wealth transfers and market degradation.

Statement of the Problem

Lack of biomass quality standards and market price information is stymieing biomass trading and industry development. A substantial void exists in farmer's knowledge of biomass market opportunities, processing quality factors, and pricing.

Purpose of the Study

The purpose of the project is to identify key biomass quality standards, value premiums and discounts based on those standards, and devise a biomass price reporting series.

Project Approach

A review of biomass conversion pathways, biomass characteristics and standards was conducted. Bioenergy companies approaching commercial production were surveyed to

identify biomass quality characteristics. Finally biomass standards and a biomass price index were developed.

Summary

Standards aid producers and buyers plan and make decisions. This report describes the results of a project to biomass standards and price indexing. In the second chapter biomass pretreatment and conversion technologies are discussed. In Chapter 3, solid biofuel standards are described. Chapter 4 presents a concise outlook of the cellulosic ethanol industry. The design and results of a survey of bioenergy firms is presented in Chapter 5. New biomass quality standards are proposed in Chapter 6 while findings, conclusions, and implications are presented in Chapter 7.

2. Cellulosic Biomass Conversion Technologies and Feedstocks

The creation of product standards requires an understanding of how the product will be used and how its attributes on impact process economics. In this section three bioenergy platforms: direct combustion and ethanol production using biochemical or thermochemical processes are reviewed is some background information on cellulosic biomass feedstocks.

Direct Combustion

Combustion is the thermal conversion of a carbon rich feedstock with an oxidant to produce heat energy. The process is used to convert wood to heat in residential stoves or coal in large industrial plants. Co-firing is the use of two or more fuels in the same combustion chamber of a power plant. This generally refers to the co-burning of coal and biomass.

Thermochemical Conversion

The thermochemical or syngas platform converts feedstocks using thermal processes including gasification and pyrolysis to breakdown feedstocks into desired products or intermediates that are converted into desired fuels and chemicals. Thermochemical conversion is well-suited for feedstocks with high levels of lignin (eg wood). Gasification occurs at higher temperatures than pyrolysis and in an oxygen-deficient environment as opposed to an oxygen-absent one as in the case of pyrolysis.

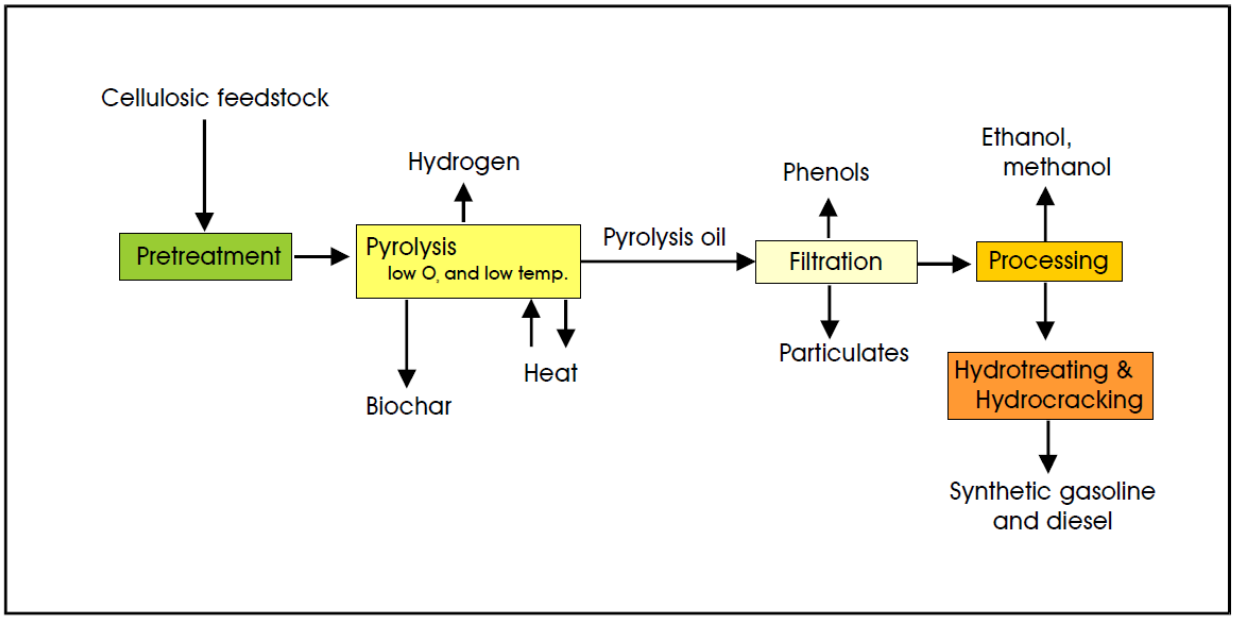

Figure 2. Thermochemical Production of Cellulosic Ethanol using Pyrolysis
Source: Patton, North Dakota State University

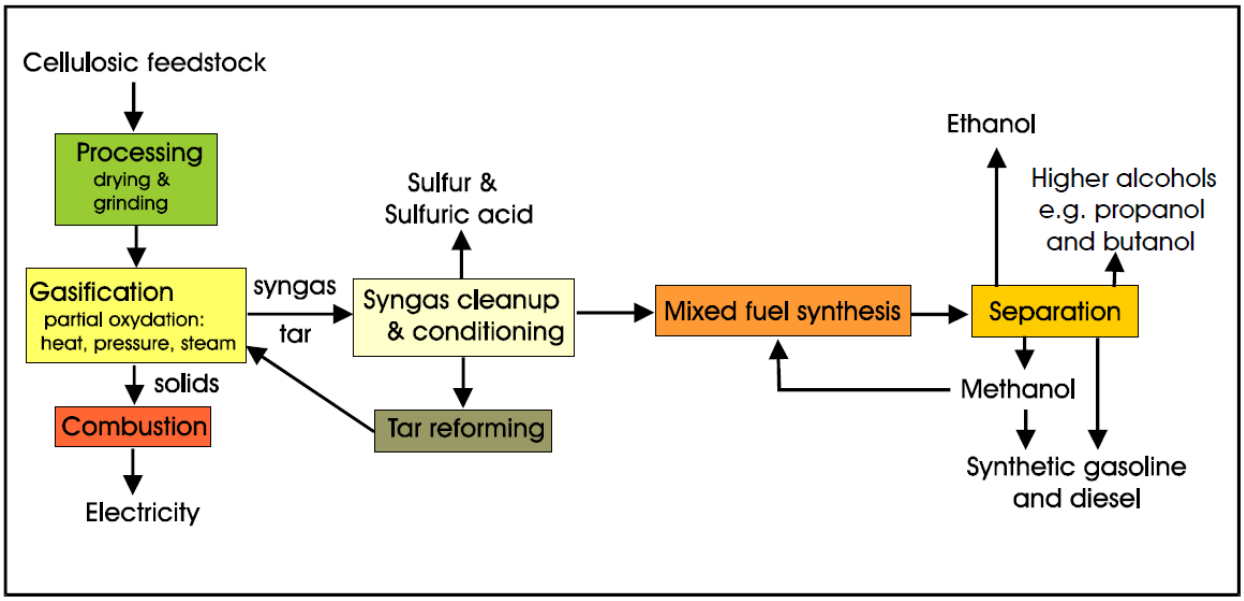

Figure 3. Thermochemical Production of Cellulosic Ethanol using Gasification
Source: Patton, North Dakota State University

