Biomass Gasification

FEEDSTOCK CLASSIFICATION

Lignocellulosic biomass and organic materials

FEEDSTOCK EXAMPLES

- alfalfa
- corn stover
- crop residues
- debarking waste
- field corn
- forage grasses
- forest residues
- hazardous organic waste
- industrial organic waste
- manure (dairy)
- manure (poultry)
- manure (swine)
- municipal solid waste
- paper mill residue
- pomace, scrap and spoilage (fruit & vegetable processing)
- sawdust
- sewage sludge
- spent grains
- spent hops
- spent yeast
- sweet corn
- switchgrass
- tires
- waste paper
- waste wood chips
- wood chips

FEEDSTOCK RESTRICTIONS

The chemical composition of the feedstock influences the constituents in the product gas, and the gasification design and product gas cleanup method must be matched to the intended use. Some feedstocks may prove more costly or challenging to gasify and clean if the product gas must be very pure. For example, a forest waste feedstock with a high alkali content (sodium, potassium) must have the alkali cleaned from the product gas prior to use in a gas turbine. In general, feedstocks should have a high carbon-to-nitrogen ratio, relatively little sulfur, and moisture content of less than 50 percent.

PROCESS DESCRIPTION

Biomass gasification is a high-temperature process (600 to 1000^{o}C)[1] to decompose the complex hydrocarbons of biomass into simpler gaseous molecules, primarily hydrogen, carbon monoxide, and carbon dioxide. In most cases, some char and tars are also formed, along with methane, water, and other constituents. Hydrogen and carbon monoxide are the desired product gases, because unlike combustion gases, they can be directly fired into a gas turbine for power generation or used in chemical synthesis. A primary advantage of biomass gasification over biomass combustion is that the power generation efficiency of a gas turbine combined cycle system can be as much as twice the efficiency of biomass combustion processes, which uses a steam cycle alone.

The gasification products cannot be readily stored, so the gasification system is integrated with other conversion processes to utilize the output. The product gas must be cleaned of solids, tars, and other contaminants sufficient for the intended use. A wide range of clean up methods are used. Co-firing the product gases in an auxiliary boiler for heating generally requires minimal cleanup, while use in gas turbines, fuel cells, and chemical synthesis demands high levels of cleanliness.

Gasification of biomass has been achieved through a wide range of designs for the gasification chamber. The design greatly influences the relative proportions of product gases and contaminants, and therefore the energy content and potential uses. Gasification by direct heating in the gasification chamber allows a limited supply of air, oxygen, steam or a combination to serve as a partial oxidizing agent for heat generation. When air is the oxidant, nitrogen accounts for about half the product gas.[2] This dilutes the concentration of hydrogen and carbon monoxide gases, resulting in a low-energy "fuel gas" or "wood gas," with a heating value[1] of 2.5 to 8.0 MJ/Nm^3. The low energy gas is generally suitable for combustion to produce thermal energy, although microturbines are being developed for low energy wood gas.[3]

Indirect heating provides gasification through an external heat source, with or without the addition of steam, with minimal oxygen. The addition of steam causes a steam reforming reaction that increases the amount of hydrogen in the product gases, raising the energy content of the product gas. Direct firing with pure oxygen, with or without steam, also results in a medium energy content product gas, with a heating value[1] in the range of 10 to 20 MJ/Nm^3. Reaction chambers may be either atmospheric or high pressure reaction chambers, up to 20 atm.[1] The cleaned medium energy content gases can be used as auxiliary fuel in boilers, as a fuel for electricity and steam generation via gas turbines or fuel cells, or as a feedstock in the production of industrial chemicals such as methanol, ethanol and acetic acid.[4]

Size of biomass gasification power generation units varies from small scale systems that generate 5 to 25 kW of electricity[5] to industrial and electric utility scale systems in the 5 MW to 12 MW electric range.[1] Systems providing up to 85 MW thermal energy are co-firing product gas into utility power generating stations.[1]

PRIMARY BIOBASED PRODUCTS

Biomass gasification produces a combustible mixture of raw gases that vary according to the feedstock and gasification approach. Steam reformed, indirect, and oxygen fired direct gasification systems produce **biobased syngas,** a medium energy combustible and reactive mixture rich in hydrogen and carbon monoxide with a heating value[1] in the range of 10 to 20 MJ/Nm^3. Air fired direct gasification systems produce a low-energy, **biobased fuel gas,** with a heating value[1] of 2.5 to 8.0 MJ/Nm^3.

PROCESS BYPRODUCTS

Hydrogen and carbon monoxide are the desired product gases from gasification. Systems producing either fuel gas or syngas must deal with the cleanup of five primary contaminants including: particulates (mineral ash and char), alkali compounds, tars, nitrogen-containing components, and sulfur.[1] Methane, ethane, and other hydrocarbons are acceptable if the products gases are to be combusted. For use in fuel synthesis or fuel cells, they must be reduced to acceptable levels. Carbon dioxide and water are also produced.

