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INTEGRATING BIOMASS & ALTERNATIVE FUELS INTO TODAY'S ETHANOL PLANTS

Biomass: The Natural Alternative

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There are many political and economic pressures facing the ethanol industry today. These pressures include opposition to use of fossil fuels, rising costs of raw feed stocks, high natural gas prices, and depressed market prices for ethanol. While most of these pressures are completely out of the hands of existing ethanol plant owners, there is an alternative available to dramatically improve the plants bottom line profits and eliminate the use of fossil fuels. This alternative is to add a renewable energy solid fuel boiler to displace the use of high cost natural gas.

The utilization of biomass in a modern energy system provides an environmentally friendly solution to economic and greenhouse gas issues. On the economic side, biomass is used to replace expensive natural gas in the production of steam and/or electrical power. This significantly reduces the plant's energy costs. From an environmental standpoint, the use of renewable fuels can actually decrease the carbon footprint of the plant when displacing fossil fuels such as coal and natural gas.

The first step in deciding if biomass makes sense for a plant is to understand the potential applications for biomass energy in today's modern ethanol plant and to identify those best suited to a specific plant. Once the potential uses for the biomass energy are identified for the facility, the next step is to identify what sources and types of biomass are available. The final step is to determine the most applicable technology to use.

In some cases the process and/or biomass fuel proposed for the facility will be a determining factor in selecting the type of technology best suited for the plant. In other cases multiple technologies may be applicable for the efficient conversion of the biomass into clean forms of energy and the decision will be based strictly on economics of the installed system.

Biomass Applications in the Ethanol Industry

The most obvious use for biomass is its utilization as fuel in a boiler that produces steam for process and/or power generation. This application of biomass as a fuel results in a dramatic decrease in natural gas costs related to steam production. Under the proper economic circumstances power production from steam produced in the biomass boiler can also be considered.

A second advantage to producing steam with the right biomass energy system is the ability for energy system to take in the dryer exhaust gases and use them as the energy system's combustion air. This eliminates the use of energy wasting, high maintenance, RTO's.

Should a plant have steam dryers the only step required for replacing the natural gas is the installation of the biomass boiler system. Should the plant's dryers be direct fired it is also necessary to utilize a biomass conversion technology that not only produces steam, but can also provide hot air that is used to replace energy supplied by the natural gas burners on the dryers.

Table 1 below compares the cost of natural gas to biomass for a typical ethanol plant.

Fuel Costs $/MMBtu	Natural Gas 9.7	Coal 2.6	Wood 2.5	Ag Waste 0.81	Tires/C&D -0.5	RDF -2.2
Boiler Size					Tipping Fee	Fuels $$$
75,000	$6,595,952	$1,767,987	$1,699,988	$550,796	-$339,998	-$1,495,989
100,000	$8,794,602	$2,357,316	$2,266,650	$734,395	-$453,330	-$1,994,652
125,000	$10,993,253	$2,946,645	$2,833,313	$917,993	-$566,663	-$2,493,315
150,000	$13,191,903	$3,535,974	$3,399,975	$1,101,592	-$679,995	-$2,991,978
175,000	$15,390,554	$4,125,303	$3,966,638	$1,285,191	-$793,328	-$3,490,641
200,000	$17,589,204	$4,714,632	$4,533,300	$1,468,789	-$906,660	-$3,989,304
225,000	$19,787,855	$5,303,961	$5,099,963	$1,652,388	-$1,019,993	-$4,487,967
250,000	$21,986,505	$5,893,290	$5,666,625	$1,835,987	-$1,133,325	-$4,986,630
275,000	$24,185,156	$6,482,619	$6,233,288	$2,019,585	-$1,246,658	-$5,485,293
300,000	$26,383,806	$7,071,948	$6,799,950	$2,203,184	-$1,359,990	-$5,983,956
325,000	$28,582,457	$7,661,277	$7,366,613	$2,386,782	-$1,473,323	-$6,482,619
350,000	$30,781,107	$8,250,606	$7,933,275	$2,570,381	-$1,586,655	-$6,981,282

Table 1 Natural Gas Cost vs. Alternative Fuel Costs

What is Biomass?