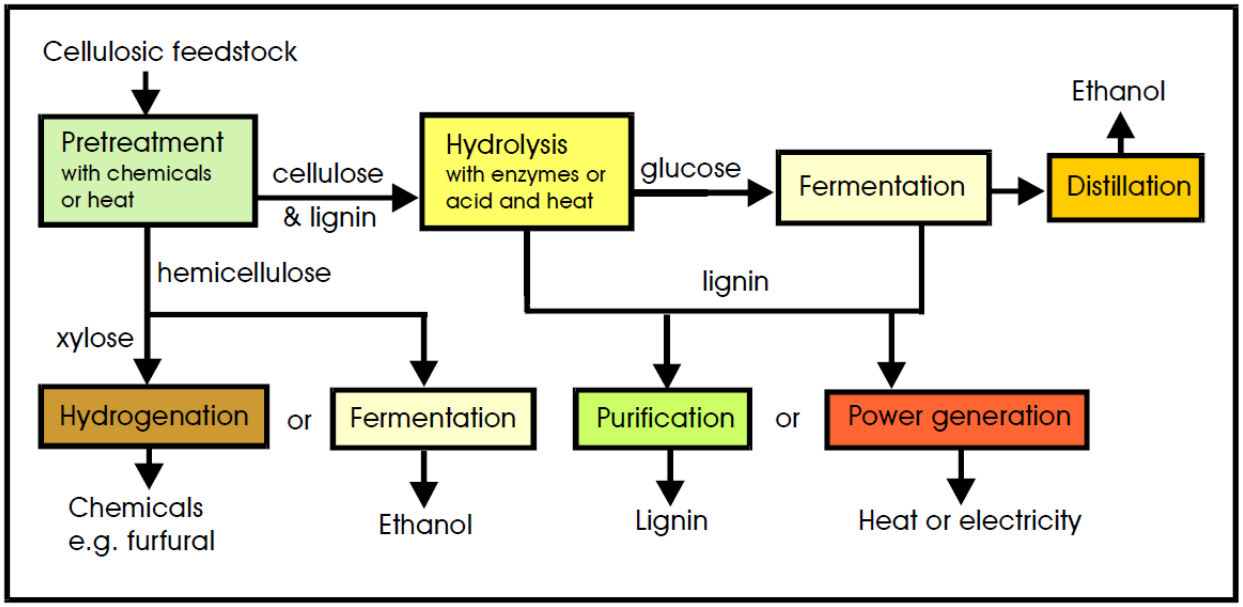

Figure 4. Biochemical Production of Cellulosic Ethanol
Source: Patton, North Dakota State University

Biochemical Conversion

Biochemical production of ethanol begins with pretreatment to separate hemicellulose from cellulose and lignin. Cellulose is then treated by enzymatic or acid hydrolysis to create fermentable sugars. Ethanol is produced from these simple sugars using microbes.

Biomass Feedstocks

Biomass includes plant and animal-based organic material including energy crops, agricultural crops, trees, food, feed, and fiber crop residue, aquatic plants, forestry and wood residues, agricultural, industrial, and municipal wastes, processing by-products and other non-fossil organic material (American Society of Agricultural and Biological Engineers 2011). It includes biomass produced directly by photosynthesis that is harvested or collected from the field or forest where it is grown (primary biomass), residues and by-products from food, feed,

fiber, wood and materials processing plants (secondary biomass), and post-consumer residues and wastes (tertiary biomass).

The physical and chemical properties of biomass vary by feedstock and sample. Physical properties include weight, density, and particle size. Chemical properties include elements that make up the material and require more advanced technology to quantify. Ultimate Analysis determines the elemental composition of the organic portion of carbonaceous materials as well as total ash and moisture. The ultimate analysis for select biomass feedstocks is presented Table 1. Higher Heating Value (HHV) is the potential combustion energy when water vapor is condensed to recover the latent heat of vaporization. HHV is measured as the amount of heat produced by combusting one unit of substance at constant volume in an oxygen bomb calorimeter. Proximate analysis determines the fixed carbon, volatile matter, moisture, and ash for biomass feedstocks are presented in Table 2.

Table 1. Biomass Feedstock Ultimate Analysis

	Corn Stover	Wheat Straw	Bagasse	Switchgrass	Poplar
HHV, Dry (btu/lb)	7,967	7,967	8,349	7,998	8,384
Ash (% mass)	10.24	10.22	3.66	5.76	2.03
Lignin	17.69	16.85	23.09	17.56	25.18
Hemicellulose	22.21	22.63	24.91	24.39	16.66
Cellulose	34.61	32.64	39.01	30.97	39.23

Source: NREL

Table 2. Biomass Feedstock Proximate Analysis

	Corn Stover	Wheat Straw	Bagasse	Switchgrass	Poplar
HHV, Dry (btu/lb)	7,967	7,967	8,349	7,998	8,384
Ash (% mass)	10.24	10.22	3.66	5.76	2.03
Lignin	17.69	16.85	23.09	17.56	25.18
Hemicellulose	22.21	22.63	24.91	24.39	16.66
Cellulose	34.61	32.64	39.01	30.97	39.23

Source: NREL

There is also considerable within sample variability for biomass. Table 3 presents variability in corn. This says nothing about the impact of different management practices.

Table 3. Corn Stover Sample Variability

Sample	Cellulose (%)	Hemicellulose (%)	Total (%)	Ash (%)	HHV (btu/lb.)	Theoretical Yield (gallons)
44	34.61	22.21	56.82	10.24	7,967	99.1
45	35.82	23.04	58.86	9.82	7,894	102.7
46	30.61	19.13	49.74	11.04	7,835	86.7
47	35.76	22.96	58.72	11.48	7,903	102.4
48	36.51	22.82	59.33	11.42	7,911	103.5
49	35.67	22.5	58.17	11.11	7,967	101.4
50	37.12	24.18	61.3	12.54	7,697	106.9
51	34.02	23.00	57.02	13.34	7,697	99.5
52	34.32	21.93	56.25	13.46	7,848	98.1
53	35.22	23.5	58.72	13.51	7,870	102.4
54	38.12	23.42	61.54	11.53	7,896	107.3
55	37.69	25.29	62.98	10.06	7,914	109.9
Average	35.46	22.82	58.29	11.63	7,867	102
Min	30.61	19.13	49.74	9.82	7,697	87
Max	38.12	25.29	62.98	13.51	7,967	110
St Dev	2.00	1.54	3.36	1.31	89	6

Source: NREL

Summary

In this section, direct combustion, thermochemical, and biochemical conversion of biomass to ethanol as well as the compositional analysis of various biomass feedstocks were reviewed . The intent was to provide a basic understanding of differences in the process as a foundation to explain differing demand for biomass feedstock attributes. In the next section, standards for solid biomass feedstocks are reviewed.

3. Solid Biofuel Standards and Pricing

The market for solid biofuel feedstocks is much more developed than that for biomass destined for liquid biofuel production. There are national and international standards already in place for these materials when used for direct combustion or co-firing.

Biomass feedstocks vary greatly among species and from batch to batch. Physical and chemical characteristics can significantly impact handling and heating with batches differing enough so as to affect their usability with a particular combustion system. Differences are usually readily identifiable and measureable allowing for the establishment of standards and the rejection or discounting of supplies that fail to meet specifications. In this section we review solid biomass feedstock classifications, characteristics, standards, and existing price indices.

3.1 Classifying Solid Biofuels

Solid biomass feedstocks are typically classified according to their source and location in the supply chain. CEN 14961, a European standard for solid biomass, differentiates sources into four groups: woody, herbaceous (agricultural and horticultural), fruit, and blends and mixtures. Biomass can be further classified as primary, secondary, or tertiary depending on its state. Primary biomass is defined as biological materials produced directly by photosynthesis and harvested directly from the forest or field. Primary biomass includes dedicated energy crops such as perennial grasses and short-rotation woody crops, as well as crop and forest residue. Secondary biomass includes materials created from the processing of primary biomass including sawdust from sawmills, black liquor from pulping, and manure. Tertiary biomass

consists of post-consumer material such as animal fats and grease, vegetable oil, packaging waste, and construction and demolition debris.

It is important to note that different combustion technologies have different fuel specifications. At the same time, energy users have different preferences and requirements for fuels. For example, residential consumers prefer fuels that produce relatively little ash and heating appliances that can run automatically in their absence.

3.2 Solid Biofuel Characteristics

Physical and chemical characteristics affect the quality of biomass as a solid fuel. Differences among species and batches may cause blockages in fuel lines, inefficient heat production, excess emissions, condensation, or in some cases system shutdown. Knowledge of biomass characteristics is also necessary to measure market supply and to determine feedstock pricing. Suppliers need to know which characteristics are valued in the market and take steps to ensure that their supplies meet required specifications.

There are numerous characteristics that impact the quality of biomass feedstocks. Here we focus on those typically considered most important: heat value, ash, sulfur, moisture, and density. Much of the information presented below comes from Pennsylvania State University's *Characteristics of Biomass as a Heating Fuel* Fact Sheet (2010).

