Facilities
Tech Tips

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The Promises and Pitfalls of Using Wood To Produce Electricity

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Highlights...

- Wood gas produced from biomass is a renewable energy resource.
- Wood gas was used extensively to fuel automobile engines and electric generators during World War II.
- A demonstration biomass gasification system at the Missoula Technology and Development Center could produce nearly 25 kilowatts of electricity, but it requires an operator while it is running.
- For a biomass gasification system to operate most efficiently, the heat generated by the system must be used as well as the electricity.

The Forest Service is investigating ways to use small-diameter or low-value trees to produce wood gas for heating and cooling and to generate electricity. Wood gas could reduce the consumption of fossil fuels, cut energy costs, lower the production of greenhouse gasses, and provide a market for excess biomass.

Biomass gasification—heating biomass to produce gasses rather than simply burning the biomass—is not a new technology. When petroleum fell into short supply throughout Europe, Asia, and Australia during World War II, wood gas was used to fuel automobile engines and electric generators. The technology began to lose popularity when natural gas and petroleum supplies became available after the war. As the demand for renewable energy resources has increased, so has interest in biomass gasification.

Despite the potential benefits of biomass gasification, problems must be solved before biomass gasification is reliable and economical enough for the small-scale applications discussed in this tech tip.

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Equipment Types

Gasification is partial combustion of a carbon-rich material to produce a synthesis gas (syngas), a mixture of carbon monoxide, hydrogen, carbon dioxide, methane, water vapor, and nitrogen. Wood gas is one type of syngas. A carbon-rich biomass and a controlled amount of oxygen are combined at high temperatures in a gasifier. Updraft gasifiers introduce oxygen through the base of the gasifier and collect gas at the top. Downdraft gasifiers introduce oxygen through the top or sides of the gasifier and collect gas at the bottom.

The updraft gasifier tolerates higher moisture content in the biomass than the downdraft gasifier, eliminating much of the need to dry fuel. However, the synthesis gas produced by the updraft version has more tar oil than is ideal for internal combustion engines. Fuel for updraft gasifiers is customarily limited to coal and nonvolatile materials such as charcoal.

In downdraft gasifiers, tar oil is consumed in the combustion process. Downdraft gasifiers are the ideal choice for the Forest Service because the gas they produce can be used in internal combustion engines with little tar buildup.

Biomass Fuel

Selecting the correct biomass fuel is crucial. Wood chips must be relatively small and about the same size to ensure uniform heating of the fuel and to prevent equipment problems. Irregularly shaped materials may get stuck in the equipment (figure 1).

Figure 1—Wood chips (left) are a desirable fuel for gasification because their shape and size are uniform. Shreddings (right) can cause uneven heating and can jam the equipment.

Although wood pellets may be a desirable biomass fuel, they cannot be produced onsite. The BioMax's computer must be adjusted when wood pellets are used. Otherwise, tar accumulates, based on the experience of researchers at Auburn University (Christian Brodbeck, personal communication 2010).

Biomass fuel should have a moisture content of 15 percent or less, although most gasifiers will function with fuels that have a moisture content of up to 25 percent. Usually, fuel should be dried before it is fed into a gasifier (figure 2).

According to the Community Power Corporation, which produces BioMax gasification systems, the characteristics of good biomass fuels include:

- Available in large quantities over the long term
- Low moisture content
- Dense
- Small, flows well
- Low ash content
- Low cost, not subject to large price swings
- Available locally
- Nontoxic, easily handled

Additional information on biomass fuels is available in the Community Power Corporation's frequently asked questions Web page (http://www.gocpc.com/faq.html).

Figure 2—This grate screens out chips that are too small or too large as fuel is fed into the BioMax system.

Operation and Maintenance

To produce clean, usable synthesis gas, typical operations follow these guidelines:

- Regulate the temperature of biomass in the gasification chamber—Char and tar are produced if too little oxygen is introduced. If too much oxygen is present, the produced gas will burn. The temperature of the gasification chamber (figure 3) should be higher than 800 degrees Celsius for efficient carbon conversion and relatively low tar production. The proper operating temperature is maintained by controlling the oxygen ratio in the gasification chamber.
- Ensure that biomass fed into the gasifier is a consistent size—Irregular-shaped material, such as shreddings, can cause bridging or channeling. The reduced fuel flow increases the oxygen-to-fuel ratio and can cause problems if the synthesis gas begins to burn.
- Use biomass with low ash and low contaminants (such as silica) to prevent formation of "clinkers" at high temperatures. These clinkers can disturb air and fuel flow in the gasifier.

The Community Power Corporation estimates that the BioMax system requires on average one-half hour of maintenance a day. A 50-kilowatt BioMax system has delivered power for 732.6 hours (30.5 days) out of 745.4 hours (31.1 days) for 98.3 percent availability.