Biomass is organic matter available on a renewable basis including forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, fast-growing trees and plants, industrial wastes, and some municipal wastes such as construction & demolition (C&D) wastes.

The range of biomass fuels is broad and can be found in most locations. Examples of biomass fuels used successfully in fluidized bed systems include Alfalfa Straw, Almond Brush, Almond Shells, Almond Wood, Apple Wood, Apricot Wood, Bark, Barley Straw, Bean Stover, Board Plant Waste, Bran, Cherry Pits, Cattle Manure, Chicken Litter, Citrus Trees, Coffee Grounds, Construction & Demolition (C&D) Waste, Corn Cobs, Corn Stalks, Cotton Gin Wastes, Cotton Seed Hulls, Cotton Stalks, Cow Manure, Cubed Garlic, Distillers Grains (wet or dry), Energy Grass, Fig Culls, Fig Wood, Garlic & Onion Skins, Germ, Grape Canes, Grape Pomace, Grape Scaffolds, Hardwoods, Lignin, Manure & Straw, Municipal Sludge, Nectarine Wood, Oat Straw, Olive Pits, Orange Peel & Pulp, Paper Sludge, Paunch Manure, Peach Pits, Peach Wood, Pear Wood, Peat, Pecan Shells, Pistachio Shells, Pistachio Wood, Planer Shavings, Plum Wood, Prune Pits, Prune Wood, Race Track Shavings, Race Track Straw, Railroad Ties, Rice Hulls, Rice Straw, Safflower Stalks, Scum Grease, Sander Dust, Saw Dust, Slash, Softwoods, Sunflower Hulls, Syrup, Tobacco Sludges, Tomato Pomace, Urban Wood Waste, Walnut Shells, Walnut Wood, Wheat Straw, Woodex Pellets and Zinc Borate Impregnated OSB Waste.

Selecting the Right Biomass Energy System

After deciding to install a biomass energy system, the selection of the appropriate core energy conversion technology from the right company is the single most important decision. The major factors that should affect your decision when making a technology selection include the fuel you are planning to use, environmental/permit issues and the experience / history / reputation of the technology supplier. If financing is involved, lenders may require approval of the technology provider.

Fuel

When considering a technology the tendency is to focus on the fuels we are planning to use *today*, that are available *today*. This focus can be so strong that the fuels of *tomorrow* are overlooked or not considered. In some cases the fuels of *tomorrow* may not yet exist. Department of Energy studies of biomass fired energy systems show that after 5 years many plants have a very different fuel mix from that for which the plant was designed.

In this highly competitive industry, or any industry today for that matter, selecting a technology that allows for changes in fuel composition and type whether the changes are minor or radical is important. This includes not only the ability to utilize solid fuels with widely varying characteristics such as Btu value, moisture content, density, and size, but also the ability to accept liquid or gaseous fuels.

In other words, the system selected must be as fuel flexible as possible. A single fuel system or system with limited fuel capabilities may appear acceptable now but could prove to be very costly in the future.

Environmental/Permit Issues

As with any project public opinion can play a very deciding roll in the ease or difficulty encountered during the planning and permitting stages. In some cases public concern can last past the permitting stage and remain an issue well after the permits are issued.

Switching from natural gas to biomass should be a positive step in the public's opinion. To minimize potential opposition to a project, both the public and the regulators must believe the technology was selected because it is the best available technology to reduce emissions and limit the overall impact to the environment.

The Technology Supplier

When selecting a technology, it is also important to consider the history of both the technology and the technology provider.

Is the proposed technology innovative but mature and proven, is it outdated and past its prime, or is it in the very early stages of development - a serial number 1 or 2? What are the chances the system will perform as advertised or will it become an R&D project at the project's expense?

Who is the technology supplier? Is the proposed technology designer and supplier experienced or a startup company. While new companies may provide a workable technology, commonly they do not have the depth of experience, the technology maturity, financial backing, or operational history to provide acceptable risk levels to the financial community.