MAJOR EQUIPMENT

The main systems of the gasification plant are fuel feeding, gasification, and gas cleanup. Fuel feeding systems may direct feed the biomass fuel, pelletize the biomass, or dry and grind the fuel to a uniform size. Biomass gasifiers have been built and operated using a wide variety of designs, including updraft or downdraft fixed beds, fluidized beds where fluidized or entrained solids serve as the bed material, and others such as moving grate bed reactors. The reaction chambers may be either atmospheric or pressurized to 20 atm. Gas cleanup systems may contain several components such as cyclones, scrubbers, or filters; each of which removes one or more byproduct contaminants.[1] Gas cleanup may also include secondary equipment to adjust the gas composition and temperature.

ENERGY REQUIRED

A series of case studies have been performed on the three conversion routes for combined heat and power applications of biomass—direct combustion, gasification, and cofiring.[6] For a 75 MW electric generating plant without combined heat and power, the study reports direct biomass combustion is 30% efficient, while gasification is 36% efficient.[6] For a 75 MW electric generating plant with combined heat and power, the study reports direct biomass combustion is 62% efficient, while gasification is 82% efficient.[6]

CAPITAL AND OPERATING COST

Capital and operating costs vary widely. Consult with suppliers of individual systems. Some data is reported in the Gasifier Inventory database.[9] Capital costs for mid-sized (75 MW electric), first-of-a-kind biomass gasification combined cycle electric plants are estimated to be in the $1,800-$2,000/kWe range, with the cost dropping rapidly to the $1400/kWe range for a mature plant in the 2010 time frame.[6] Capital costs for biomass gasification plants that produce only thermal energy or co-fire product gases into existing electric generating plants are significantly less costly. For example, a 16 MW thermal output plant was built in Jonesboro, Arkansas by Primenergy in 1996 at a cost of $5 million ($312/kW thermal).[9]

Assuming a base feed cost of $2/Mbtu, the cost of production from gasification has been recently estimated at 6.7¢/kWh for electricity for a 75 MW plant.[6] Steam costs were estimated at $6.70 per 1000 lb steam.[6] Assuming a base feed cost of zero, the cost of production from gasification has been recently estimated at about 5¢/kWh for electricity for a 75 MW plant.[6] Steam costs were estimated at $5.00 per 1000 lb steam.[6]

COMMERCIALIZATION STATUS

Biomass gasification is an emerging commercial technology evolving out of intensive R&D in the 1970's and 1980's, although its developmental roots in small-scale biomass gasifiers and coal gasification date to early in the 20th century. Biomass gasification systems from small to large are commercially available. Many technology developers are in the prototype and first commercial demonstration stage.

Research is ongoing worldwide. One example is the use of supercritical water for gasification. Supercritical water – which exists above 706°F and 3191 psi – has the density of liquid but the diffusivity of vapor, making it a unique medium for dissolving biomass. By being placed in supercritical water, plant biomass is easily broken into constituents such as cellulose, which is itself easily broken apart into gaseous products such as hydrogen.[7] The process is in particular suitable for the conversion of wet organic materials (moisture content 70 - 95%) which can be renewable or non-renewable.[8]

COMMERCIAL SUPPLIERS

The Gasifier Inventory[9] gives an overview of existing biomass gasifier installations and accompanying manufacturers. The scope covers all types of gasifier technologies, capacity ranges and manufacturers, worldwide. Another source for information on suppliers is the Biomass Energy Foundation (BEF), a non profit foundation devoted to biomass energy and specializing in gasification.[10]

An example of a smaller scale gasification unit is provided by the Community Power Corporation of Littleton Colorado.[11] They produce the BioMax Power System, a modular system to produce heat, electricity, and shaft power from wood scraps, forest and agricultural residues. They currently offer a 15 kW electric unit, with modules under development that will provide electrical power output from 5 kW to 50 kW, and thermal output from 50,000 btu/hr to 500,000 btu/hr.

An example of a mid-sized gasification system is provided by Carbona Corporation, of Atlanta Georgia.[12] Through its sister company Carbona Inc., it has signed a contract with I/S Skive Fjernvarme for delivery of a Biomass Gasification Plant to Skive, Denmark for a Combined Heat and Power (CHP) plant. The CHP plant will produce 5.5 MW of electricity and 11.5 MW of district heat for the town of Skive. The plant, which will be the first commercial application of Carbona's technology, will start construction in late fall 2004 and initial operations by the end of 2005.

Large biomass gasification systems are operating in the U.S. Future Energy Resources Corporation, an Atlanta-based, privately held technology development and marketing company, was formed in 1992 to commercialize and market a gasification process now known as the FERCO SilvaGas process, originally developed by the Battelle Memorial Institute in the 1980s. FERCO selected the McNeil Generation Station in Burlington, Vermont as the location to build its first commercial scale plant in 1994, with 5 MW electric capacity.[1] FERCO is now actively marketing the SilvaGas process worldwide.[13]

Another large gasification system supplier is Primenergy, L.L.C. an Oklahoma corporation with principal offices located in Tulsa, Oklahoma. Primenergy has a plant in Stuttgart, Arkansas that gasifies over 500 tons per day of rice hulls with electrical power generation, via steam turbine, of over 12 MW, with the ability to extract up to 100,000 pounds per hour of medium pressure process steam.[14] Primenergy has other plants within and outside the U.S.

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[14] Primenergy, L.L.C, P O Box 581742, Tulsa Oklahoma 74158, Phone: (918) 835-1011 **http://www.primenergy.com** (April 21, 2004).