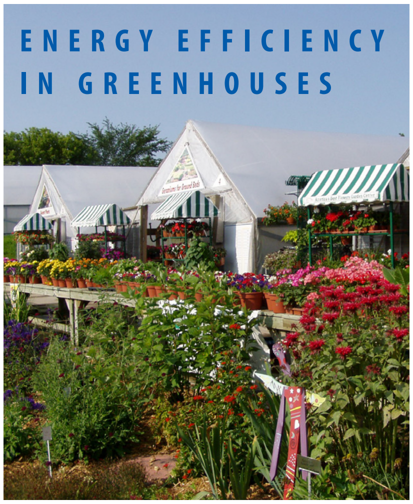

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Biomass energy for heating greenhouses

Scott Sanford

What is biomass energy?

BIOMASS refers to renewable organic matter that can be used as heating fuel. Examples include cordwood, wood chips, wood pellets, shell corn and other grains, waste paper, and cherry pits. In the Midwest, many growers are interested in using switchgrass and other prairie grasses for fuel. These grasses make excellent fuel once they have been densified into pellets, cubes, briquettes, or bales to facilitate handling.

Natural gas and propane (LP gas) prices have been on a roller coaster lately but have been trending upward since 1999. Increased demand, hurricanes, global political unrest, and tight supplies have all caused prices to fluctuate. Total energy costs for greenhouse production are typically about 10 to 15% of total production costs, but between 2003 and 2008, energy costs for heating doubled, decreasing profit margins and putting some growers out of business. Unfortunately, this energy price volatility is expected to continue, and energy costs will likely continue to move upward in the coming years.

Higher energy costs have motivated growers to search for ways to reduce their energy expenses. Many growers have considered heating with wood, a type of biomass, because it is perceived to be a low-cost fuel. However, wood and other biomass fuels have some costs that are not always obvious. If you're looking to reduce energy costs, be sure to compare the expected savings from energy conservation and efficiency improvements to the savings from alternative energy projects, such as switching to biomass. Energy conservation and efficiency improvements often have a faster payback or higher return on investment and will potentially reduce the cost of future alternative energy projects by reducing the heating capacity needed.

This publication will provide an overview of heating greenhouses with wood and other types of biomass.

Biomass boilers and furnaces

A boiler heats a liquid such as water or makes steam, while a furnace heats air directly. Whether to choose a boiler or a furnace in part depends on the heating system location and the number of greenhouses the system will service. A boiler can be centrally located on the site and the hot water piped to the greenhouse, while a furnace is best located inside or directly adjacent to the heated space (figure 1).

Biomass boilers and furnaces can be divided into two main groups: those that require manual stoking, or loading, and those with automatic stoking. Manually stoked boilers and furnaces are generally fueled by cordwood or waste wood, while automatic-stoking boilers and furnaces can handle a wide variety of biomass, including wood chips, wood pellets, biomass pellets (grass, corn fodder, etc.), paper pellets, and grains (corn, rye, and other small grains). When choosing a heating system, be sure to consider the amount of labor available for managing the system and the amount of capital available for investment.

Permits

When installing biomass furnaces and boilers, be aware that local town and county permits may be required. Depending on the size of the heating system, it may also require an air emissions permit from the state Department of Natural Resources or Environmental Protection office. In Wisconsin, wood boilers with a capacity greater than 5 million British thermal units (5 MMBtu) require an air emissions permit; see the first item in the **Resources** list for details.

Figure 1. Outdoor wood-fired boilers can be centrally located on a site. Many are suited for the elements and do not require the protection of a building or shelter.

Cordwood and waste wood boilers

As energy prices have increased, cord- and waste wood boilers have gained popularity, especially with growers who have an existing supply of wood. Many of these units are designed for outdoor placement and require no building or shelter. Outdoor wood-fired boilers (OWBs), as they are called, range in size from about 100,000 to 1,000,000 British thermal units per hour (Btu/hr) heat output. The Environmental Protection Agency (EPA) recently tested some OWBs to determine the emissions and thermal efficiencies of various units. It found that the typical OWB is between 20 and 55% efficient, with an average efficiency of 43%.