The final and ultimate question is *"Will the project's investors and lenders support the technology and technology supplier as a positive, economic and low risk choice?"*

The Biomass System

Two major components to a biomass energy system are the fuel receiving and storage system and the solid fuel boiler island.

Fuel Receiving and Handling Systems

Fuel receiving and storage systems can run the gambit from extremely simple to highly automated. The design of these systems is heavily influenced by the types of biomass fuels to be used, site size and conditions, plant environmental permit requirements and the plant's general operating philosophy.

A typical biomass fuel receiving system consists of:

- Truck Scale - Upon arrival at the plant fuel is weighed. If the plant already has a truck /scale it can be shared with the fuel system otherwise a truck scale is required. A scale is not required if the fuel is self generated.
- Unloading System - Fuel unloading is accomplished with either a truck unloader or by self unloading trucks.
- Screening System - To minimize fuel plugging in the storage and conveying systems the fuel passes through a screening device which removes oversize pieces.
- Fuel Storage - After screening the fuel is conveyed to the main storage site. This may be an open pile or an enclosed facility. There are many options in this area and careful study is required to select the proper style of system.
- Fuel Reclaimer and Transfer System - This system removes fuel from the main storage facility and delivers it to the biomass boiler. The design of the reclaimer and transport system is usually dictated, or heavily influenced, by the type of fuel storage system selected.

The fuel receiving and storage systems must be robust and designed to minimize the potential for plugging, bridging, and failures that may cause an interruption of the fuel supply to the boiler.

TECHNOLOGY CHOICES

Selection of the biomass boiler technology for your project is your single most critical decision. The technology must provide the maximum fuel flexibility for utilizing a wide range of fuels and fuel types. The boiler island must meet the most stringent emissions standards, both for regulatory and permitting, but also for public relations reasons. Finally, you must be able to finance the project based upon the technology selected.

There are many technologies being offered to convert biomass into steam or energy. These can be broken down into several general classifications including level of product maturity or commercialization. For this paper the focus is on mature commercialized energy systems. The technologies considered include suspension fired boilers, grate boilers, and fluidized bed thermal oxidizers and gasifiers.

Suspension Fired Boilers

The suspension fired boiler is usually the lowest capital cost of the three technologies under consideration. It is also the most limited technology in the types of fuel that can be used and it tends to have some of the highest emissions.

Suspension burners burn biomass in a horizontally mounted tube, or combustion chamber with one open end. Combustion air is provided by a fan that blows the air through an air manifold into the burner. Biomass is introduced into the burner from the side with high velocity air. Fuel and air are mixed as they swirl through the burner. Hot gases exit the burner through the open end of the tube.

Proper fuel is critical to this type of burner. The typical suspension burner fuel is dry with a maximum moisture content of 15 percent on a wet basis, and must be sized to 1/8-inch or less.

Since the fuel is fired through a burner operating at temperatures in excess of 2,400°F there is a significant amount of thermal NO_x formed. The thermal NO_x combines with the NO_x formed when a percentage of the fuel bound nitrogen is converted to NO_x during the combustion process. NO_x reduction is accomplished with a selective non-catalytic reduction (SNCR) system but the amount of reduction is limited due to the short reaction time allowed by this type of boiler’s design. There is no effective way to capture sulfur or other pollutants in the boiler itself. All emissions reduction must take place outside the boiler itself.

Grate or Stoker Boilers

There are many styles of grate boilers on the market today. Most, if not all grate boiler designs are not considered to be “State of the Art” due to their limited ability to switch between wide fuel variations during operation and their high emissions levels when compared to newer technologies.

Combustion grates come in many styles and configurations including slotted, pinhole, shaker, and traveling. In all cases the grates support the burning fuel and allow air to pass up through the fuel bed from below. The fuel bed tends to be deep and contain up to 45 minutes of fuel inventory. This feature makes it difficult to adjust quickly to load changes or changes in the fuel’s heating value.

Due to the many moving parts in the combustion zone and high temperature zones maintenance cost and time tends to be higher than with new technologies such as the fluidized bed.