Heat Value - is the amount of energy available in a fuel and is measured as higher heating value (HHV) or lower heating value (LHV). Higher heating value considers the full energy content of the fuel including that contained in water vapor and is the value typically reported for

combustion processes. Lower heating value does not consider this energy. Heat value is measured in terms of energy per unit of weight, e.g. J/kg or Btus/lb. The amount of energy per unit of mass varies by feedstock, species, and condition. Heat value can be impacted by the climate and soil where biomass is grown.

Moisture Content - impacts that amount of energy in wet fuel that must be used to vaporize water. At the same time, extremely dry fuel can be an explosion hazard. Moisture content is measured as the mass of water divided by the total mass of the fuel (wet basis) or by the dry mass of the fuel (dry basis).

Ash - is the inorganic, noncombustible residue left after combustion. Ash content is typically much higher for grasses, bark, and crop residue. The amount of ash left from combusting herbaceous feedstocks may overwhelm systems designed for wood.

Slagging and Fouling – are molten ash deposits identified as chunks at the base of the combustion chamber (slagging) or on combustion surfaces (fouling). The occurrence of slagging and fouling varies by temperature and can result at lower temperatures due to the presence of minerals such as silica, potassium, and chlorine. Many agricultural feedstocks have high mineral content creating potential slagging or fouling problems. For example, facilities have experienced difficulty using corn stover because of its chlorine content. Specialized systems may address this by ensuring combustion occurs at relatively low temperatures or by including additives to chemically collect and remove unwanted material.

Size and Density – can affect burning characteristics of the fuel as well as the type of handling equipment needed. Improperly sized fuel will impact the efficiency of the combustion process

by affecting the rate of heating and drying or may result in jamming or damage to the handling equipment. Low density fuels may combust too quickly or float above the primary combustion zone.

Higher Heating Value, moisture content, ash content, and density of select biomass feedstocks are presented in Table 4. Note that the ash content of wood varies greatly depending on bark content and that crop residue contains approximately 8,000 Btus on a dry weight basis.

Table 4. Thermal and Physical Properties of Biomass

	Density	HHV	Moisture	Ash
Firewood (hardwood)		24 million btus/cord	12	0.5*
Firewood (softwood)		20 million btus/cord	12	0.3*
Wood pellets	40 lbs/cu ft	8,200 btus/lb	7.5	0.8
Wood chips	10-30 lbs/cu ft	4,000 btus/lb	45	
Barley	37.2 lbs/cu ft	6,820 btus/lb	11.4	2.5
Corn	45 lbs/cu ft	6,970 btus/lb	15.5	1.3
Corn cobs	13 lbs/cu ft	7,370 btus/lb	7.1	2.2
Corn stover		7,060 btus/lb	9.1	6.8
Oats	26 lbs/cu ft	7,140 btus/lb	12.5	3.2
Wheat	48 lbs/cu ft	7,160 btus/lb	10.4	2.1
Wheat straw		6,840 btus/lb	9.9	10.4

Source: Buffington, 2008; *Pettersen, 1984

The combustion of biomass can result in the release of a number of pollutants. Actual emissions will depend on the fuel, type, and completeness of combustion.

3.3 Solid Biofuel Standards

Standards play a critical role in the development and operation of markets. The growth and promise of the solid biofuels industry has led to a number of standard development efforts. These include standards for biomass definitions, testing, specifications, and sustainable supply chains. Much of this activity has occurred in Europe which has a larger, more established solid

biofuel industry. Here we review select standard development activities to illustrate the importance of biomass standardization.

The Pellet Fuels Institute released its standards for residential/commercial densified fuel in 2011. The standards include the scope of the standard, definition of terms, detailed requirements (presented in Table 5), and sampling and testing methods. The standards' detail requirements including three specifications for premium, standard, and utility grade fuels. Requirements include density and size, physical durability, percentage of fines, ash, moisture, chloride, and heating value. The Pellet Fuels Institute mandates that bags of fuel be labeled to identify which grade of material is in the bag as well as any additives. The standard does not differentiate by the type of biomass. The American Lumber Standard Committee will serve as the program's accreditation body.

Comparing the specifications for pellets in Table 5 and the properties of biomass from Table 4 one can see that only round wood can meet the ash specification for premium fuel pellets. At the same time, corn stover is unable to meet even the utility spec because of its ash content.

In Europe, Technical Committee 335 of the European Committee for Standardization (CEN) has developed 28 related solid biofuel standards. This includes CEN-TS 14961 which was referenced previously in the section when discussing biomass classification. However, these standards are not the only ones that exist in Europe with many individual countries including Austria, Sweden, and Germany having their own.

Table 5. Residential/Commercial Densified Fuel Standards

	Residential/Commercial Densified Fuel Standards See Notes 1 - 3		
Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative Information - Mandatory			
Bulk Density, lb./cubic foot	40.0 - 46.0	38.0 - 46.0	38.0 - 46.0
Diameter, inches Diameter, mm	0.230 - 0.285 5.84 - 7.25	0.230 - 0.285 5.84 - 7.25	0.230 - 0.285 5.84 - 7.25
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at the mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, %	≤ 1.0	≤ 2.0	≤ 6.0
Length, % greater than 1.50 inches	≤ 1.0	≤ 1.0	≤ 1.0
Moisture, %	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm	≤ 300	≤ 300	≤ 300
Heating Value	NA	NA	NA
Informative Only - Not Mandatory			
Ash Fusion	NA	NA	NA

Source: Pellet Fuels Institute

Work to harmonize international standards has been the goal of a technical committee (ISO TC 238) of the International Organization for Standardization. This group currently has eight standards under development including a common set of terminology, definitions, and descriptions; general requirements; as well as specifications for six distinct fuels: wood pellets, wood briquettes, wood chips, firewood, non-woody pellets, and non-woody briquettes. The American Society of Agricultural and Biological Engineers (ASABE) coordinates the U.S. position in this international effort.

The Council on Sustainable Biomass Production (CSBP) is developing voluntary sustainability standards for biomass production and conversion (Council on Sustainable Biomass Production 2011). The intent is for the standard to serve as the basis for third-party accreditation. CSBP's

provisional standard defines the scope as including dedicated energy crops, crop residue, and native vegetation. Sustainability criteria include soil quality, biological diversity, water quality and quantity, climate change, socio-economic well-being, legality, transparency, and continual improvement.

3.4 Solid Biofuel Price Indices

Several solid fuel price indices have been established. As with the trade itself, most indices focus on Europe as opposed to North America. These indices are prepared and available for fee from Argus, FOREX, and RISI.

Argus, an international market news organization, has a biomass price index for spot delivery of solid biofuels, industrial wood pellets and wood chips, cif northwest Europe. The Argus Biomass Index relies on a survey of market participants and a volume-weighted average of verified trades that fit index specifications.

FOEX provides bioenergy and biomass price indices as well as for pulp, paper, and recovered paper. FOEX currently has one woody biomass price index, the Forest Biomass Finland Index, and plans two others: a global wood chip index and forest biomass index for another Nordic country. With regard to woody pellets, FOEX currently maintains the Pellet Nordic Index and the Pellet Continental Index. The Forest Biomass Finland Index considers forest residue and industry byproducts and has been in place since March 2012. The Pellet Nordic Index, published since 2009, concentrates on industrial wood pellets in Nordic and Baltic countries. The Pellet Continental Index focuses on medium-scale users (small power plants, hotels, green houses) in Germany and Austria. 2011. Each of FOEX's biomass price indices are based on

actual trades. The Forest Biomass Finland and Pellet Nordic Index report prices per MWh or ton, while the Pellet Continental Index reports on a tonnage basis.

RISI prepares two price indices, a North American woody biomass price index and North American pellet grade wood price index. Each is published in its monthly Wood Biomass Market Report. The formula of each index is not known.

Summary

In this section, solid biomass feedstock classifications, characteristics, standards, and price indices were presented. The goal was to recognize the important differences among biomass feedstocks as well as variability that may be found among batches of a particular material. These differences have resulted in efforts to develop standards which are critical to the development and operation of biomass markets.

4. Cellulosic Ethanol Outlook

The revised Renewable Fuel Standard passed into law in 2007 included targeted levels of cellulosic ethanol blending by year until 2022. To date, commercial production of cellulosic ethanol has fallen far short of these targets. As shown in Table 6, RFS2 initially mandated 100 million gallons of production in 2010. This level was reduced to 6.5 million gallons by EPA, as allowed by RFS2, in response to insufficient domestic capacity. At the same time, the Energy Information Administration (EIA) projected that just less than that amount, 6.44 million gallons would be produced in 2010. Despite the projections and revisions, no cellulosic ethanol was sold in 2010 (or in 2011).