OWBs and emissions

As OWBs have grown in popularity, their smoke emissions have become a growing problem (figure 2). The report *Smoke Gets in Your Lungs,* from the State of New York's Office of the Attorney General, cited that due to incomplete combustion, OWBs emit 10.5 times more particulate matter and 5.4 times more creosote than an EPA-certified wood stove. According to the report, one OWB emits as much particulate matter as 11 homes with EPA-certified woodstoves, 17 homes with EPA-certified wood pellet stoves, 6,500 homes with heating oil (fuel oil) furnaces, and 2,500,000 homes heated with natural gas. Excessive smoke emissions have lead to regulations or bans on OWB use in a growing number of communities and states.

Figure 2. Emissions from outdoor wood-fired boilers are a concern in a growing number of communities.

A new generation of cleaner-burning OWBs has entered the marketplace. These OWBs meet the lower emissions standards of EPA's voluntary Outdoor Wood-Fired Hydronic Heaters Program. An OWB that meets the program's Phase 2 requirements emits 90% less particulate matter than unqualified models. Lower emissions from a boiler also result in higher thermal efficiency. An OWB that meets the Phase 2 emissions requirements uses an average of 42% less fuel than an OWB that was sold before the program started in 2007. Before purchasing an OWB, check for local regulations and refer to EPA's website (see "List of Cleaner Hydronic Heaters" in the **Resources** section) to select a boiler that meets EPA Phase 2 emissions requirements. Efficiencies of approved boilers range from approximately 45 to 89% with an average of 67%. You can calculate the approximate efficiency using the data listed on EPA's Burn Wise website: divide the "Heat Input Annual Average Emission Level" by the "Heat Output Annual Average Emission Level."

Fuel types and considerations

Fuel sources for OWBs vary from cordwood (soft or hard) to scrap lumber to pallets. On average, seasoned wood has an energy content of 6,400 to 7,000 Btu per pound, or about 22 million Btu (MMBtu) per full cord. (1 MMBtu is 1,000,000 Btu.) A full cord is 128 cubic feet, or a pile of 4-foot logs piled 4 feet high and 8 feet deep. Which type of fuel is best depends on availability and procurement cost. Scrap wood and old pallets often cost little or nothing and may require less labor and handling than cordwood, especially if the scrap is delivered. However, using scrap wood has potential disadvantages: Pallets may be contaminated with chemicals, and nails may pose a hazard during handling, cutting, loading, and ash disposal.

Many people think that if they have a woodlot their wood is free, but it's not. Several costs often go unrecognized, including labor, equipment, and time. Someone has to harvest the wood, transport it to the point of use, split any larger logs, be available to stoke the boiler as needed, and remove and dispose of ash. Then there are equipment expenses, including the chainsaw, truck, wood splitter, gas, oil, sharpening chains, trailers, and possibly a skid-steer or loader tractor.

Harvesting wood is physical work; the average piece of wood is handled three or four times before it is burned. Each cord of wood burned requires moving about 9,000 to 12,000 pounds to get the wood from the woodlot to the wood boiler. A typical 30- x 96-foot freestanding greenhouse in Madison, Wisconsin, requires 12 full cords of wood for heating from February 15 to May 31 with a typical OWB. A new Phase 2–qualified OWB would require 8 full cords for the same period.

The moisture content of wood is an important factor in its efficiency as a fuel. Burning green wood produces more emissions and less net energy because the moisture must be vaporized before the wood will burn. Properly seasoned wood has a moisture content of 20% or less. It takes 1 or 2 years (summers) for the wood to dry, depending on the species of tree. Species such as oak retain moisture for long periods unless the bark is removed or the logs are split.

Despite the labor and equipment costs, keep in mind that wood may still be cheaper than other fuel options and may offer the advantage of providing work for employees during slower times of the year.

Firebox management

The volume of emissions and the nuisance of OWB smoke can be reduced by following these recommendations:

- Make sure the chimney is two feet higher than any building or trees within 300 feet of the OWB.
- Only burn well-seasoned wood; low moisture content improves efficiency and reduces emissions. Wood burns best if seasoned for 2 years (summers).
- Never burn garbage, wet cardboard, painted or treated wood, asphalt shingles, or plastic. In addition to being a good firebox management practice, it's illegal to burn these items in many municipalities.
- Keep doors of the OWB closed unless stoking, or loading, the fire.
- Burn small, hot fires. Load only enough wood for the next 6 to 12 hours. Excess wood in the boiler will cause incomplete combustion and high emissions rates when the damper closes.
- Load the firebox at night when there will be a demand for heat, not in the morning when the demand will be reduced as the sun warms.