Fixed grate spacing is a limiting factor when considering fuel size. A pinhole grate which is suited to sawdust or other fine fuels may not be able to operate of larger fuel particles and conversely, a slotted or herringbone style designed for larger chips, say 2"-3", may not be able to handle smaller fuel particles. In all cases moisture content of the fuel must remain fairly constant.

As with the suspension burners referenced above, grates operate at temperatures in excess of 2,200°F thereby creating a significant amount of thermal NO_x formed.

Fluidized Bed Technologies for Biomass

Fluidized bed technologies typically are inherently more fuel flexible and produce lower emissions. Thermal oxidization (combustion), gasification, and advanced staged gasification can all be accomplished using fluidized bed technologies. Each of these technologies has uses and advantages that need to be evaluated on a project by project basis.

What is a fluidized bed? The fluidized bed is comprised of a layer of sand-like material 'suspended' by an upward flowing stream of air. With sufficient air velocity to lift the particles of sand and hold them in suspension, this reaction zone resembles a violently boiling container of water, hence the term "fluidized bed." This turbulence created by the air and sand mixture results in extremely effective and efficient distribution of the incoming feedstock.

Thermal Oxidization

Thermal oxidation is the process of completely oxidizing the fuel creating hot gases that exit the fluidized bed cell and flow into a waste heat style boiler generating steam for the process or turbine/generator. This technology accepts the widest range of fuels and provides low CO, NO_x, and SO_2 emissions with minimal back-end gas cleanup equipment. The turbulent bed material acts to separate ash from the usable fuel particles, thereby assuring the most efficient conversion of every fuel particle into useable energy.

Complete oxidation, high efficiency and low emissions are governed by the three T's of thermal oxidation; temperature, time and turbulence. These three T's and resultant high efficiency and low emissions are the result of EPI's fluidized bed design featuring a refractory lined oxidation vessel in place of a normal water wall boiler section. Gases exiting the fluidized bed are subject to sufficient residence time before the removal of significant energy by heat transfer surfaces in the boiler. The flue gas temperature is elevated from a bed temperature of 1200 - 1,500°F to a vapor space temperature of less than 1,600 - 1,800°F over a long period of time in a turbulent environment. This turbulent environment with a regulated temperature ensures complete conversion of the available fuel to usable energy while limiting emissions of VOC's and other harmful gasses. Limiting the upper range of the temperature prevents the formation of thermal NO_x. The technology is capable of producing an ideal environment for thermal oxidation due to the high turbulence of the flue gas caused by the fluid bed action and the high velocity injection of overfire air. This creates a very through mixing of the flue gas with the overfire air. The mixing of combustion air with the flue gas combined with the minimum 4 second residence time provides very high combustion efficiency that results in an efficient system with very low CO, NO_x and VOC emissions.

When the fuel is oxidized, a portion of the fuel bound nitrogen is converted to NO_x. The NO_x formed in this manner can be reduced by 80%, or higher in some cases, using selective non-catalytic reduction (SNCR) system. NO_x reduction with SNCR when used in other styles of biomass boilers is typically limited to a maximum of 50%. The high reduction efficiency achieved by SNCR system is due to the excellent mixing properties of the reagent, typically ammonia, with the flue gas caused by the high turbulence of the flue gas and its extended residence time in the vessel.

SO_2 emissions are reduced in the vessel with the introduction of limestone or other similar reagent into the bed. When operated at the correct temperature limestone is calcined and reacts with fuel bound sulfur compounds to reduce SO_2 formation. The calcined limestone also combines with the biomass ash to raise the ash softening temperature which minimizes the potential for ash fouling in the boiler.

One of the premier fluidized bed technology suppliers, Energy Products of Idaho (EPI), developed a unique and highly effective method of incorporating boiler tubes directly in the bed region of the fluidized bed system. These modules have a very high heat transfer coefficient which reduces the system's overall mass flow and can replace up to 50% of the boiler's convective surface. They replace the need for flue gas recirculation and reduce the overall system capital cost.

