Waste-to-Energy Technologies

The U.S. EPA Environmental Technology Verification (ETV) Program provides credible performance information for commercial-ready environmental technologies for the benefit of purchasers, regulators, and vendors/developers.[1] ETV has verified eight technologies (see **Table 1**) that produce or use fuels generated from biomass wastes.

ETV's Greenhouse Gas Technology (GHG) Center, operated by Southern Research Institute under a cooperative agreement with US EPA, verified two biogas processing systems and four distributed generation (DG) energy systems in collaboration with the Colorado Governors Office or the New York State Energy Research and Development Authority (NYSERDA).

The verified gas processing systems remove hydrogen sulfide (H_2S) and other sulfur species from biogas so it is amenable for DG energy system use. During verification testing one of the systems increased the low heating value (LHV) of the gas by 8.5%, from 569 British thermal units per standard cubic foot (Btu/scf) to 617 Btu/scf. The other system did not show any change in gas heating value after being processed.

Fuels from Waste

Opportunity fuels are usually by-products or waste streams from other processes. Although these fuels do not have the same heating value characteristics as conventional fossil fuels, they still are beneficial as a potential source of alternative energy, especially when used with distributed generation (DG) energy systems. Common opportunity fuels are anaerobic digester gas, landfill gas, wood and wood waste. These fuels are derived mostly from solid biomass waste such as crop residues, farm waste from animal feeding operations, municipal solid waste, sludge waste and wood waste.

The verified DG systems include one fuel cell, two internal combustion engines, and one microturbine in a heat and power application. All four DG systems were operated on-site using either landfill gas or anaerobic digester gas generated from animal waste or municipal sludge. Power production and emissions performance were verified for all four DG energy systems, as shown in **Table 2**.

(Continued on page 2)

Table 1. Summary of ETV Technologies that Have Been Verified, Plan to Verify and Use Fuels from Waste[A]

Technology Name	Technology Description/Application	Opportunity Fuel Source
Gas Processing Systems		
NATCO Group, Inc., Paques THIOPAQ	A Sour gas processing system for biogas purification that removes H_2S	Biogas from a water pollution control facility; LHV is 569 Btu/scf for processed gas.
US Filter/Westates Carbon, Gas Processing Unit (GPU) (verified with the PC25C Fuel Cell Power Plant)	A carbon based filter that removes H_2S, other sulfur species and hydrocarbons from biogas	Anaerobic digester gas from a water pollution control facility; LHV is 551 Btu/scf for processed gas
Fuel Cells		
UTC Fuel Cells, LLC, PC25™ Fuel Cell (Now called PureCell™ 200) (*Technology was tested using two different opportunity fuel source*)	A 200 kilowatt (kW) phosphoric acid fuel cell for commercial or institutional use with the potential for heat recovery in a CHP application	Biogas from municipal solid waste landfills; included a landfill gas processing unit, verified 1998, LHV is 446 Btu/scf
		Anaerobic digester gas from a wastewater treatment facility; included a gas processing unit, verified 2004; LHV is 550 to 650 Btu/scf
Internal Combustion Engines		
Martin Machinery Internal Combustion Engine	An internal combustion engine combined with heat recovery system for distributed electrical power and heat generation	Anaerobic digester gas from a Colorado Pork facility with up to 5,000 sows and an average LHV of 625 Btu/scf
CAT 379 Engine/Generator Set with Integrated Martin Machinery CHP	A DG/CHP system consisting of a Caterpillar Model 379, 200 kW engine-generator with integrated heat recovery capability	Anaerobic digester gas from a dairy farm with 1,725 cows and heifers; anaerobic digester gas has an average LHV of approximately 525 Btu/scf
Microturbines and Combined Heat and Power (CHP) Systems		
Capstone 30 kW Microturbine System	Microturbine combined with heat recovery system for distributed electrical power and heat generation	Anaerobic digester gas from a Colorado Pork facility with up to 5,000 sows and an average LHV of 625 Btu/scf
Flex, Flex-Microturbine® (Flex)[B] (planned verification 2011)	Uses a proprietary flameless catalytic combustion system to oxidize and destroy hydrocarbons in the waste fuel stream before entering the turbine	Biogas from landfill or other waste gases
Biomass Co-fired Boilers		
Minnesota Power's Rapids Energy Center Boiler 5	A boiler with a steaming capacity of 175,000 lb/hour. Fired with western subbituminous coal, wood waste, railroad tires, on-site generated waste oils and solvents, and paper wastes	Waste wood and bark from a paper mill and waste wood from other facilities was co-fired with coal; Heating value of 7700 Btu/lb
University of Iowa Main Power Plant's Boiler 10	A boiler unit rated at 170,000 lb/h steam fired with Renewafuels Pelletized Wood Fuel	Wood Pellets from a Renewafuel, LLC facility in Michigan was co-fired with coal; heating value of 4600 Btu/lb

[A] Complete verification reports and statements for the technologies listed above, *except* for Flex Microturbine, may be found at http://www.epa.gov/etv/vt-ggt.html#advanceenergy. [B]Planned verification; not yet verified. Anticipated project completion 2011

[1] The ETV Program operates largely as a public-private partnership through competitive cooperative agreements with non-profit research institutes. The program provides objective quality-assured data on the performance of commercial-ready technologies. Verification does not imply product approval or effectiveness. ETV does not endorse the purchase or sale of any products and services mentioned in this document.