Wood-chip boilers

Wood chips are a viable alternative fuel for medium to large greenhouses.

Fuel types and considerations

There are a variety of wood-chip types, including whole-tree chips, green sawdust, bark waste, and municipal wood waste, and a variety of sources, including sawmills, harvesting operations, municipalities, and wood manufacturers such as furniture makers. Chip size and moisture levels are important for proper operation and combustion. Chips with lower moisture content will provide more net energy but may be in greater demand for other uses, such as animal bedding and fuel pellet production.

Regardless of the source and type of chip, wood chips are delivered in truck-sized loads (typically tractor-trailer loads) and require bulk storage. It takes five to six tractor-trailer loads of wood chips (115 tons) to equal the energy from a 7500-gallon tanker load of heating oil. Fuel storage capacity should be 1¼ to 1½ times the delivery volume so the bin can be refilled without interrupting your heating system.

Wood chips can be stored in above- or below-ground bins, or in a pile in a ground-level shed with a concrete floor. Ground-level storage is cheaper to construct but requires daily labor to move chips to the boiler with a bucket loader. Below-ground storage bins have a few advantages: no special handling equipment is needed to unload a self-unloading truck (dump truck or trailer with walking floor), the bins are less visible, and the chips don't freeze because the bins are below the frost line. A fully automated system to move the chips from storage to the boiler can cost twice as much as a semi-automated system, but the fully automated system will reduce daily labor requirements (figure 3).

Boiler sizes range from about 1 to 150 MMBtu/hr input capacity. Units above 10 MMBtu/hr are custom engineered for the site. The steady state efficiency of wood-chip boiler systems—their efficiency while providing a continuous, steady heat output—can range from 50 to 75%, depending on the air-to-fuel ratio, fuel moisture content, and stack temperature. The period while fire is being started and ramped up to full capacity is not factored into the steady state efficiency.

Combustion systems

There are two types of combustion systems typically used with wood-chip boilers: direct-burn, or single-chamber, and two-chamber. In both types of systems, an auger moves the fuel into the combustion chamber, where the air and fuel are mixed and combustion is initiated. In the direct-burn system, the secondary combustion zone may be part of the same chamber where combustion is initiated. In the two-chambered system, a blast tube connects the primary and secondary chambers. This type of system produces higher gas temperatures in the secondary chamber. A third type, the close-coupled gasifier, is a modification of the two-chamber system. It limits combustion air in the primary chamber and adds combustion air in the blast tube to increase turbulence, facilitating complete combustion of the gas.

Wood-chip boilers require less labor and have lower fuel costs than boilers fueled with cordwood or wood pellets, but they have higher equipment costs and more moving parts to maintain. Also, the fuel characteristics of wood chips tend to vary from load to load more than other types of fuel, potentially requiring more adjustments to achieve maximum efficiency.

Figure 3. This wood-chip boiler's fully automated stoking system significantly reduces the daily labor required to maintain the system.

Pellet- or grain-fueled boilers

Pellet stoves have been heating homes for many years, but many manufacturers now produce commercial-sized boilers and furnace units with input capacities of 1 to 3.5 MMBtu/hr and greater. Pellet boilers and furnaces have relatively low labor costs because they have automatic stoking and pellets are a homogeneous fuel easily handled by conventional grain-handling equipment. They also have high efficiency (80 to 93%) and low emissions because unlike a cordwood-fired boiler, a pellet-fueled boiler meters fuel into the firebox at the minimum rate necessary to meet the heating demand. Many pellet boilers also have automatic ash removal and can be outfitted with a soot and particulate matter cleaning system to further reduce air pollutants.

Fuel types and considerations

Wood pellets are the most common pellet fuel, but there are many others, including corn, rye, and other grains; paper pellets; and cherry pits. Whether a boiler or furnace can burn all of these various fuels depends on its design. Combustion airflow requirements are different for wood pellets than they are for corn or cherry pits, and the stove must be able to meter the fuel into the firebox without disruption in order to perform efficiently.

