New Technologies Advance Biomass for Power Generation

As U.S. utilities seek to increase the percentage of carbon-neutral biomass used in their generation portfolios, they must deal with a number of complex challenges unique to this fuel source. Several breakthrough technologies are poised to help promote greater use of biomaterials.

By Angela Neville, JD

Reflecting the growing role that biomaterials are playing in the electric power generation industry, this year's ELECTRIC POWER conference offered a session titled "Biomass Technology: From Harvest to Grid." Dr. Ashwani Gupta, engineering professor at the University of Maryland, and Ken Upchurch, vice president of sales and marketing for BRKS Rockwood Inc., served as session cochairs. The three speakers focused on several new technologies that promise to increase the successful use of biomass as a fuel for electric power generation.

Biomass proponents point to several advantages of this fuel source. For example, biomass energy sources such as trees are beneficial to the environment because they take in carbon dioxide (CO_2) as they grow. This can offset the CO_2 produced when they are burned as an energy source. In addition, using biomass such as municipal solid waste (MSW) can reduce waste disposal and landfill costs.

Table 1. Comparison of coal and coal/hardwood (HW) blends. The BCAS software tool benchmarks the propensities of fuel-related parameters involved in firing any coal/biomass blend or 100% biomass. *Source: International Environmental & Energy Consultants Inc.*

Factors	Base coal	Plus 20% HW	Plus 30% HW	Plus 50% HW	100% HW
Gross HV (mJ/kg)	24.70	22.70	21.80	20.20	17.04
Firing rate (kg/s)	60.00	69.00	72.00	78.00	92.00
Gas volume (Nm^3/s)	660.00	678.00	680.00	659.00	623.00
Dust (g/Nm^3)	11.80	7.90	6.90	5.20	0.50
SO_2 (g/Nm^3)	1.60	1.30	1.20	0.90	0.03
Parameters					
Abrasion	2	3	3	3	4
Erosion	1	2	2	2	3
Fouling	1	2	3	4	4
Slagging	0.67	3	3	3	3
Carbon in ash	2	1	1	1	1
Fuel combustibility	2	1	1	1	2
Char combustibility	1	1	1	1	1
Primary NO_x	2	1	1	1	1
Resistivity	1	1	1	1	1
Corrosion	1	1	1	1	1

Optimizing Biomass Cofiring with Coal

Dr. Anupam Sanyal, president of International Environmental & Energy Consultants Inc., said that to reduce CO_2 emissions in line with international agreements (to which the U.S. is not a party), there has been a recent upsurge worldwide in cofiring of biomass, considered a carbon-neutral fuel, with coal. However, the disparate quality of biomass poses a challenge for selecting the optimum blend/type of biomass for a given power plant, according to Sanyal. At present, this challenge is addressed by test-firing various mixtures, which involves considerable time and cost.

Sanyal described a new web-based software known as BCAS (biomass cofiring assessment and services), which incorporates the fundamental properties of combustion and mineral matter transformation. The only inputs required are standard fuel and ash properties.

The software tool instantaneously benchmarks the propensities of all fuel-related parameters involved in firing any coal/biomass blend, or even 100% biomass. These characteristics include grindability, abrasion, and combustion. The software also benchmarks the carbon in ash, erosion, corrosion, emission of particulates, and oxides of sulfur and nitrogen.

Sanyal said the software enables power plant operators to compare individual biomass samples/mixtures for their compatibility with the coal used in their plant. In addition to evaluating the parameters mentioned, a secondary combustion program uses the same inputs to evaluate total gas flow and fly ash and sulfur oxides carryover for a given generation output. The programs provide operators with a short list of "near-best" biomass mixtures for their plant without the need for a comprehensive test burn program, saving time and money.

In addition, Sanyal described the software's development and successful application as well as several examples of cofiring different types of biomass—including hardwood, bagasse, and tires—with world-traded coals (Table 1).

The results seen by plants using BCAS "demonstrate the capability of the software as a design and operational tool in determining the optimum biomass quality and quantity for cofiring with coal while maintaining the bottom-line revenue under emission compliance," Sanyal said.

