Feedstock Composition Glossary

The Feedstock Composition Database is based upon many specific definitions for materials and processes. The following is an alphabetic list of those definitions.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A

Acetic Acid — An acid with the structure of $C_2H_4O_2$. Acetyl groups are bound through an ester linkage to hemicellulose chains, especially xylans, in wood and other plants. The natural moisture present in plants hydrolyzes the acetyl groups to acetic acid, particularly at elevated temperatures.

Acid Detergent Fiber (ADF) — organic matter that is not solubilized after 1 hour of refluxing in an acid detergent of cetyltrimethylammonium bromide in 1N sulfuric acid. ADF includes cellulose and lignin. This analytical method is commonly used in the feed and fiber industries. [8]

Acid Hydrolysis — The treatment of cellulosic, starch, or hemicellulosic materials using acid solutions (usually mineral acids) to break down the polysaccharides to simple sugars.

Acid Insoluble Lignin — Lignin is mostly insoluble in mineral acids, and therefore can be analyzed gravimetrically after hydrolyzing the cellulose and hemicellulose fractions of the biomass with sulfuric acid. ASTM E-1721-95 describes the standard method for determining acid insoluble lignin in biomass. See lignin and acid soluble lignin.

Acid Soluble Lignin — A small fraction of the lignin in a biomass sample is solubilized during the hydrolysis process of the acid insoluble lignin method. This lignin fraction is referred to as acid soluble lignin and may be quantified by ultraviolet spectroscopy [1]. See lignin and acid insoluble lignin.

Agricultural Residue — Agricultural crop residues are the plant parts, primarily stalks and leaves, not removed from the fields with the primary food or fiber product. Examples include corn stover (stalks, leaves, husks, and cobs); wheat straw; and rice straw. With approximately 80 million acres of corn planted annually, corn stover is expected to become a major biomass resource for

bioenergy applications.

Aldoses — Occur when the carbonyl group of a monosaccharide is an aldehyde [2].

Alkali Lignin — Lignin obtained by acidification of an alkaline extract of wood.

Aquatic Plants — The wide variety of aquatic biomass resources, such as algae, giant kelp, other seaweed, and water hyacinth. Certain microalgae can produce hydrogen and oxygen while others manufacture hydrocarbons and a host of other products. Microalgae examples include *Chlorella*, *Dunaliella*, and *Euglena*.

Arabinan — The polymer of arabinose with a repeating unit of $C_5H_80_4$ [2]. Can be hydrolyzed to arabinose.

Arabinose — A five-carbon sugar $C_5H_{10}0_5$. A product of hydrolysis of arabinan found in the hemicellulose fraction of biomass.

Ash — Residue remaining after ignition of a sample determined by a definite prescribed procedure [3].

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Bark — The outer protective layer of a tree outside the cambium comprising the inner bark and the outer bark. The inner bark is a layer of living bark that separates the outer bark from the cambium and in a living tree is generally soft and moist. The outer bark is a layer of dead bark that forms the exterior surface of the tree stem. The outer bark is frequently dry and corky. [8]

Biomass — Any plant-derived organic matter. Biomass available for energy on a sustainable basis includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, and other waste materials including some municipal wastes. Biomass is a very heterogeneous and chemically complex renewable resource.

Biomass Processing Residues — Byproducts from processing all forms of biomass that have significant energy potential. For example, making solid wood products and pulp from logs produces bark, shavings and sawdust, and spent pulping liquors. Because these residues are already collected at the point of processing, they can be convenient and relatively inexpensive sources of biomass for energy.

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Carbohydrate — Organic compounds made up of carbon, hydrogen, and oxygen and having approximately the formula $(CH_2O)_n$; includes cellulosics, starches, and sugars [8].