Table 6. Cellulosic Biofuels Projected Production and Actual Domestic Sales, 2010-12
(million gallons ethanol equivalent)

Year	EISA RFS2 Target	EPA RFS2 Standard	EIA Projected Production	Fuel Sold in United States
2010	100	6.5	6.44	0
2011	250	6	3.94	0
2012	500	10.45	6.9	-

Source: EIA 2012

The EIA actively tracks cellulosic ethanol projects in order to make annual domestic production projections. Table 7 lists the projects the Energy Information Administration has considered when preparing cellulosic biofuel projections. Of the ten firms tracked, one has been abandoned, three have been delayed, and two have been closed. Only three firms produced fuel with none utilizing more than 10 percent of their capacity. Of the five commercial scale projects, none have been completed on schedule or are in operation.

Table 7. EIA Tracked Projects, 2009-12

Company	Location	Product	Project Scale	Nameplate Capacity (mm	Utilization (%)	Production (mm gallons)	Current Project Status
Blue Sugars	Upton, WY	Ethanol	Pilot	0.75	10	0.08	Active
BP Biofuels	Jennings, LA	Ethanol	Pilot	1.4	0	0	Completed
Terrabon	Bryan, TX	Bio-Crude	Pilot	0.93	0	0	Closed
Zeachem	Boardman, OR	Ethanol	Pilot	1.5	0	0	Completed
Cello Energy	Bay Minette, AL	Diesel	Commercial	20	0	0	Closed
Range Fuels	Soperton, GA	Methanol	Commercial	2	0	0	Abandoned
Fiberight, LLC	Blairstown, IA	Ethanol	Commercial	3.8	0	0	Delayed
Dupont Cellulosic Ethanol	Vonore, TN	Ethanol	Pilot	0.25	0	0	Completed
INEOS Bio	Vero Beach, FL	Ethanol	Commercial	8	<3	<0.24	Delayed
KiOR	Columbus, MS	Liquids	Commercial	11	<3	<0.33	Delayed

Source: EIA 2012

The EIA uses biomass feedstock procurement as a signal that a proposed facility is nearing commercial operation. Of EIA's ten identified projects, KiOR and INEOS Bio began procuring feedstocks in 2011 and are expected to produce cellulosic ethanol at commercial scale in late 2012 or 2013. Abengoa, POET, and Fiberight are expected to start-up in 2013. Cellulosic biofuel projects tracked by EIA are presented in Table 8.

Table 8. Cellulosic Biorefineries Projected to Produce Commercial Volumes, 2012-2013

Company	Location	Nameplate Capacity (mm gallons per year)	Year of Expected Start-up
KiOR	Columbus, MS	11	2012/13
INEOS Bio	Vero Beach, FL	8	2012/13
Abengoa Bioenergy	Hugoton, KS	23	2013
POET	Emmetsburg, IA	25	2013
Fiberight	Blairstown, IA	4	2013

Source: EIA 2012

The slow development of domestic cellulosic ethanol production capacity has resulted in a lack of cellulosic feedstock market activity. Consequently, there has been little learning necessary to develop robust standards by either buyers or sellers.

5. Bioenergy Survey

A two-part survey was designed to collect information on advanced bioenergy firms and biomass feedstock quality factors. The first line of questions asked participants about their firm. The second focused on physical and chemical factors that impact conversion technology with an emphasis on those currently included in purchase agreements. Biomass feedstock alternatives specifically targeted by the survey are listed in Table 9. Participants can and did identify other, unlisted feedstocks.

Table 9. Biomass Survey Feedstocks

Crop Residue	Crop Residue	Energy Crops	Wood	
sorghum bagasse	corn stover	camelina	firewood and logs	logging residue
sugarcane bagasse	corn cobs	miscanthus	wood chips	stumps
	wheat straw	switchgrass	wood pellets	wood waste
			whole trees	black liquor
			stemwood	

5.1 Survey Sample

The survey targeted domestic advanced bioenergy firms that currently or plan to have commercial scale production by 2015. A database consisting of existing and planned bioenergy facilities was created using public and private sources including the Status of 2nd Generation Biofuels Demonstration Facilities in June 2010 (Bacovsky, Dallos, Wörgetter 2010), Biofuel Digest's Advanced Biofuels Tracking Database, Oakridge National Laboratories, Biomass Heat and Power, and the Department of Energy. A total of 283 bioenergy facilities were identified. These facilities included planned and existing pilot, demonstration, and commercial-scale sites in the United States and abroad.

The number of facilities was reduced to 168 by limiting the scope to domestic advanced bioenergy plants. Facilities using algae, commodity crops, or municipal solid waste as the primary feedstock were also removed. Algae were removed as a tradable market is not expected to develop due to place-bound nature of the industry. Facilities that use commodity crops such as corn and sugar as feedstock to produce renewable drop-in fuels were removed as those commodities already have established standards and markets. Municipal solid waste was not included as it was considered outside the scope of the project. The final candidate list includes 104 combined heat and power (CHP) facilities that use or plan to use biomass. The names and locations of these facilities, their feedstock, and conversion technology are included in Appendix B.

The final sample filter was that facilities needed to be at or planned to be commercial scale. This was defined as those facilities planning to produce at least 10 million gallons per year of fuel by 2015. The final candidate list included 18 advanced biofuel companies and two biomass-fired combined heat and power facilities.

5.2 Survey Design

The survey looked to identify physical and chemical factors that impact conversion technology with an emphasis on those currently included in purchase agreements. The survey asked for the unit of measure, thresholds, and discounts or premiums for each factor. Physical properties included green weight, dry weight, energy content, size, density, durability, energy density, and presence of fines and debris. Chemical properties included moisture, ash content,

and elemental composition. Questions on species, time of harvest and delivery, and binding type were also asked.

The survey asked about sampling and testing procedures, the most important quality factors for the particular feedstock, any factors that the participant thought should be mandatory, and if they would be willing to provide a purchase contract. The survey instrument is located in Appendix A.

5.3 Administration and Response

The survey instrument, methods, and procedures were submitted to North Dakota State University's Institutional Review Board (IRB) to ensure that the rights, safety, and welfare of individuals participating in the survey were protected. IRB approval was received prior to the start of the survey.

The survey was pretested to determine its effectiveness with regards to question format, wording, and order. Jim Epstein of the USDA Agricultural Marketing Service reviewed the survey. Minor question wording and formatting changes were made based on his comments.

Candidate firms were contacted in the spring and summer of 2011. Firms were informed of the study and invited to participate by phone. Electronic copies of the questionnaire were provided for review. The survey was conducted by phone.

Twelve of the 20 final candidate firms, including both CHP firms, participated in the survey for a response rate of 60%. Six of the companies did not respond to repeated phone and email

requests. Two declined to participate. Survey participants included directors of business development, technical staff, plant managers, and feedstock procurement specialists.

5.4 Results

Three participating firms, Abengoa, Dupont Danisco Cellulosic Energy (DDCE), and POET, use enzymatic hydrolysis technology to break down cellulose and hemicellulose into fermentable sugars for conversion into ethanol. Abengoa is constructing a 23 million gallon per year (mgy) cellulosic biorefinery in Hugoton, Kansas. POET is adding a cellulosic front-end to its existing Emmetsberg, Iowa, corn ethanol plant. This addition is capable of handling the feedstock necessary to produce 25 million gallons of cellulosic ethanol per year. DDCE has secured land in Nevada, Iowa, where it will construct its first commercial-scale plant capable of producing up to 50 mgy of cellulosic ethanol.

Show Me Energy is currently producing biomass pellets using a variety of biomass feedstocks at its facility in Centerview, Missouri, with plans to produce cellulosic ethanol. It is securing switchgrass acres in Missouri and Kansas as part of the Biomass Crop Assistance Program (BCAP). Aloterra Energy is contracting for miscanthus acres in Ohio, Pennsylvania, Missouri, and Arkansas under BCAP. It plans to begin producing biomass pellets in 2013 then transition to cellulosic ethanol production when licensed technology becomes available.