Waste-to-Syngas Conversions

Michael Radovich, a consulting engineer with URS, described the conceptual design of a power plant designed to burn MSW. In 2010, the total MSW combusted for power generation in the U.S. was approximately 250 million tons, according to the U.S. Environmental Protection Agency. Organic materials continue to be the largest component of MSW, with paper and paperboard accounting for 29% and yard trimmings and food scraps accounting for another 27%. The remaining components include plastics, metals, rubber, leather, textiles, wood, glass, and other miscellaneous wastes.

Radovich said the new power plant design is an improvement over a previous Radovich cycle design, which he profiled in a 2009 ASME Power Conference presentation titled "The Radovich Cycle: A Novel MSW-Fired Heat Cycle."

Radovich said that to improve performance and reduce cost, fuel cell pressure has been increased, anode and cathode exhaust gas expanders have been placed between the fuel cell and gasifier, new gas cleanup technologies have been utilized, and an anode exhaust recycling loop has been added.

As with the original design, this revised system produces gas from MSW in a gasification vessel using steam and hot-bed material, Radovich said. Carbon-bearing ash and cooled bed material leave the gasification vessel and enter a combustor vessel, where the carbon is burned out and the bed material is reheated by combustion air. In this cycle, the combustion air or flue gas never combines with the fuel gas. It is compressed, passed through the cathode space of the fuel cells, then through the combustor vessel, and expanded to produce power.

Radovich also discussed syngas treatment, which starts with a gas mixture containing varying amounts of carbon monoxide, CO_2, and hydrogen. After leaving the gasification vessel, the syngas is sweetened and filtered to remove particulates and sulfur, then cooled to recover thermal energy and remove water vapor from the stream. The gas is then compressed and sent through a treatment system that removes heavy metals and CO_2 before the gas is heated and diluted with steam to prevent carbon coking. The gas then enters the anode space of a solid oxide fuel cell, where it is largely converted to steam and CO_2 before returning to the gasification vessel.

CO_2 for Biofuel Coproduction

Robert Tang, president and CEO of CEFCO Global Clean Energy, noted that CO_2 capture technologies for thermal power plants based on chemical absorption-adsorption of flue gas under conventional thermodynamic conditions "have very high energy penalties to obtain between 30% and 90% CO_2 removal and are not cost-efficient." They produce CO_2 with impurities—"not suitable for coproduction with another technology to make biofuels." The CEFCO process, in contrast, has been designed to work below 10% total energy penalty for CO_2 capture.

Tang, co-inventor of the CEFCO process, explained his company's process is based on aerodynamic reactor technology, where the post-operation "waste steam" (returning for condensation in the steam return loop) is injected through aerodynamic nozzles generating supersonic shockwaves, causing a collision between molecules of the flue gas and the select reagent. This, in turn, causes the formation of a subatmospheric and adiabatic reaction zone inside the reactor, which causes the CO_2 capture. This aero-physics phenomenon enables the endothermic-exothermic reactions desired in the intended selective pollutant capture and its conversion via relevant reagent(s) into solid products, after the metals or toxics are removed from the gas (the carbon recovery module is the last of four multipollutant capture reactor modules.)

Tang said that "within this condition, the targeted CO_2 intimately collides with and mixes with very fine fast-moving liquid droplets of the injected absorbing or adsorbing reagents."

Instead of capturing the CO_2 and sending it to a permanent storage facility or using the gas in an enhanced oil recovery process, Tang suggests a more practical use: "The low energy usage provides a cost-efficient pathway, together with another hydrocarbon technology, to coproduce liquid biofuels."

Hydrocarbon conversion technologies under intense research and development include special organic catalysts and engineered microbiological processes to directly produce biofuels.

CEFCO Global Clean Energy and Peerless Manufacturing Co. are partnering to operate a 1- to 3-MWe pilot plant at the Peerless facilities in Wichita Falls, Texas. The goal is to successfully demonstrate CO_2 and multipollutant capture. ■

—***Angela Neville, JD**, is POWER's senior editor.*

CIRCLE 28 ON READER SERVICE CARD

July 1, 2012

New Technologies Advance Biomass for Power Generation

By Angela Neville, JD

As U.S. utilities seek to increase the percentage of carbon-neutral biomass used in their generation portfolios, they must deal with a number of complex challenges unique to this fuel source. Several breakthrough technologies are poised to help promote greater use of biomaterials.