Corn has been a popular fuel because of its availability and lower cost per heating unit than other fuels, but it has some unique issues. As corn burns, it produces hard, glassy slag called *clinkers*, and these clinkers can coat the inside of the boiler and need to be removed frequently—often daily. Corn-burning boilers and stoves are specifically designed to accommodate slag removal and usually have some type of agitation in the firepot to keep clinkers from piling up.

Pellet materials and fuel grains are best stored in a dry location. They are usually available in 40- or 50-pound bags and in bulk. Bulk handling requires watertight bins to store the fuel and augers to transport the fuel to the furnace or boiler. If using a bulk storage bin, it needs to be sized about 1¼ to 1½ times the size of the delivery volume so the bin can be refilled without interrupting the heating system. Figure 4 shows an outside pellet burner with a white bulk storage bin, which is filled by a delivery truck equipped with an auger.

Wood pellets typically have a moisture content of 6 to 10% or less depending on grade. If using grain, it needs to be dried to at least 15% moisture content to burn properly, but 12% or less is preferred because it will burn more consistently.

A typical 30- x 96-foot freestanding greenhouse in Madison, Wisconsin, heated with a typical wood pellet boiler requires 8 tons of wood pellets for heating from February 15 to May 31.

How do various fuels compare?

Table 1 on page 5 provides a comparison of several types of fuels—both biomass and fossil.

Growers can calculate their own energy costs by using the following equation:

$$Cost\ per\ MMBtu \Rightarrow \frac{1{,}000{,}000\ Btu}{Btu\ per\ energy\ unit} \times \frac{Cost\ per\ energy\ unit}{efficiency}$$

Assuming the energy costs in table 1, if you are currently using natural gas it would be wise to invest in energy efficiency or a wood-chip boiler, if wood chips are available. If you're currently using propane and have natural gas service nearby, determine your best investment by comparing the costs of connecting to natural gas, taking energy efficiency measures, and using alternative energy. If propane or heating oil are your only choices, compare energy efficiency measures and alternative energy costs to determine the best investment.

The typical, unqualified OWB (not meeting EPA Phase 2 requirements) has the second highest cost per MMBtu, about 18% less than electricity but 12% and 17% more than propane and heating oil, respectively. This high cost is due to the low efficiency of unqualified OWBs (40%) compared to other types of fuel boilers (75 to 80%). (Note that the Phase 2–qualified boiler offers a 42% fuel savings.) The cost or value assigned to a cord of wood will also affect the cost per MMBtu. If the wood is self-harvested, the cost might be as low as $150 per cord, reducing the cost to $17 per MMBtu.

When comparing options, use a net present value analysis instead of simple payback so that all costs, including maintenance and labor, are considered and not just the capital cost. See the **Resources** section for more information on doing a net present value analysis, or contact your local county Cooperative Extension agent for assistance.

Figure 4. This commercial-sized pellet boiler is equipped with a storage bin and an ash cart, part of the automatic ash removal system.

Energy conservation usually has a better return on investment than switching to an alternative fuel. By reducing the energy demand first, both the cost of equipment and the amount of alternative energy needed will be reduced if you make the switch in the future. There will be an increasing demand for biomass energy in the future, particularly as large heating and electric power plants convert to biomass. This trend will put upward pressure on biomass prices in regions near the power plants.

Table 1. Fuel type comparison, in order of cost

Fuel type	Energy content per unit of fuel (Btu)	Thermal efficiency[a] (Seasonal efficiency)[b]	Costs: Per unit of fuel[c]	Costs: Per MMBtu of heat[d]
Wood chips	3780 (50%)–6190 (25%)/lb[e]	80%	$50/ton (50%)[e]	$6.50
Natural gas[f]	100,000/therm[g]	70–85% (78%)	$0.95/therm	$12.18
Grass-based biomass pellets	14,400,000/ton	70–85% (80%)	$180/ton	$13.88
Corn	380,000/bushel	70–85% (80%)	$5.00/bushel	$16.45
OWB (EPA Phase 2–qualified)[h]	22,000,000/full cord[i]	69%	$250/full cord[j]	$16.47
Wood pellets	15,600,000/ton	70–85% (80%)	$230/ton	$18.67
Heating oil #2	138,000/gal	70–85% (75%)	$2.50/gallon	$24.15
Propane (LP gas)[f]	92,000/gal	70–85% (78%)	$2.00/gallon	$27.87
OWB (unqualified)[k]	22,000,000/full cord[i]	40%	$250/full cord[j]	$28.41
Electricity	3413/kWh	100%	$0.119/kWh	$34.87

[a] Typical thermal efficiencies for new equipment.