Coskata, Ineos Bio, and ZeaChem use syngas technology to produce ethanol. Coskata will use various woody biomass at its planned 55 mgy facility in Boligee, Alabama. Ineos Bio will rely on wood and vegetative waste as feedstock at its planned 8 mgy Indian River County, Florida,

plant. ZeaChem has contracted acres for the production of hybrid poplar using BCAP and has plans for a 25 mgy refinery in Boardman, Oregon.

Minnesota Power and Xcel Energy use wood, forest residue, and wood waste as feedstock at power plants in Minnesota and Wisconsin. Minnesota Power co-fires with biomass while Xcel Energy runs on coal or biomass.

Dynamic Fuels hydroprocesses animal fat, grease, and oil into synthetic diesel, which is distinct from biodiesel in its conversion technology and final attributes, at its 90 mgy facility in Geismar, Louisiana. Mascoma uses consolidated bioprocessing (CPB) technology that converts cellulose directly to ethanol.

A list of participating companies, the location of their bioenergy facility, their products, technology, and primary feedstocks are listed in Table 10.

Bioenergy Products

Survey participants were asked the type of energy their facility produces. Xcel and Minnesota Power produce electricity and heat. Show Me Energy produces solid biofuel which Aloterra Energy plans to do once the dedicated energy crops it is currently contracting mature. Dynamic Fuels produces synthetic diesel. Nine companies plan to produce cellulosic ethanol including Show Me Energy and Aloterra once licensed technology is available.

Table 10. Biomass Quality Factors Survey Participants

Company	Location	Product	Technology	Primary Feedstocks
Abengoa	Hugoton, KS	Ethanol	Enzymatic Hydrolysis	Agricultural residue
Aloterra Energy	Ashtabula, OH	Solid biofuel	Physical	Dedicated energy crop-miscanthus
Coskata	Boligee, AL	Ethanol	Syngas	Woody biomass
DDCE	Nevada, IA	Ethanol	Enzymatic Hydrolysis	Agricultural residue
Dynamic Fuels	Geismar, LA	Synthetic diesel	Hydroprocessing	Fat, grease, oil
Ineos Bio	Indian River County, FL	Ethanol	Syngas	Woody biomass
Mascoma	Kinross, MI	Ethanol	CBP	Woody biomass
Minnesota Power	Duluth, MN; Grand Rapids, MN	Heat and Power	CHP	Woody biomass
POET	Emmetsburg, IA	Ethanol	Enzymatic Hydrolysis	Agricultural residue
Show Me Energy	Centerview, MO	Solid biofuel	Physical	Agricultural residue, dedicated energy crop - switchgrass, waste wood
Xcel Energy	Ashland, WI	Heat and Power	CHP	Woody biomass
ZeaChem	Boardman, OR	Ethanol	Syngas	Dedicated energy crop-hybrid poplar

Biomass Feedstocks

The next question asked what feedstocks their facility uses or plans to use. Abengoa, DDCE, and POET plan on using corn stover as their primary biomass feedstock. Abengoa is also contracting for wheat straw. Show Me Energy can use 21 biomass herbaceous feedstocks and also accepts wood waste. Aloterra is contracting for new miscanthus production.

Minnesota Power and Xcel Energy accept a variety of woody biomass including forest and mill residue as well as wood waste. Dynamic Fuels can use a variety of fats, oils, and greases. Yellow grease makes up the majority of its feedstock supply due to its low price. ZeaChem is using hybrid poplar a dedicated energy crop. Coskata and Mascoma will use woody biomass. Ineos Bio will use wood and herbaceous waste.

Feedstock Flexibility

Each survey participant noted that there is considerable flexibility in the feedstock that can be utilized by their conversion technology. In general, sugar platform technologies want higher levels of material that can be converted to useable sugars while syngas platform technologies want energy content.

Biomass feedstock availability plays a large role in facility siting. A survey participant whose firm uses the syngas platform noted that the feedstocks they use will change as they expand into new areas. Their plants in the Midwest will use agricultural biomass; those located in the Southeast, northern Great Lakes, New England, and Pacific Northwest will use woody biomass; while those in populated areas will use waste. Two participants pointed out a more local consideration - the value of co-locating near facilities and infrastructure. This allows for sharing resources such as power and steam, lab equipment, storage, or transportation infrastructure. Co-location can also allow for joint marketing of traditional and cellulosic ethanol.

An alternative framework is that being used by POET who already sources large quantities of corn from farmers across the Midwest to supply its 26 ethanol plants. These same farmers have educated and involved the process of developing POET's biomass supply chain that is expected to use corn residue to displace grain use.

Biomass Feedstock Pricing

Firms sourcing agricultural residue and dedicated energy crops are contracting by the acre and paying by the dry ton when delivered. Most woody biomass is purchased by the green ton. The standard characteristics reported by nearly all survey participants are weight,

moisture, and ash. Ineos Bio levies a tipping fee for wood and vegetative waste that it receives. These feedstocks make up all of its currently secured feedstock.

A number of firms stated that they absorb the cost of negative feedstock factors as 'the cost of doing business'. For example, all but one of the companies procuring woody biomass pay by the green ton, even though moisture provides no benefit to their conversion technology. The same situation holds for ash.

Firms are seeking low-cost forms of energy that can be converted by their process. Syngas companies avoid inert materials. One syngas company noted that fungal presence negatively impacts its conversion technology. Another pointed out that bark is detrimental. The presence of metals is a challenge for solid biofuel processing, syngas technology using catalysts, and combustion. Two companies buying agricultural residue were concerned about debris (rocks) while others stated that they it is not a significant concern.

CHP facilities must monitor post-consumer wood supplies closely. Xcel Energy stated that it must pay particular attention to the composition of materials to ensure compliance with its state permit.

Only one firm provided detailed biomass feedstock specification information. The survey participant from that firm stated that is possible that the specifications listed would change once its commercial-scale facility went on line and additional learning occurred.

Survey participants were helpful in general, but most declined to provide specific feedstock information. Technology companies were less likely to volunteer information possibly to

protect their business interests. Companies whose commercialization efforts were just beginning spoke with less certainty that those who have commercial scale production or who had already broken ground on their facility.

One firm is interested in using the sugar beet industry's scheduled payment method. Here each load is weighed and sampled before getting tipped into large piles. Sample information is used to determine the sugar content of the load and the growers' payment. Growers are paid a fixed percentage of their total payment at scheduled intervals during the processing campaign.

Paying on Value

Survey participants recognized the benefits of paying for feedstock on a value basis. Half stated that their firm's plan or would like to move toward testing of all loads, using more complete and precise testing procedures, and pricing loads accordingly. Others were hesitant stating that high costs or unsupportive and unresponsive suppliers would offset the benefits.

Feedstock Sampling, Testing, and Technology

All 12 participants noted that they currently or plan to test feedstocks. Reported biomass sampling and testing processes vary considerably. Of the four current advanced bioenergy facilities, three test onsite and one contracts for offsite testing. Two test every load while the others test weekly or randomly. The types of test conducted vary greatly. Three of the operational commercial scale bioenergy facilities test for moisture, ash, and ultimate analysis while the other has a very sophisticated onsite lab.

DDCE is relying on custom balers to conduct second pass baling of corn stover. Technology that allows for moisture detection and bale weighing is being used. This information can then be

compared to that collected upon delivery at the yard allowing for measuring in dry matter loss and other material degradation.

One survey participant noted the importance of the development of new technology on their ability to capture value in the biomass feedstock supply chain. This would involve recording and tracking detailed information at it each step of the supply chain allowing them the ability to make improvements to their supply chain, managing risk, and paying suppliers based on the value of their feedstock.

Learning

Four firms are currently operating at commercial scale. The remaining firms are currently working at pilot or demonstration scale. Consequently, they don't have stable or precise measures of the impacts of feedstock characteristics on their conversion technology. At the same time, many of these firms have not fully addressed handling and logistics issues which may also impact their contract specifications.

One survey participant who works to secure feedstocks for a Midwest cellulosic plant stated that the company expects to learn a lot during the early stages of commercial operation that is scheduled to begin in 2013. This learning will likely result in changes to its contract specifications despite having detailed contract specs in place and nearly of their feedstock secured.

Supplier Education

Advanced bioenergy firms currently in production noted that suppliers often need to be educated on supply requirements. This is typically the case for smaller, intermittent suppliers

as well as when suppliers change their source. In practice, firms reject loads that are identified as unacceptable either by visual inspection or testing. Suppliers are informed of the basis for rejection with repeated rejections resulting in suppliers being banned.