Fluidized bed thermal oxidizers are the technology of choice when:

- The highest thermal oxidation efficiency is required.
- The greatest fuel flexibility is required. This includes the use of high moisture fuels (up to 70% MC), low moisture fuels (as low as 5% MC), the use of liquids, solids and gaseous fuels in the same system, and the use of high ash content fuels (+55% ash)
- Mixing of multiple fuels and fuel types in the same system
- Inbed sulfur capture is required.
- Thermal oxidization is also used for non-biomass fuels such as coal and lignite which have a low volatiles to carbon ratio.

Gasification

Gasification has become the politically preferred method of energy recovery from a variety of fuel feedstocks, including biomass and waste. Biomass gasification is a process of converting the feedstock, typically wood, paper, agricultural residue, or other waste products, into a synthetic gas that is utilized as a fossil fuel replacement. In biomass gasification, a portion of the feedstock is consumed to provide the heat energy required to convert the volatiles in the feedstock into a combustible gas. This is accomplished in a sub-stoichiometric (less oxygen than required for complete oxidation) environment. Depending upon the initial quality of the feedstock, a typical gasification process generates a low Btu gas, or LBG. typically in the range of 150-250 Btu per cubic foot. By comparison, natural gas, at similar pressures, contains about 1000 Btu per cubic foot.

While fluidized bed gasifiers share the same basic fluidized bed platform and mechanical components as the thermal oxidizer, the operating philosophies of the two technologies are diametrically opposed. The goal of the thermal oxidizer is to provide the most complete combustion possible. The gasifier on the other hand is designed to maximize the creation of CO, methane, hydrogen, and other gases formed through incomplete combustion.

The LBG created in the gasification process is used, in conjunction with burners specially designed for hot LBG fuel, to produce steam, or hot gas for dryers and calciners. Other potential applications for gasification include direct conversion of the gas to liquid fuels or, when gas cleaning technology is commercialized, using the LBG in reciprocating engines and turbines.

Fluidized bed gasifier is the technology of choice when:

- LBG is needed to direct fire another device such as a calciner or kiln
- For full or partial conversion of a pulverized coal (PC) boiler from coal to biomass
- Thermal oxidization is not politically correct
- Direct conversion from LBG to liquid fuels is desired

Advanced Staged Gasification

The advantages of the gasification process are combined with the inherent benefits of proven fluidized bed technology to create a process that represents the most advanced means of energy conversion and recovery currently available. In this process, gasification of biomass occurs in the fluidized bed reaction zone at temperatures of around 1200 - 1400 degrees Fahrenheit. This gas along with the remaining tar, char and ash enters a secondary reaction chamber where it is exposed to turbulent jets of air provided to complete the oxidation process. The air is introduced in multiple levels, or stages, whereby the temperature profile of the reactant gases can be better controlled to eliminate formation of gaseous pollutants, such as nitrogen dioxide (NOx). The design of this second stage oxidation unit provides for significant residence time, plus further mixing and enhanced turbulence in the gas stream at each stage of additional air injection. Emissions from this system are extremely low due to the staged introduction of oxygen where residence time, turbulence and temperature are optimized. In addition, flexibility in the system is significantly enhanced. The advanced staged gasifier can utilize normal biomass fuels with moisture contents of 5 -60%.

Once the fuel is completely oxidized in the secondary chamber it is introduced into a boiler for steam production.

A simplified diagram of the staged gasification cell is shown in figure 1 below. The fluidized bed/gasification zone of the unit is located in the base section and is represented as an oxygen starved zone. The balance of the air required for complete oxidation is introduced in the second stage area above the bed.