(Continued from page 1)

In 2008 ETV completed a waste-to-energy project under its Environmental Sustainability Technology Evaluation (ESTE) Project, during which two biomass co-fired boilers (See **Table 3**) were tested using woodwaste. EPA Office of Air and Radiation, Office of Air Quality Planning and Standards, and Office of Resource Conservation and Recovery collaborated with ETV on this project. The results could potentially be used to support the development of a new area-source Maximum Achievable Control Technology standard.

Selected Outcomes of Verified Distributed Energy Technologies

Based on ETV case studies for technologies verified prior to 2004 and published in 2006, a capacity of 28 megawatts (MW) of ETV-verified fuel cells and microturbines (in CHP applications) have been installed in the U.S. since the verifications were completed. ETV estimates that these systems:

- Reduced CO_2 emissions by 53,000 tons per year and NO_X by 240 tons per year, with associated climate change, environmental, and health benefits.
- Increased utilization of renewable fuels resulting in reductions in the consumption of natural resources. (Note: Fuel cells that utilize anaerobic digester gas are responsible for 2 MW of the capacity listed above and 14,000 tons per year of the CO_2 reductions.)

Assuming annual sales continue at the same rate as in 2005, ETV estimates the total installed capacity of ETV-verified fuel cells should reach 89 MW by 2010, reducing CO_2 by 191,000 tons per year and NO_X by 600 tons per year.

Table 2. Performance for the Four DG Energy Technologies

Parameters	Fuel Cells[A]	Microturbines
Power Production[B]		
Electrical efficiency	36.8%	19.7% to 26.7%
Potential thermal efficiency	56.9%	8.14% to 33.3%
Potential total system efficiency	93.8%	34.8% to 53.7%
Emissions Rates		
CO_2, lbs/kWh[C]	1.44	1.44 - 3.45
NO_X, lbs/kWh[C]	1.3×10^{-5}	8.21×10^{-5} - 2.13×10^{-2}

[A] Based on 2004 Verification data only
[B] At full load, under normal operation
[C] lbs/kWh = pounds per kilowatt-hour

Upcoming ETV Projects

ETV expects to complete its second waste-to-energy ESTE project involving an anaerobic digester of animal manure in winter 2009. The digester is being used to treat animal wastes at a large-scale farm. Methane and energy generation, organic solids reduction, phosphorus reduction, and the reduction of potentially pathogenic microorganisms will be verified. There is also a planned joint demonstration and verification of a microturbine using landfill gas with the Department of Defense Environmental Security Technology Certification Program. This project is expected to be completed by 2011.

Table 3. Verified Biomass(Woodwaste) Co-Fired Boilers

	Performance Measures	Boiler Efficiency, %	Total PM[E]	CO_2 Emissions[E]
Minnesota Power's Rapids Energy Center Boiler 5 (MP-5), Wood Waste Co-Firing with Coal	Baseline[A] Averages	74.5 ± 0.3	0.0317 ± 0.005	160 ± 7
	Co-fire[B] Averages	61.3 ± 0.7	0.0060 ± 0.003	131 ± 4
	% Difference[C]	-17.7%	-81.2%	-18.3
Iowa Main Power Plant's Boiler 10 (UI-10), Renewafuel Pelletized Wood Fuel	Baseline[A] Averages	84.9 ±0.4	0.061 ± 0.03	205 ± 2
	Co-fire[D] Averages	84.1 +0.7	0.044 ± 0.003	207 ± 0.3
	% Difference[C]	-0.90%	-28.1%	0.82%

[A] Baseline fuel = 100% coal; [B] Co-fire fuel = 8% coal; 92% woody biomass; [C] Statistically significant changes are underlined; [D] Co-fire fuel = 85.1% coal; 14.9% wood; [E] pounds per million Btu (lb/MMBtu) output

Benefits and Outcomes of the Use of Selected Opportunity Fuels

- The EPA AgSTAR Program estimates that 2,290 dairy operations and 6,440 swine operations are potential candidates for anaerobic digestion and manure biogas production in the U.S.. Manure digester gas contains 60 to 80% methane, with an energy content of 600 to 800 Btu/scf.
- The EPA Landfill Methane Outreach Program estimates that there are approximately 410 landfills already collecting landfill gas (LFG) for energy recovery in the U.S.. In addition 570 landfills are good candidates for LFG energy recovery and have the potential to generate approximately 1,370 MW of electricity.
- The 2004 Clean Watersheds Needs Survey estimates that there are 544 municipal wastewater treatment facilities in the U.S. with influent flow rates greater than 5 million gallons per day that operate anaerobic digesters. Anaerobic/CHP systems if installed by these facilities can generate approximately 340 MW of electricity.

References

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