POET has developed standard operating procedures (SOP) to assist feedstock suppliers, including farmers and third-party aggregators, properly harvest, transport, and store bales so that they can ensure a consistent feedstock supply. The document was developed in partnership with farmers and refined after its first feedstock campaign in 2010.

The use of third-party aggregators provides benefits including allowing for the use of equipment throughout the year, which may allow for more expensive, specialized equipment to be used. It also allows for the employment of specialists who may have years of experience in aggregating biomass and that have the ability to work closely with buyers to ensure that supplies are collected in a manner that ensures they'll meet specifications.

Long-term Feedstock Securement

Five companies have or plan to secure 100% of their feedstock before starting production. These include companies sourcing crop residue, dedicated energy crops, and woody biomass. Other firms are securing about 60-80% of their supply with the rest to be purchased in the spot market. Biomass feedstock supply contracts are being signed for periods up to five years. Survey participants stated that their firms may increase the amount of uncontracted biomass once the market matures and a reliable spot market emerges. At the same time, one participant commented that he does not believe that a spot market for feedstock will develop in the next few years, if ever.

Seven firms work with partners or contractors to secure feedstock supplies. These are primarily technology companies that plan license their technology after proving it at commercial scale. Partners include major wood and paper companies, food processors, sugar cane producers, and tree farms.

The Value of Standardization

Each company expressed strong interest in and support for the study. There was recognition of the importance of standards and price information for markets to function properly. However, the development of these standards and collection of price information is challenging given the small size and diversity of technologies and feedstocks used by advanced bioenergy firms.

Bioenergy Expansion

All participants with the exception of the CHPs stated that their companies plan to either license technology, build additional plants, or bolt-on technology to existing bioenergy facilities after proving and refining their technology. These 10 firms make up nearly all of the advanced bioenergy companies that will be producing advanced bioenergy in 2015. They also have the capability to scale up rapidly.

Summary

The biomass feedstock markets targeted by the survey are still in their infancy. In general, the findings were influenced by technological processes that are being continually refined as firms move from demonstration to commercial scale production and modifications are made to existing commercial scale plants. At the same time, most firms desire to keep

their feedstock specifications confidential. While some firms plan to contract their entire feedstock supply, the potential size of the market where some firms buy up to 40% of their feedstock in the spot market make continued attention to the issue necessary if markets are going to have the information necessary to function efficiently.

6. Biomass Quality Standards and Price Series

Knowledge of biomass conversion technologies, feedstock attributes, and the practical experience of the bioenergy firms moving toward commercial scale biofuel production support the development of biomass quality standards. At the same time, an inactive biomass market combined with limited price and quality data limits the ability of economic tools to explore, test, and define standards. While the slow development of cellulosic biomass markets in the United States prevents conducting a robust economic analysis of standards and pricing, preliminary work can be done to develop grades by utilizing the information that is available.

The foremost attribute of a biomass feedstock is the amount of material that can be converted into bioenergy. This logically leads to consideration of dry matter as the basis of measure. Use of a near infrared spectroscopy (NIRS), which is commonly used to measure forage quality, would allow for more precise biomass quality determination. Other attributes include those that impact, either positively or negatively, harvest, storage, and handling as well as pretreatment or conversion processes. Material dimensions and density are important physical characteristics. Little or no metal and silicates may be relevant factors as they can negatively impact many conversion processes.

Cellulosic Biomass Price Series

Given the emerging state of cellulosic biomass markets, establishment of a permanent biomass market price series is challenging. There is little to no trade of cellulosic biomass for bioenergy. At the same time, deferring creation and dissemination for too long will deprive the market of information just as it begins to emerge.

A simple arithmetic average of regional biomass prices for major biomass feedstocks is proposed. The price index for feedstock i in market J is calculated as sum of the price of feedstock in each state, j, in the market

$$P_{i,J} = \frac{\sum_{j=1}^{n} Pi,j}{n} \qquad (1)$$

The National Biomass Energy Report is the only publically available course of biomass price information. Given the sites of projects nearing commercialization as identified by EIA, price indices for cornstalks and wheat straw for a central region consisting of Iowa, Nebraska, South Dakota, and Kansas is most promising.

Two challenges are presented by National Biomass Energy Report data. The first is that many prices are reported by the bale as opposed to weight. Second, is that ranges as opposed to averages are reported. To address these issues, round and square bales are converted to tons using industry averages and the midpoint of reported ranges is used for price. Round bales are estimated to weigh 1,300 pounds, large square bales 800 pounds.

Biomass markets are defined as the collection of states where producers and consumers communicate, supply and demand conditions operate, and ownership of biomass is transferred. While no formal regional biomass markets exist for agricultural residue, one was constructed based on existing hay markets. This Western Corn Belt market consists of Iowa, Kansas, Nebraska, and South Dakota. The results of applying the simple price index model to market information reported by the USDA's National Biomass Report on Monday November 19, 2012 are presented in Tables 11 and 12.

Table 11. Western Corn Belt Cornstalk Price Index

	Price	Measure	Per Ton Price
KS	$ 65.00	Ton	$ 65.00
IA	$ 67.50	Rounds	$ 103.85
NE	$ 85.00	Rounds	$ 130.77
SD	$ 80.00	Rounds	$ 123.08
WCB Cornstalk Price Index			**$ 105.67**

Table 12. Western Corn Belt Wheat Straw Price Index

	Price	Measure	Per Ton Price
KS	$ 60.00	Ton	$ 60.00
IA	$ 72.50	Rounds	$ 111.54
NE	$ 87.50	Rounds	$ 134.62
SD		Rounds	
WCB Wheat Straw Price Index			**$ 102.05**

Biomass prices vary considerably across each market, with Nebraska prices being nearly double those of neighboring Kansas. At the same time, no wheat straw prices were reported for South Dakota. The price indexes do reflect the relative state of the market. However, they do not reflect the price of bioenergy feedstocks as these materials are currently destined for other purposes.

Considering general biomass quality standards with the information collected by existing hay (biomass) markets there is clearly a significant gap. Our information on the trades is limited to price, feedstock, and in some cases form (large or small bale). Moisture data is not collected, nor is density. A precise measure of the energy content available is not taken, so the actual yield of the material is not known.

Summary

In this section, biomass quality standards were discussed and a biomass price index proposed. Price index values were calculated using prices collected by the Agricultural

Marketing Service of the United States Department of Agriculture. While the analysis is preliminary and basic it is a first step using available data.

7. Conclusions and Recommendations

The slow development of domestic cellulosic ethanol production makes establishment of economic-based standards and price indices difficult. Buyers are not far along in their learning to have identified which factors should be included in feedstock contracts, let alone what premium or discounts should be used when product quality differs. Farmers too have little understanding of what qualities are in demand and how crop management practices impact output price.

Despite the slower than expected development of the industry, the benefits of cellulosic ethanol remain and commercialization efforts continue. The operation of commercial-scale biorefineries that are expected to come online in the next three years will require massive amounts of feedstock and increase the importance of biomass standards and price information. Three recommendations and next steps naturally follow from learning resulting from the project.

Recommendation 1. Continue biomass market reporting. USDA's reporting of biomass prices should continue. A number of cellulosic biorefineries are scheduled to begin production. These facilities will require hundreds of thousands of biomass to operate. As the market for these materials emerge, current reporting infrastructure will be able to be leveraged to collect and disseminate market news. This is especially true as many of the technologies, if feasible will able to be bolted on to existing corn-ethanol refineries allowing for a rapid expansion of cellulosic biofuel across the nation.

Recommendation 2. Collect additional biomass information. USDA should collect more detailed biomass quality information as possible. This could include moisture content, density, and energy content. This will provide valuable information to buyers and sellers and provide the basis for the creation of cellulosic biomass standards.

Recommendation 3. Monitor cellulosic ethanol market. Public market news agencies should actively monitor industry activity to ensure that new biorefinery locations and biomass markets are identified. Knowledge of new markets will allow timely reporting of biomass market information.

Recommendation 4. Revisit development of biomass standards and price indices. Cellulosic biomass markets are too immature and data and understanding of processes to allow for the establishment of robust standards. If cellulosic ethanol does reach widespread commercial production, the need for standards will be there.