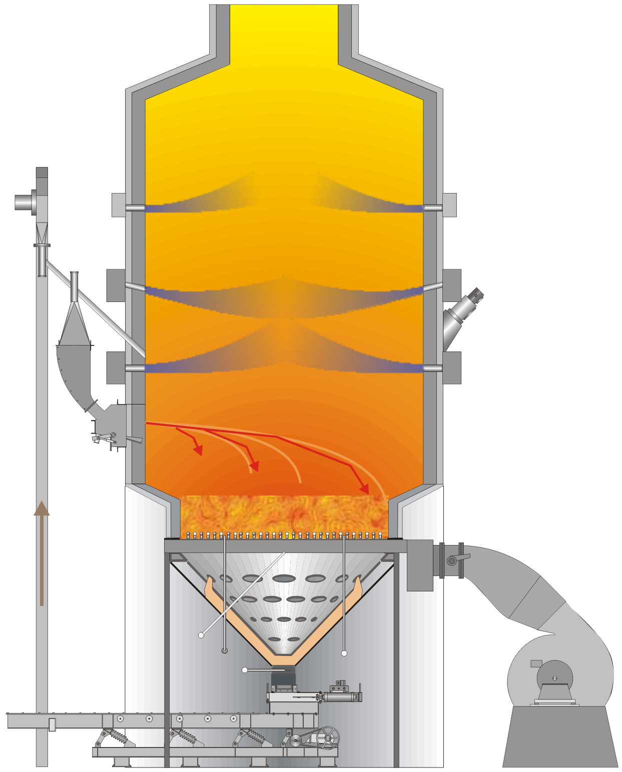

Figure 1 Typical EPI Fluidized Bed Staged Gasifier

EPI's advanced staged gasifier technology has been permitted in a non-attainment area such as New York state. This technology is in operation in several Canadian and US locations and has been successfully utilized to retrofit an existing 16 MW power boiler in New England.

The technology is qualified as Advanced Biomass Conversion Technology for renewable energy credits requirements in a number of states.

Fluidized bed advanced staged gasifier is the technology of choice when:

- Combustion is not considered politically correct
- An advanced *state of the art* conversion technology is mandated
- To destroy other plant VOC's (from dryers, press vents, etc.)
- For fuels with low softening temperature ash
- To reduce FD fan HP
- For gasification of wet fuels

The Existing Natural Gas Energy Center

When adding a biomass boiler to an existing facility, the natural gas boiler is usually left in place. It serves as a backup when the biomass boiler is shut down for annual maintenance or in the unlikely event a trip forces the biomass boiler off line.

Adding a biomass boiler to the existing energy center does not require the addition of all new ancillary boiler room equipment. Existing equipment such as the deaerator, boiler feedwater pumps, water treatment, etc. currently used with the existing natural gas boiler are now shared with the new biomass boiler.

The conversion of these ancillary systems to serve both the natural gas boiler and the new biomass boiler is simply a matter of adding new piping and valves between the now shared systems and the biomass boiler. The new piping allows the ancillary devices to be automatically switched between the boilers as necessary.

The new boiler system typically comes with a separate control system and human/machine interface (HMI) station. The HMI screen and control keyboard are located in the existing control room.

The new control system is fully programed for the operation of the biomass boiler and can be operated as a stand-alone system. Optionally, the biomass boiler controls can be integrated into the existing boiler control system or total plant distributed control system (DCS). The method of integrating the biomass boiler in to the current plant control room is at the option of the plant management.

Summary

Biomass boilers have a critical role to play in today's ethanol industry. They provide relief from high natural gas prices and the use of biomass can helps the industry's public image of creating a non-green fuel due to the perceived heavy use of fossil fuels in the manufacturing process.

The selection of the biomass boiler technology and technology supplier is critical to a project's success. The technology needs to be innovative , but mature enough to satisfy investors and lenders. At the same time as satisfying the financial side of the project, the regulator's and the public's perception of the technology must be one of confidence and acceptance for environmental issues.

Above all the selected technology must be appropriate for the proposed fuel but have the capability to switch to completely different fuels in the future as necessary for the plant to maintain its competitive edge in the marketplace.

Energy Products of Idaho has more than 35 years developing state of the art fluidized bed biomass energy systems which have operated on over 250 different fuels and fuel mixes. EPI's technology is classed as a State of the Art Biomass Conversion Technology by multiple states thereby qualifying the projects to qualify for renewable energy credits (REC's). EPI's technology has also helped bring nearly100 projects to a successful completion proving it to be a premier partner in projects both in the ethanol industry as well as many other industry segments.