Cellulose — The carbohydrate that is the principal constituent of wood and other biomass and forms the structural framework of the wood cells. It is a polymer of glucose with a repeating unit of $C_6H_{10}O_5$ strung together by ß-glycosidic linkages. The ß-linkages in cellulose form linear chains that are highly stable and

resistant to chemical attack because of the high degree of hydrogen bonding that can occur between chains of cellulose (see below). Hydrogen bonding between cellulose chains makes the polymers more rigid, inhibiting the flexing of the molecules that must occur in the hydrolytic breaking of the glycosidic linkages. Hydrolysis can reduce cellulose to a cellobiose repeating unit, $C_{12}H_{22}O_{11}$, and ultimately to glucose, $C_6H_{12}O_6$. Heating values for cellulose may be slightly different based upon the feedstock. Example values are shown below (higher heating value [HHV] at 30°C, dry basis) [3].

cotton linters: HHV=7497 BTU/LB (4172.0 cal/g, 17426.4 J/g)
wood pulp: HHV=7509.6 BTU/LB (4165.0 cal/g, 17455.6 J/g)

Linear Chains of Glucose linked by b-Glycosidic Bonds Comprise Cellulose

Linear Chains of Glucose linked by b-Glycosidic Bonds Comprise Cellulose

Chips — small fragments of wood chopped or broken by mechanical equipment. Total tree chips include wood, bark, and foliage. Pulp chips or clean chips are free of bark and foliage.

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Elemental Analysis — The determination of carbon, hydrogen, nitrogen, oxygen, sulfur, chlorine and ash in a sample. See Ultimate Analysis.

Extractives — Any number of different compounds in biomass that are not an integral part of the cellular structure. The compounds can be extracted from wood by means of polar and non-polar solvents including hot or cold water, ether , benzene, methanol, or other solvents that do not degrade the biomass structure. The types of extractives found in biomass samples are entirely dependent upon the sample itself [4].

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Fixed Carbon — The carbon remaining after heating in a prescribed manner to decompose thermally unstable components and to distill volatiles. Part of the proximate analysis group.

Forestry Residues — Includes tops, limbs, and other woody material not removed in forest harvesting operations in commercial hardwood and softwood stands, as well as woody material resulting from forest management operations such as precommercial thinnings and removal of dead and dying trees.

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Galactan — The polymer of galactose with a repeating unit of $C_6H_{10}O_5$. Found in hemicellulose it can be hydrolyzed to galactose.

Galactose — A six-carbon sugar with the formula $C_6H_{12}0_6$. A product of hydrolysis of galactan found in the hemicellulose fraction of biomass.

Glucan — The polymer of glucose with a repeating unit of $C_6H_{10}O_5$ [2]. Cellulose is a form of glucan. Can be hydrolyzed to glucose.

Glucose — A simple six-carbon sugar $C_6H_{12}O_6$. A product of hydrolysis of glucan found in cellulose and starch. A sweet, colorless sugar that is the most common sugar in nature and the sugar most commonly fermented to ethanol.

Guaiacyl — A chemical component of lignin. It has a six-carbon aromatic ring with one methoxyl group attached. It is the predominant aromatic structure in softwood lignins. See syringyl.

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Hardwood — One of the botanical groups of dicotyledonous trees that have broad leaves in contrast to the conifers or softwoods. The term has no reference to the actual hardness of the wood. The botanical name for hardwoods is angiosperms. Short-rotation, fast growing hardwood trees are being developed as future energy crops. They are uniquely developed for harvest from 5 - 8 years after planting. Examples include: Hybrid poplars (*Populus sp*.), Hybrid willows (*Salix sp*.), Silver maple (Acer saccharinum), and Black locust (Robinia pseudoacacia).

Heating Value — Higher heating value (HHV) is the potential combustion energy when water vapor from combustion is condensed to recover the latent heat of vaporization. Lower heating value (LHV) is the potential combustion energy when water vapor from combustion is not condensed. See also higher heating value and lower heating value.