Reflecting the growing role that biomaterials are playing in the electric power generation industry, this year's ELECTRIC POWER conference offered a session titled "Biomass Technology: From Harvest to Grid." Dr. Ashwani Gupta, engineering professor at the University of Maryland, and Ken Upchurch, vice president of sales and marketing for BRKS Rockwood Inc., served as session cochairs. The three speakers focused on several new technologies that promise to increase the successful use of biomass as a fuel for electric power generation.

Biomass proponents point to several advantages of this fuel source. For example, biomass energy sources such as trees are beneficial to the environment because they take in carbon dioxide (CO_2) as they grow. This can offset the CO_2 produced when they are burned as an energy source. In addition, using biomass such as municipal solid waste (MSW) can reduce waste disposal and landfill costs.

Optimizing Biomass Cofiring with Coal

Dr. Anupam Sanyal, president of International Environmental & Energy Consultants Inc., said that to reduce CO_2 emissions in line with international agreements (to which the U.S. is not a party), there has been a recent upsurge worldwide in cofiring of biomass, considered a carbon-neutral fuel, with coal. However, the disparate quality of biomass poses a challenge for selecting the optimum blend/type of biomass for a given power plant, according to Sanyal. At present, this challenge is addressed by test-firing various mixtures, which involves considerable time and cost.

Sanyal described a new web-based software known as BCAS (biomass cofiring assessment and services), which incorporates the fundamental properties of combustion and mineral matter transformation. The only inputs required are standard fuel and ash properties.

The software tool instantaneously benchmarks the propensities of all fuel-related parameters involved in firing any coal/biomass blend, or even 100% biomass. These characteristics include grindability, abrasion, and combustion. The software also benchmarks the carbon in ash, erosion, corrosion, emission of particulates, and oxides of sulfur and nitrogen.

Sanyal said the software enables power plant operators to compare individual biomass samples/mixtures for their compatibility with the coal used in their plant. In addition to evaluating the parameters mentioned, a secondary combustion program uses the same inputs to evaluate total gas flow and fly ash and sulfur oxides carryover for a given generation output. The programs provide operators with a short list of "near-best" biomass mixtures for their plant without the need for a comprehensive test burn program, saving time and money.

In addition, Sanyal described the software's development and successful application as well as several examples of cofiring different types of biomass—including hardwood, bagasse, and tires—with world-traded coals (Table 1).

Factors	Base coal	Plus 20% HW	Plus 30% HW	Plus 50% HW	100% HW
Gross HV (mJ/kg)	24.70	22.70	21.80	20.20	17.04
Firing rate (kg/s)	60.00	69.00	72.00	78.00	92.00
Gas volume (Nm^3/s)	660.00	678.00	680.00	659.00	623.00
Dust (g/Nm^3)	11.80	7.90	6.90	5.20	0.50
SO_2 (g/Nm^3)	1.60	1.30	1.20	0.90	0.03
Parameters					
Abrasion	2	3	3	3	4
Erosion	1	2	2	2	3
Fouling	1	2	3	4	4
Slagging	0.67	3	3	3	3
Carbon in ash	2	1	1	1	1
Fuel combustibility	2	1	1	1	2
Char combustibility	1	1	1	1	1
Primary NO_x	2	1	1	1	1
Resistivity	1	1	1	1	1
Corrosion	1	1	1	1	1

Table 1. Comparison of coal and coal/hardwood (HW) blends. The BCAS software tool benchmarks the propensities of fuel-related parameters involved in firing any coal/biomass blend or 100% biomass. *Source: International Environmental & Energy Consultants Inc.*

The results seen by plants using BCAS "demonstrate the capability of the software as a design and operational tool in determining the optimum biomass quality and quantity for cofiring with coal while maintaining the bottom-line revenue under emission compliance," Sanyal said.