The project set out to identify biomass standards and establish a biomass price index. A review of engineering and economic attributes was conducted and a survey of bioenergy companies was conducted to frame the issue. Due to an absence of public information, a rigorous economic analysis of standards and pricing was not possible. Despite these cellulosic biomass standards were proposed and the formula for a biomass price index proposed and calculated using biomass data that is available.

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Appendix A: Biomass Feedstock Questionnaire

Biomass Market Standards and Pricing Project
Biomass Quality Factors Questionnaire

North Dakota State University is conducting a USDA-funded study to establish biomass market standards. We are currently collecting information on biomass quality factors that are included in feedstock purchase decisions and/or contract specifications. Your firm has been identified as a user of biomass and is invited to participate in the project.

1. In what sector(s) of the bioenergy industry is your firm active?

   Fuel ☐ Electricity ☐ Heat ☐

   1.a. If your firm is a biorefinery, what fuels do you currently make?

   Ethanol ☐ Biobutanol ☐ Other _____

2. What biomass feedstocks does your firm purchase?

   Crop Residue
   - Corn stover ☐
   - Corn cobs ☐
   - Straw ☐

   Ag Byproducts
   - Bagasse-sugarcane ☐
   - Bagasse-sorghum ☐

   Dedicated Crops
   - Camelina ☐
   - Miscanthus ☐
   - Switchgrass ☐

   Animal waste - manure ☐

   Wood
   - Firewood and logs ☐
   - Wood chips ☐
   - Wood pellets/briquettes ☐
   - Woody biomass
     - Whole trees ☐
     - Stemwood ☐
     - Logging residues ☐
     - Stumps ☐
   - Wood waste ☐
   - Black liquor ☐

   Other(s) ☐ _____

Complete questions 3-6 for each feedstock.

Feedstock: _____

3. What quality factors are included in your current biomass purchase contracts for this feedstock?

	Quality Factor	Factor Included	Unit of Measure	Standard/ Threshold	Discount Threshold/Rate	Rejection Threshold
Physical Properties	Weight, as received					
	Weight, dry basis					
	Energy value, dry basis					
	Energy value, as received					
	Particle size					
	Diameter					
	Length					
	Ash Content					
	Moisture Content					
	Bulk Density					
	Mechanical Durability					
	Energy Density					
	Fines					
	Debris					
Chemical Properties	Carbon					
	Nitrogen					
	Hydrogen					
	Arsenic					
	Cadmium					
	Chlorine					
	Chromium					
	Copper					
	Lead					
	Sulpher					
	Zinc					
	Other Heavy Metals					
	Alkali Metals					
Other	Species					
	Time of Harvest					
	Binding Type					
	(1)					
	(2)					
	(3)					
	(4)					
	(5)					

4. What are your firm's sample and testing procedures for quality factors for this feedstock?
5. Which quality factors are most significant for this feedstock? Are there certain factors that should definitely be included as standards for this feedstock?
6. Would you be willing to provide a purchase contract (which will be kept confidential) to assist us in the project?

Appendix B: Planned and Existing U.S Bioenergy Facilities, Spring 2011

Project	Location	Feedstock	Product
Abengoa	Hugoton, KS	Agricultural residue	Ethanol
Abengoa	York, NE	Agricultural residue	Ethanol
Adage	Jasper , FL	Wood waste	CHP
Adage LLC	Shelton, WA	Wood	CHP
ADM	Decatur, IL	Agricultural residue	Ethanol
AE Biofuels	Keyes, CA	Dedicated energy crops, agricultural residue	Ethanol
Agrilectic Power Partners	Lake Charles, LA	Agricultural byproduct (rice hulls)	CHP
Aloterra Energy	Ashtabula, OH	Dedicated energy crop (miscanthus)	Ethanol
AltAir Fuels	Anacortes, WA	Crop (camelina)	RDIF
American Process	Alpena, MI	Wood	Ethanol
American Renewables	Gainesville , FL	Wood, forest residue, wood byproducts, wood waste	CHP
American Renewables	White Springs, FL	Wood, forest residue, wood byproducts, wood waste	CHP
Amyris	Emeryville, California	Crop (sugarcane)	RDIF
Aspen Power	Lufkin, TX	Wood waste	CHP
Avista	Kettle Falls , WA	Wood waste	CHP
BBI BioVentures	Denver, CO	Wood, dedicated energy crops, agricultural residue	Ethanol
Beaver Biodiesel	Portland, OR	Crop (camelina)	RDIF
Beaver Wood Energy	Fair Haven, VT	Forest residue	CHP
Beaver Wood Energy	Pownal, VT	Forest residue	CHP
BFC Gas and Electric	Cedar Rapids, IA	Wood, agricultural byproducts	CHP
Biomass One LP	White City , OR	Wood, forest residue, wood byproducts, wood waste	CHP
Boralex	Ashland, ME	Wood waste	CHP
Boralex	Fort Fairfield, ME	Wood waste	CHP
Boralex	Stratton, ME	Wood waste	CHP
Boralex Sherman	Stacyville, ME	Wood waste	CHP
Boralex New York	Chateagay, NY	Wood	CHP
Bridgewater Power	Bridgewater, NJ	Wood	CHP
Buckeye Technologies/University of Florida	Perry, Florida	Wood, agricultural waste	Ethanol

Appendix B: Planned and Existing U.S Bioenergy Facilities

Project	Location	Feedstock	Product
Caletta Renewable Energy	Springfield, MA	Wood	CHP
Central Hudson Energy Group Inc.	Lyons Falls, NY	Wood	CHP
City of Burlington electric	Burlington, VT	Wood	CHP
Clean Power Development LLC	Berlin, NH	Wood	CHP
Clean Power Development LLC	Winchester, NH	Wood	CHP
ICM Inc.	St. Joseph, MO	Agricultural residue	Ethanol
CMS Enterprises	Flint, MI	Wood waste	CHP
CMS Enterprises/Decker Energy/Fortistar	Grayling, MI	Wood waste	CHP
Cobalt	Sausalito, CA	Crop (corn)	Biobutanol
Colmac Energy Inc.	Mecca, CA	Wood waste	CHP
Concord Steam Corp.	Concord , NH	Wood	CHP
Coskata	Boligee, AL	Wood	Ethanol
Coskata	Madison, PA	Wood, dedicated energy crops, agricultural residue, used wood	Ethanol
Coskata	Warrenville, IL	Wood, dedicated energy crops, agricultural residue, used wood	Ethanol
Covanta Energy	Burney, CA	Wood waste	CHP
Covanta Energy	Delano, CA	Wood waste	CHP
Covanta Energy	Mendota, CA	Wood waste	CHP
Covanta Energy	Jonesboro, ME	Wood waste	CHP
Covanta Energy	Westwood, CA	Wood waste	CHP
Covanta Energy	Oroville, CA	Wood waste	CHP
Covanta Energy	Jamestown, CA	Wood waste	CHP
Covanta Energy	West Enfield, ME	Wood waste	CHP
DDCE	Nevada, IA	Agricultural residue (corn cob)	Ethanol
DDCE	Vonore, TN	Agricultural residue (corn cob)	Ethanol
Decker Energy Instrational/NuPower	Plainfield, CT	Wood, forest residue, used wood	CHP
Decker Energy International	Fitzgerald , GA	Forest residue, mill waste, logging residue	CHP