Hemicellulose — Hemicellulose consists of short, highly branched chains of sugars. In contrast to cellulose, which is a polymer of only glucose, a hemicellulose is a polymer of five different sugars. It contains five-carbon sugars (usually D-xylose and L-arabinose) and six-carbon sugars (D-galactose, D-glucose, and D-mannose) and uronic acid. The sugars are highly substituted with acetic acid. The branched nature of hemicellulose renders it amorphous and relatively easy to hydrolyze to its constituent sugars compared to cellulose. When hydrolyzed, the hemicellulose from hardwoods releases products high in xylose (a five-carbon sugar). The hemicellulose contained in softwoods, by contrast, yields more six-carbon sugars.

Herbaceous Plants — Non-woody species of vegetation, usually of low lignin content such as grasses.

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Herbaceous Energy Crops — Perennial non-woody crops that are harvested

annually, though they may take 2 to 3 years to reach full productivity. Examples include: Switchgrass (*Panicum virgatum*), Reed canarygrass (*Phalaris arundinacea*), Miscanthus (*Miscanthus x giganteus*), and Giant reed (*Arundo donax*).

Hexose — any of various simple sugars that have six carbon atoms per molecule (e.g. glucose, mannose, and galactose.)

Higher Heating Value (HHV, also known as Gross Heat of Combustion) — The heat produced by combustion of one unit of substance at constant volume in an oxygen bomb calorimeter under specified conditions. The conditions are: initial oxygen pressure of 2.0-4.0 MPa (20-40 atm), final temperature of 20°-35°C, products in the form of ash, liquid water, gaseous CO_2 and N_2, and dilute aqueous HCl and H_2SO_4. It is assumed that if significant quantities of metallic elements are combusted, they are converted to their oxides. In the case of materials such as coal, wood, or refuse, if small or trace amounts of metallic elements are present, they are unchanged during combustion and are part of the ash.

Holocellulose — The total carbohydrate fraction of wood — cellulose plus hemicellulose.

Hydrolysis — The conversion, by reaction with water, of a complex substance into two or more smaller units, such as the conversion of cellulose into glucose sugar units.

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Klason Lignin — Lignin obtained from wood after the non-lignin components of the wood have been removed with a prescribed sulfuric acid treatment. A specific type of acid-insoluble lignin analysis.

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Lignin — The major noncarbohydrate, polypenolic structural constituent of wood and other native plant material that encrusts the cell walls and cements the cells together. It is a highly polymeric substance, with a complex, cross-linked, highly aromatic structure of molecular weight about 10,000 derived principally from coniferyl alcohol ($C_{10}H_{12}O_3$) by extensive condensation polymerization. Higher heating value (oven dry basis): HHV=9111 BTU/LB (5062 CAL/G, 21178 J/G) [3].

Lignin Ratio of MeO to C9 — Lignin empirical formulae are based on ratios of methoxy groups to phenylpropanoid groups (MeO:C_9). The general empirical formula for lignin monomers is $C_9H_{10}O_2$ (OCH_3)n, where n is the ratio of MeO to C9 groups. Where no experimental ratios have been found, they are estimated as follows: 0.94 for softwoods; 1.18 for grasses; 1.4 for hardwoods. These are averages of the lignin ratios found in the literature. Paper products, which are produced primarily from softwoods, are estimated to have an MeO:C9 ratio of 0.94.

Lignin Pseudo-Molecule for Modeling — The n Lignin ratio of methoxy groups

to phenylpropanoid groups (MeO:C9) is used to calculate an ultimate analysis for the lignin pseudo-molecule and then this ultimate analysis is used to estimate other properties of the molecule, such as its higher and lower heating values.

Lignocellulose — Refers to plant materials made up primarily of lignin, cellulose, and hemicellulose.

Lower Heating Value (LLV also known as Net Heat of Combustion) — The heat produced by combustion of one unit of a substance, at atmospheric pressure under conditions such that all water in the products remains in the form of vapor. The net heat of combustion is calculated from the gross heat of combustion at 20°C by subtracting 572 cal/g (1030 Btu/lb) of water derived from one unit mass of sample, including both the water originally present as moisture and that formed by combustion. This subtracted amount is not equal to the latent heat of vaporization of water because the calculation also reduces the data from the gross value at constant volume to the net value at constant pressure. The appropriate factor for this reduction is 572 cal/g [3].