[b] Seasonal efficiency accounts for thermal losses such as using heated air for combustion and gravity-vented flues. It has been provided in parentheses where applicable.

[c] Fuel costs in Madison, Wisconsin, delivered to point of use (spring 2010). Does not include cost of storage or combustion equipment.

[d] MMBtu = 1 million Btu. Cost calculated using seasonal efficiency where one is given. Otherwise calculated using thermal efficiency.

[e] Values in parentheses indicate moisture content.

[f] Assumed to be a power-vented unit heater because gravity-vented heaters are no longer manufactured.

[g] One therm (100,000 Btu) equals approximately 1 CCF (100 cubic feet) but varies with source.

[h] Outdoor wood-fired boiler that meets the EPA Phase 2 emissions requirements.

[i] A full cord measures 4 x 4 x 8 feet, or 128 cubic feet.

[j] Cost is based on purchasing cut and split wood from a vendor.

[k] Typical pre-2008 outdoor wood-fired boiler (does not meet Phase 2 requirements).

Resources

For more information on heating with biomass, see the following resources, some of which were used in the preparation of this publication:

Combustion Sources and Air Pollution Construction Permits (Bulletin SBCA-NS2-0909). Clean Air Facts. Wisconsin Department of Commerce. Accessed May 2010. commerce.wi.gov/BD/docs/BD-CA-CombustionNSR.pdf.

Guide to Commercial Biomass Energy Conversion Systems. S.K. Hanson, T.D. Buckley, D.D. Schmidt, K.M. Leroux. University of North Dakota Energy & Environmental Research Center, 2006. www.focusonenergy.com/files/Document_Management_System/Renewables/W_RW_RESE_UND_Biomass_Buyers_Guide.pdf.

Heating Buildings and Business Operations with Biomass Fuel: A Planning Guide (Extension Bulletin E-3044). C.H. Schilling, M. Seamon, T. Dudek, and S. Harsh. East Lansing: Michigan State University Extension, 2008.

Heating with Wood and Coal (NRAES-23). J.W. Bartok, Jr. Ithaca, NY: Natural Resource, Agriculture, and Engineering Service, 2004.

List of Cleaner Hydronic Heaters. Burn Wise. United States Environmental Protection Agency. www.epa.gov/burnwise/owhhlist.html.

"Net Present Value Analysis: A Primer for Finance Officers." R. Gregory Michel. *Government Finance Review,* February 2001. Accessed March 2010. www.gfoa.org/services/dfl/budget/documents/NetPresentValueAnalysis.pdf.

Outdoor Wood Boilers (Water Stoves). Guidance for Health Professionals. Wisconsin Division of Public Health, 2010. Accessed March 2010. www.dhs.wisconsin.gov/eh/HlthHaz/pdf/waterstoves.pdf.

Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State. Judith Schreiber et al. Office of the Attorney General, Environmental Protection Bureau, October 2005. www.ag.ny.gov/media_center/2005/aug/August%202005.pdf.

Wood-Chip Heating Systems. Timothy M. Maker. Montpelier, VT: Biomass Energy Resource Center, 2004. www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf.

Tools

Energy Self Assessment–Greenhouse Self Assessment Tool. USDA–Natural Resources Conservation Service www.ruralenergy.wisc.edu.

Provides baseline energy use estimates and recommends energy efficiency measures to reduce energy consumption.

Virtual Grower Software. USDA–Agricultural Research Service. www.ars.usda.gov/services/software/software.htm.

Determines energy use and potential savings for energy efficiency measures.

Author: Scott Sanford is senior outreach specialist with the department of Biological Systems Engineering, College of Agricultural and Life Sciences, University of Wisconsin–Madison. Cooperative Extension publications are subject to peer review.

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