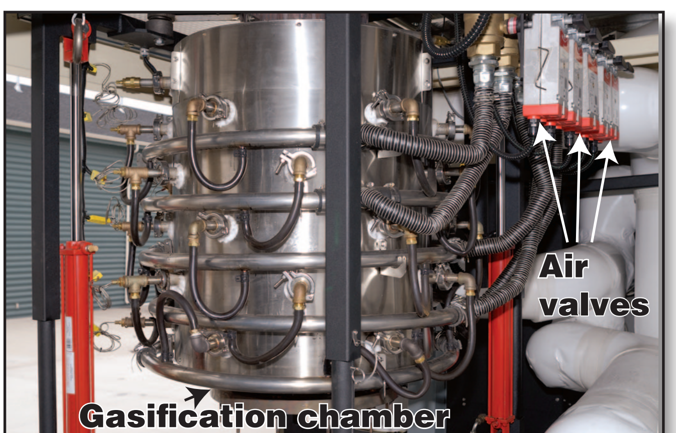

Figure 3—Air valves regulate the temperature inside the BioMax gasification chamber.

Mobile BioMax Operation at MTDC

Since 2008, the Missoula Technology and Development Center (MTDC) has worked with the University of Montana's energy technology program to demonstrate the potential for renewable energy produced by a mobile BioMax system (figure 4).

A grant by the Biomass Research and Development Initiative, a joint effort of the U.S. Department of Agriculture and the U.S. Department of Energy, provided funding to purchase the BioMax system. The 25-kilowatt system is completely mobile, but stays at MTDC when it is not on display elsewhere. The BioMax system's electric generator (figure 5) feeds power to MTDC when the system is operating, offsetting power purchased from NorthWestern Energy.

Figure 4—The mobile BioMax system at MTDC.

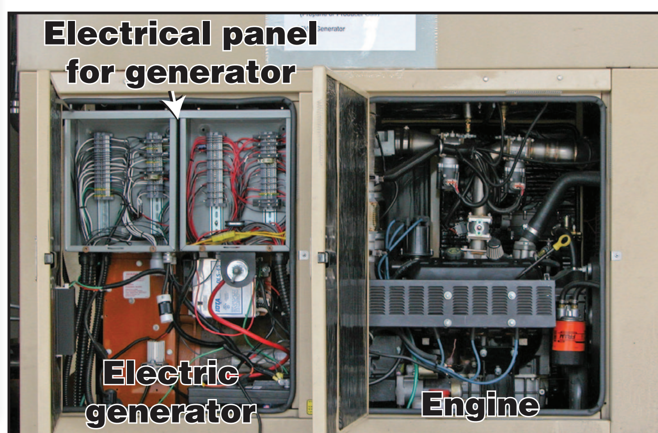

Figure 5—The BioMax's electric generator is driven by a standard V-6 engine modified to run on wood gas.

Stationary BioMax Operation at the Southern Research Station

The Southern Research Station has installed a 25-kilowatt BioMax system at the Kisatchie National Forest's Winn Ranger District office in Winnfield, LA. The BioMax system can provide all of the power needed by the Winn Ranger District. Excess power is returned to the power grid.

Thomas Elder, research chemist for the Southern Research Station in Pineville, LA, says that the BioMax system is being used to provide electricity and to study the feasibility of gasification technology. The BioMax system was attractive because it can be purchased as a turnkey system and the Community Power Corporation has been available for support when problems arise.

Additional information on the Southern Research Station's BioMax system is available at:

- http://www.srs.fs.usda.gov/usfr/Gasification_Unit_Overview_Presentation.pdf (2.98-megabyte Acrobat file)
- http://www.srs.fs.usda.gov/usfr/Gasification_Unit_Overview_Video.wmv (3-minute 38-second movie)

Mobile BioMax Operation at Auburn University

Christian Brodbeck, a research engineer at Auburn University, operates a mobile 25-kilowatt BioMax system and in his opinion, the BioMax system needs the following:

- The heat must be used by a heating system.
- The electricity must be needed onsite or be sold to an electric company.
- The biomass that fuels the unit must be free or have its cost subsidized.

Mobile BioMax systems require extra precautions compared to stationary systems, Brodbeck said. After the mobile BioMax system has been moved, the system should be checked to ensure that parts have not vibrated loose.

What Information Is Available?

In 1989, the Federal Emergency Management Agency released the report "Construction of a Simplified Wood Gas Generator for Fueling Internal Combustion Engines in a Petroleum Emergency" (http://www.woodgas.net/files/FEMA%20emergency%20gassifer.pdf). The report includes instructions for fabricating and implementing a device modeled closely on the Imbert Gasifier used during World War II to produce transportation fuels. This device can be produced using readily accessible materials by anyone with moderate machining skills.

Forest Service researchers modeled the economic feasibility of gasifying slash to power electric generators and return electricity to the grid in southern Oregon ("Fuel to Burn: Economics of Converting Forest Thinnings to Energy Using BioMax in Southern Oregon," http://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr157.pdf). Although the largest BioMax system commercially available generates just 75 kilowatts of electricity, researchers considered whether the systems might be economical if they generated 100 or 1,000 kilowatts. The report concluded that a biomass gasification plant producing 1,000 kilowatts or more of electricity may be worth considering:

- If the plant could be located at a forest landing near an existing powerline.
- If the plant received operating subsidies of at least 1.8 cents per kilowatt hour.