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Mannan — The polymer of mannose with a repeating unit of $C_6H_{10}O_5$ [2]. Can be hydrolyzed to mannose.

Mannose — A six-carbon sugar $C_6H_{12}0_6$. A product of hydrolysis of mannan found in the hemicellulose fraction of biomass.

Mass Closure (%) — The percent by weight of the total samples extracted from the biomass sample compared to the weight of the original sample. It is a sum of the weight percent of moisture, extractives, ash, protein, total lignin, acetic acid, uronic acids, arabinan, xylan, mannan, galactan, glucan, and starch. This is a good indicator of the accuracy of a complete biomass compositional analysis.

Moisture — This is a measure of the amount of water and other components that are volatilized at 105°C present in the biomass sample [6].

Moisture Free Basis — Biomass composition and chemical analysis data is typically reported on a moisture free or dry weight basis. Moisture (and some volatile matter) is removed prior to analytical testing by heating the sample at 105°C to constant weight. By definition, samples dried in this manner are considered moisture free.

Monosaccharide — a simple sugar such as a five-carbon sugar (xylose, arabinose) or six-carbon sugar (glucose, fructose). Sucrose, on the other hand is a disaccharide, composed of a combination of two simple sugar units, glucose and fructose.

Municipal Wastes — Residential, commercial, and institutional post-consumer wastes contain a significant proportion of plant-derived organic material that constitutes a renewable energy resource. Waste paper, cardboard, construction and demolition wood waste, and yard wastes are examples of biomass resources in municipal wastes.

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Native Lignin — The lignin as it exists in the lignocellulosic complex before separation.

Neutral Detergent Fiber (NDF) — Organic matter that is not solubilized after one hour of refluxing in a neutral detergent consisting of sodium lauryl sulfate and EDTA at pH 7. NDF includes hemicellulose, cellulose, and lignin. [8]

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Polysaccharide — A long-chain carbohydrate containing at least three molecules of simple anhydrosugars linked together. Examples include cellulose and starch.

Proximate Analysis — The determination, by prescribed methods, of moisture, volatile matter, fixed carbon (by difference), and ash. The term proximate analysis does not include determinations of chemical elements or determinations other than those named [7]. The group of analyses is defined in ASTM D 3172.

Protein — A protein molecule is a chain of up to several hundred amino acids and is folded into a more or less compact structure. Because about 20 different amino acids are used by living matter in making proteins, the variety of protein types is enormous. In their biologically active states, proteins function as catalysts in metabolism and to some extent as structural elements of cells and tissues [7]. Protein content in biomass (in mass %) can be estimated by multiplying the mass % nitrogen of the sample by 6.25.

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Residues, Biomass — Byproducts from processing all forms of biomass that have significant energy potential. For example, making solid wood products and pulp from logs produces bark, shavings and sawdust, and spent pulping liquors. Because these residues are already collected at the point of processing, they can be convenient and relatively inexpensive sources of biomass for energy.

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Saccharide — A simple sugar or a more complex compound that can be hydrolyzed to simple sugar units.

Softwood — Generally, one of the botanical groups of trees that in most cases have needle-like or scale-like leaves; the conifers; also the wood produced by such trees. The term has no reference to the actual hardness of the wood. The botanical name for softwoods is gymnosperms.

Starch — A molecule composed of long chains of a-glucose molecules linked together (repeating unit $C_{12}H_{16}O_5$). These linkages occur in chains of a-1,4 linkages with branches formed as a result of a-1,6 linkages (see below). This polysaccharide is widely distributed in the vegetable kingdom and is stored in all grains and tubers. A not-so-obvious consequence of the a linkages in starch is that this polymer is highly amorphous, making it more readily attacked by human and animal enzyme systems and broken down into glucose. Gross heat of

combustion: Qv(gross)=7560 Btu/lb (4200 cal/g,17570 J/g)[3].