Appendix B: Planned and Existing U.S Bioenergy Facilities

Project	Location	Feedstock	Product
Decker Energy International	Ahoskie, NC	Forest residue, wood byproducts	CHP
Decker Energy International	Lindale, TX	Forest residue, wood byproducts, used wood	CHP
Decker Energy InternationalCMS Eneterprises	New Bern, NC	Wood waste	CHP
Diamond Green	Norco, LA	Animal residue, waste oil	RDIF
DTE Energy	Woodland , CA	Wood waste, ag residue	CHP
DTE Energy	Stockton, CA	Woody Biomass	CHP
Dynamic Fuels	Geismar, LA	Oils and grease	Diesel
EcoPower Generation	Hazard , KY	Wood	CHP
Energy Investors Funds	Watertown, CT	Forest residue	CHP
Evergreen BioPower Co.	Lyons, OR	Forest residue	CHP
Evergreen Forest Products Inc.	New Meadows, ID	Forest residue	CHP
Fibrominn	Benson, MN	Animal waste	CHP
FirstEnergy Generation Corp.	Shadyside, OH	Woody biomass, ag residue	CHP
Flambeau River Biofuels	Park Falls, Wisconsin	Wood, forest residuals	FTL
Florida Biomass Energy	Manatee, FL	Dedicated energy crops	CHP
Fortistar	Hillman, MI	Wood waste, shredded tires	CHP
Gallop Power	Greenville, ME	Wood waste	CHP
GDF Suez	Tamworth, NH	Wood chips	CHP
GDF Suez	Lincoln, MI	Wood waste, TDF	CHP
GDF Suez	McBain, MI	Wood waste, TDF	CHP
GDF Suez	Northumberland, PA	Wood chips, wood waste	CHP
GDF Suez	Bethlehem, NH	Whole tree chips	CHP
GDF Suez	East Ryegate, VT	Whole tree chips	CHP
GDF Suez	Westminster, MA	Wood chips, landfill gas, paper-derived fuel	CHP
Gevo	St Joseph, MO	Dedicated energy crops, forest residue, agricultural residue	Biobutanol
GreenHunger Mesquite Lake	Brawley, CA	Woody biomass	CHP
HCL Clean Tech	Durham, NC	Dedicated energy crops, forest residue, agricultural residue	Ethanol
Helios Scientific	Curwensville, PA	Crops, dedicated energy crops, forest residue, agricultural residue	Ethanol
HL Power Co.	Susanville, CA	Wood waste, ag residue	CHP

Appendix B: Planned and Existing U.S Bioenergy Facilities

Project	Location	Feedstock	Product
Iberdrola Renewables	Lakeview, OR	Woody biomass	CHP
Ineos BIO	Vero Beach, FL	Agricultural waste, wood waste, MSW	Ethanol
Iogen Biorefinery Partners	Shelley, ID	Agricultural residue, dedicated energy crops	Ethanol
Joule	Leander, TX	CO2	RDIF
KiOR	Columbus, MS	Wood waste, agricultural residue	RDIF
KL Energy Corporation	Upton, WY	Wood waste, wood byproducts	Ethanol
Klamath Falls Bioenergy	Klamath Falls, OR	Wood waste	CHP
Kopper Inc. - Susquehanna	Montgomery, PA	Used wood	CHP
Laidlaw Berlin Biopower	Berlin, NH	Wood, forest residue	CHP
L'Anse Warden Electric	L'Anse, MI	Wood waste, used wood	CHP
LG Biomass Missouri LLC	Perryville, MO	Wood waste	CHP
Liberty Green Renewables Indiana	Scottsburg, IN	Wood waste	CHP
Lignol Energy Corporation	Grand Junction, CO	Agricultural residue; forest residue	Ethanol
Logos Technologies	Visalia, CA	Agricultural residue, dedicated energy crops	Ethanol
LS9 / California	San Francisco, CA	Crop (Sugar)	RDIF
LS9 / Florida	Okeechobee, FL	Crop (Sugar)	RDIF
Madera Energy	Greenfield, MA	Wood, forest residue, wood byproducts	CHP
Mancelona Renewable Resources	Mancelona, MI	Wood chips	CHP
Marubeni Sustainable Energy	Whitefield, NH	Wood	CHP
Marubeni Sustainable Energy	Springfield, NH	Wood	CHP
Mascoma Corporation	Kinross, MI	Wood, dedicated energy crops (switchgrass)	Ethanol
Mascoma Corporation	Rome, NY	Wood, dedicated energy crops (switchgrass)	Ethanol
MFA Oil	Columbia, MO	Dedicated energy crops (miscanthus)	Ethanol
Minnesota Power	Duluth, MN	Forest residue, wood byproducts	CHP
Minnesota Power	Grand Rapids, MN	Forest residue, wood byproducts	CHP
Murphy Oil	Hereford, Texas	Animal waste	Ethanol
Myriant	Lake Providence, LA	Crop (Sugar)	Ethanol
NewPage	Wisconsin Rapids, WI	Forest residue	FTL
Nippon Paper Group	Port Angeles, WA	Woody biomass	CHP
NRG Energy	Uncasville, CT	Woody biomass	CHP

Appendix B: Planned and Existing U.S Bioenergy Facilities

Project	Location	Feedstock	Product
Oglethorpe Power	Warrenton, GA	Woody biomass	CHP
Otoka Energy Corp.	Ione, CA	Forest residue, agricultural residue	CHP
Pacific Ethanol	Boardman, OR	Dedicated energy crops, agricultural residue	Ethanol, biogas, lignin
PacWest Energy LLC	Kaumakani, HI	Wood, agricultural byproduct (bagasse)	CHP
Patriach Partners	Old Town, ME	Woody biomass, wood byproducts	CHP
Placer County/Calpeco	King's Beach, CA	Forest woody biomass	CHP
POET	Emmetsburg, IA	Dedicated energy crops, agricultural residue	Ethanol
POET (Scotland)	Scotland, SD	Agricultural residue (corn stover)	Ethanol
Public Service of New Hampshire	Portsmouth, NH	Wood	CHP
Range Fuels	Soperton, GA	Wood, forestry residue	Ethanol, methanol
Range Fuels	Denver, CO	Wood	Ethanol
Renegy Holdings	Snowflake, AZ	Wood ships, paper sludge	CHP
Red Shield Acquisition	Old Town, ME	Wood	Butanol
Rentech	Rialto, CA	Dedicated energy crops, forest residue, agricultural residue	RDIF, jet fuel
Rentech	Commerce City, CO	Agricultural byproduct (bagasse), wood waste	RDIF, jet fuel
Russell Biomass	Russell , MA	Wood chips	CHP
Sierra Pacific	Aberdeen, WA	Forest residue, wood byproducts	CHP
Sierra Pacific	Anderson, CA	Forest residue, wood byproducts	CHP
Sierra Pacific	Burlington, CA	Forest residue, wood byproducts	CHP
Sierra Pacific	Burney, CA	Forest residue, wood byproducts	CHP
Sierra Pacific	Lincoln, CA	Forest residue, wood byproducts	CHP
Sierra Pacific	Loyalton, CA	Forest thinnings, MSW, ag residue	CHP
Sierra Pacific	Quincy, CA	Forest residue, wood byproducts	CHP
Sierra Pacific	Sonora, CA	Forest residue, wood byproducts	CHP

Appendix B: Planned and Existing U.S Bioenergy Facilities

Project	Location	Feedstock	Product
Show Me Energy	Centerview, MO	Dedicated energy crops, used wood	Ethanol
Southeast Renewable Energy	Brookhaven, GA	Forest residue	CHP
Southeast Renewable Energy	Camden, SC	Forest residue	CHP
Southeast Renewable Energy	Florala, AL	Forest residue	CHP
Southeast Renewable Energy	Harleyville, SC	Forest residue	CHP
Southeast Renewable Energy	Luverne, AL	Forest residue	CHP
Southeast Renewable Energy	Pineland, SC	Forest residue	CHP
Stimson Lumber Co.	Plummer, ID	Wood byproducts	CHP
SynGest	Menlo, IA	Dedicated energy crops, agricultural residue, used wood	Ammonia
Taylor Biomass Energy-Montgomery	Montgomery, NY	Wood	CHP
Terrabon	Bryan, TX	Dedicated energy crops, agricultural residue, animal waste	Ethanol
Tetravitae	Chicago, IL	Crop (corn)	Biobutanol
ThermoChem Recovery	Durham, NC	Wood byproducts	Ethanol
Trenton Fuel Works	Trenton, NJ	Mixed cellulose	Ethanol
U.S. Renewables Group	Niagara Falls, NY	Wood byproducts	CHP
U.S. Renewables Group	Tracy, CA	Wood byproducts	CHP
Vercipia	Jennings, LA	Agricultural byproduct (bagasse)	Ethanol
Vercipia	Highlands CO, FL	Dedicated energy crop	Ethanol
Virent	Madison, WI	Dedicated energy crops, agricultural residue, forest residue	RDIF
We Energies	Rothschild, WI	Forest residue	CHP
Wheelabrator	Auburndale, FL	Wood byproducts	CHP
Wheelabrator	Anderson, CA	Wood byproducts	CHP
Xcel Energy	Ashland, WI	Wood byproducts	CHP
Xcel Energy	Lacrosse, WI	Wood byproducts	CHP
ZeaChem	Boardman, OR	Dedicated energy crops	Ethanol