The Energy Efficiency and Renewable Energy (EERE) office of the U.S. Department of Energy published a 2006 report (http://www.nrel.gov/docs/fy06osti/39945.pdf) outlining improved techniques for purifying gas produced by small biomass gasification systems. In August 2006, EERE collaborated with Mount Wachusett Community College in Gardner, MA, to determine the benefits of a modular biomass gasification system used to supply electricity, heating, and cooling for a daycare facility on its campus. The project is ongoing.

Researchers at Mississippi State University and Texas A&M studied the quality of the gas produced by an 18-kilowatt gasification system manufactured by the Community Power Corporation in Littleton, CO. The authors said that "Overall, the system, which has extensive electronic controls based on temperatures and pressures at numerous locations, produced a remarkably consistent high-quality syn-gas [synthesis gas] regardless of input parameters." ("Syn-Gas Quality Evaluation for Biomass Gasification with a Downdraft Gasifier" 2009, http://asae.frymulti.com/newresults.asp, search for "syn-gas quality").

Where Do We Go From Here?

The 25-kilowatt BioMax system (figure 6) being demonstrated at MTDC is a work in progress.

One of the biggest challenges is fully using the waste heat the system generates. Now waste heat dries the wood chips used as fuel. About 50 percent of the biomass energy is converted to heat—just 20 to 30 percent is converted to electricity.

The BioMax system requires an operator when it is running, an expense that the energy being produced cannot cover. If the system could be operated remotely, and the heat it produces could be used, the system probably could save money for MTDC while putting renewable resources to work.

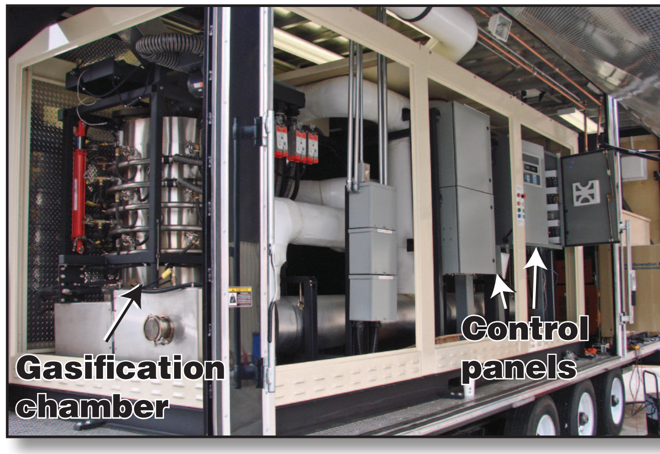

Figure 6—The BioMax system includes a module that heats wood (or other biomass) to produce wood gas.

About the Authors

James "Scott" Groenier began working for MTDC during 2003 as a civil engineer. Groenier earned a bachelor's degree from the University of Wisconsin at Madison and a master's degree from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation before starting his career with the Forest Service. He worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests.

Gary Kees joined MTDC in 2002 as a project leader. Kees works in the reforestation and nursery, forest health, and GPS programs. His current projects involve laser guidance systems, ATV and backpack sprayers, nursery seeders, and remote weather stations. Kees, who has a degree in mechanical engineering from the University of Idaho, worked for 10 years as a mechanical and structural engineer, project manager, and engineering group leader for Monsanto Co., in Soda Springs, ID.

Ted Etter joined MTDC in 2002 as an electronics engineer and project leader. He has 20 years of experience designing test equipment, display devices, and medical instrumentation for private industry. For 6 years before joining MTDC, Etter taught courses in electronics at the University of Montana College of Technology, Missoula. His work at MTDC includes projects in wireless communications, alternative energy sources, instrumentation, and process control. Etter received a bachelor's degree in mathematics from the University of Oregon and a master's degree in teacher education from Eastern Oregon State University.

Samantha Lidstrom is a civil engineering student at Montana State University in Bozeman, MT. Lidstrom has worked part time for MTDC as a research and publications assistant since 2008.

Charles Showers, professional engineer, became engineering program leader at MTDC in 2002 after serving 2 years as operations program leader. Showers came to MTDC after 9 years as assistant forest engineer on the Payette National Forest. He began his Forest Service career on the Boise National Forest after 8 years as a construction project engineer with the Idaho Transportation Department.

Library Card

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Biomass gasification is partial combustion of a carbon-rich material to produce a synthesis gas. Synthesis gas is a renewable energy resource that may reduce the use of fossil fuels, cut energy costs, reduce production of greenhouse gasses, and provide a market for excess biomass. The Missoula Technology and Development Center has worked with the University of Montana College of Technology's energy technology program to demonstrate the promises and pitfalls of using a 25-kilowatt portable downdraft biomass gasification system to produce electricity.

Keywords: alternative energy, biogas, biomass, BioMax, Community Power Corporation, downdraft gasifiers, forest health, fossil fuels, greenhouse gasses, renewable energy, syngas, updraft gasifiers, wood gas

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