Diagram of the structure of glucose

The polymeric structure of glucose in starch tends to be amorphous

Stover — The dried stalks and leaves of a crop remaining after the grain has been harvested.

Structural Chemical Analysis — The composition of biomass reported by the proportions of the major structural components; cellulose, hemicellulose, and lignin. Typical ranges are shown in the table below.

Component	Percent Dry Weight
Cellulose	40-60%
Hemicellulose	20-40%
Lignin	10-25%

Syringyl — A component of lignin, normally only found in hardwood lignins. It has a six-carbon aromatic ring with two methoxyl groups attached. See guaiacyl.

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Total Lignin — The sum of the acid soluble lignin and acid insoluble lignin fractions.

Total Solids — The amount of solids remaining after all volatile matter has been removed from a biomass sample by heating at 105°C to constant weight [6].

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Ultimate Analysis — The determination of the elemental composition of the organic portion of carbonaceous materials, as well as the total ash and moisture. Determined by prescribed methods. See **elemental analysis** [8].

Uronic Acid — A simple sugar whose terminal -CH2OH group has been oxidized to an acid, COOH group. The uronic acids occur as branching groups

bonded to hemicelluloses such as xylan [8].

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Volatile Matter — Those products, exclusive of moisture, given off by a material as a gas or vapor, determined by definite prescribed methods that may vary according to the nature of the material [8]. One definition of volatile matter is part of the proximate analysis group usually determined as described in ASTM D 3175.

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Whole Tree Chips — wood chips produced by chipping whole trees, usually in the forest. Thus the chips contain both bark and wood. They are frequently produced from the low-quality trees or from tops, limbs, and other logging residues.

Willstatter Lignin — Lignin obtained from the lignocellulosic complex after it has been extracted with fuming hydrochloric acid.

Wood — a solid lignocellulosic material naturally produced in trees and some shrubs, made of up to 40%-50% cellulose, 20%-30% hemicellulose, and 20% - 30% lignin.

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Xylan — A polymer of xylose with a repeating unit of $C_5H_80_4$, found in the hemicellulose fraction of biomass. Can be hydrolyzed to xylose. Gross heat of combustion: Q_v(gross)=17751.9 Jg-1[3].

Xylose — A five-carbon sugar $C_5H_{10}0_5$. A product of hydrolysis of xylan found in the hemicellulose fraction of biomass.

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References:

1. Ehrman, Tina. *Determination of Acid-Soluble Lignin in Biomass*. NREL-LAP-004. Golden, CO: National Renewable Energy Laboratory, September 9,1996.
2. Voet, Donald; Voet, Judith G. *Biochemistry*. New York: John Wiley, 1990.
3. Domalski, E.S.; Milne T.A., ed. Thermodynamic Data for Biomass Materials and Waste Components. The ASME Research Committee on Industrial and Municipal Wastes, New York: The American Society of Mechanical Engineers, 1987.
4. Fengel, Dietrich; Gerd, Wegener. *Wood Chemistry, Ultrastructure, and Reactions*. Berlin-New York: Walter de Gruyter, 1989.
5. Smook, Gary A. *Handbook for Pulp and Paper Technologists*. Vancouver, BC: Angus Wilde Publications, 1992.
6. Ehrman, Tina. *Standard Method for Determination of Total Solids in Biomass*. NREL-LAP-001. Golden, CO: National Renewable Energy

Laboratory, October 28,1994.
7. "Biofuels Glossary." (September 1986). Solar Technical Information Program, Solar Energy Research Institute.
8. Milne, T.A.; Brennan, A.H.; Glenn, B.H. *Sourcebook of Methods of Analysis for Biomass Conversion and Biomass Conversion Processes*. SERI/SP-220-3548. Golden, CO: Solar Energy Research Institute, February 1990.

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Content Last Updated: 06/15/2004