Waste-to-Syngas Conversions

Michael Radovich, a consulting engineer with URS, described the conceptual design of a power plant designed to burn MSW. In 2010, the total MSW combusted for power generation in the U.S. was approximately 250 million tons, according to the U.S. Environmental Protection Agency. Organic materials continue to be the largest component of MSW, with paper and paperboard accounting for 29% and yard trimmings and food scraps accounting for another 27%. The remaining components include plastics, metals, rubber, leather, textiles, wood, glass, and other miscellaneous wastes.

Radovich said the new power plant design is an improvement over a previous Radovich cycle design, which he profiled in a 2009 ASME Power Conference presentation titled "The Radovich Cycle: A Novel MSW-Fired Heat Cycle."

Radovich said that to improve performance and reduce cost, fuel cell pressure has been increased, anode and cathode exhaust gas expanders have been placed between the fuel cell and gasifier, new gas cleanup technologies have been utilized, and an anode exhaust recycling loop has been added.

As with the original design, this revised system produces gas from MSW in a gasification vessel using steam and hot-bed material, Radovich said. Carbon-bearing ash and cooled bed material leave the gasification vessel and enter a combustor vessel, where the carbon is burned out and the bed material is reheated by combustion air. In this cycle, the combustion air or flue gas never combines with the fuel gas. It is compressed, passed through the cathode space of the fuel cells, then through the combustor vessel, and expanded to produce power.

Radovich also discussed syngas treatment, which starts with a gas mixture containing varying amounts of carbon monoxide, CO_2, and hydrogen. After leaving the gasification vessel, the syngas is sweetened and filtered to remove particulates and sulfur, then cooled to recover thermal energy and remove water vapor from the stream. The gas is then compressed and sent through a treatment system that removes heavy metals and CO_2 before the gas is heated and diluted with steam to prevent carbon coking. The gas then enters the anode space of a solid oxide fuel cell, where it is largely converted to steam and CO_2 before returning to the gasification vessel.

CO_2 for Biofuel Coproduction

Robert Tang, president and CEO of CEFCO Global Clean Energy, noted that CO_2 capture technologies for thermal power plants based on chemical absorption-adsorption of flue gas under conventional thermodynamic conditions "have very high energy penalties to obtain between 30% and 90% CO_2 removal and are not cost-efficient." They produce CO_2 with impurities—"not suitable for coproduction with another technology to make biofuels." The CEFCO process, in contrast, has been designed to work below 10% total energy penalty for CO_2 capture.

Tang, co-inventor of the CEFCO process, explained his company's process is based on aerodynamic reactor technology, where the post-operation "waste steam" (returning for condensation in the steam return loop) is injected through aerodynamic nozzles generating supersonic shockwaves, causing a collision between molecules of the flue gas and the select reagent. This, in turn, causes the formation of a sub-atmospheric and adiabatic reaction zone inside the reactor, which causes the CO_2 capture. This aero-physics phenomenon enables the endothermic-exothermic reactions desired in the intended selective pollutant capture and its conversion via relevant reagent(s) into solid products, after the metals or toxics are removed from the gas (the carbon recovery module is the last of four multipollutant capture reactor modules.)

Tang said that "within this condition, the targeted CO_2 intimately collides with and mixes with very fine fast-moving liquid droplets of the injected absorbing or adsorbing reagents."

Instead of capturing the CO_2 and sending it to a permanent storage facility or using the gas in an enhanced oil recovery process, Tang suggests a more practical use: "The low energy usage provides a cost-efficient pathway, together with another hydrocarbon technology, to coproduce liquid biofuels."

Hydrocarbon conversion technologies under intense research and development include special organic catalysts and engineered microbiological processes to directly produce biofuels.

CEFCO Global Clean Energy and Peerless Manufacturing Co. are partnering to operate a 1- to 3-MWe pilot plant at the Peerless facilities in Wichita Falls, Texas. The goal is to successfully demonstrate CO_2 and multipollutant capture.

*— **Angela Neville, JD**, is POWER's senior editor.*

Close Window