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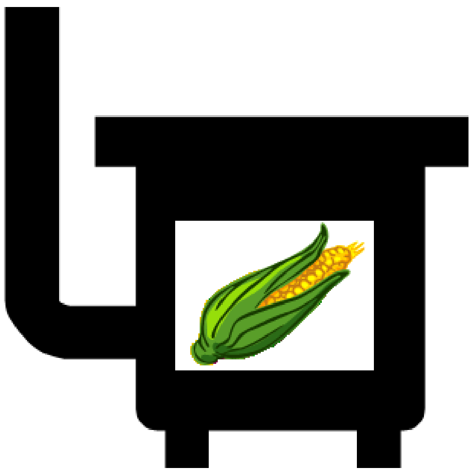
Three types of biomass burners are shown on page 2

Corn and Biomass Stoves



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For centuries, people have burned biomass as a source of heat.

Biomass is a fuel or energy source derived from plant material or agricultural byproducts. One of the most common types of biomass has been wood. From campfires to simple stoves, wood served heating needs long before electricity, natural gas or fuel oil were available. With increasing fossil fuel prices, more attention is being paid to biomass fuels for heating buildings.

The renewability of biomass fuels provides an advantage over other forms of energy. Shelled corn can be renewed in as little as 180 days. Advances in the efficiency, simplicity and convenience of biomass stoves all have increased the popularity of these heating sources. While corn-burning stoves will be the primary focus of this publication, stoves that burn wood pellets are similar.

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Types of Burners

Three main types of biomass burners are readily available on the market: stoves, furnaces and boilers. One of the most common forms of biomass burners is a free-standing stove that can be used to warm a room using forced air and radiation. Fireplace inserts would be another type of stove. Biomass furnaces can be installed to replace fuel oil, propane or natural gas furnaces and can be integrated into current home heating installations. Hot-water boilers that burn biomass are also available.

Figure 1.
Corn-burning boiler.

(Image courtesy of
LDJ A-Maize-Ing Heat)

Figure 2.
Example of a corn burning furnace

(A-maizein-heat)

Figure 3.
Example of a corn-burning stove

(www.northerntool.com)

How They Work

Pellet or corn stoves all work on the same basic principles. The most common design involves a metering system that adds the granular product (fuel) to a burning chamber from a storage hopper. The fuel must be added slowly because pellets or corn are too dense to burn in a pile (Spieser, 1997). In the burning chamber (firebox), the granular fuel is combined with air supplied by a blower. Typically the combustion air is taken from outdoors and an exhaust blower forces the combustion fumes outside through an exhaust vent.

With most stoves, negative pressure is created in the firebox by creating a draft with the exhaust blower. Therefore, if the stove has any air leaks, the air is pulled into the stove, eliminating the risk of exhaust air escaping into the room (Muske, 2005). Adjusting the draft may be required to obtain efficient combustion.

Most stoves use one of two types of metering systems. In one system, the fuel is dropped in from above the burning chamber. In the other design, fuel is added to the bottom of the burning chamber. Both systems usually use a metering auger to add the granular fuel to the chamber. By adjusting the speed of the metering auger, the rate of fuel consumption can be controlled. Heat production is directly related to the amount of fuel consumption. A stirring auger or tumbler often is used to aerate the corn that is in the firebox to provide a more efficient burn.

A fire starter normally is used to light the stove. The fire starter can consist of a gel used to cover the fuel to help it ignite, compressed wood products or even small pieces of kindling. A small pile of the granular fuel is added to the burning chamber with the fire starter. Once the fuel is thoroughly burning, the fuel metering system is started. American Energy Systems recommends using wood pellets to ignite the fire, even if you are burning corn or other fuels. Corn is often too difficult to ignite and may take a long time to ignite a sustainable burn. Following the ignition instructions listed by the manufacturer is important. Depending on the manufacturer, the model of stove and the type of fuel used, a self-igniter may be available.

Before purchasing a biomass stove, the purchaser needs to seriously consider the implications. Burning corn or other biomass requires a time and effort commitment that other heating sources do not. While biomass burners generally do save in fuel costs, the time to operate a biomass burner needs to be considered. Working with a reputable distributor that has been in the business for a number of years is recommended. Ask the stove distributor for references of customers. The distributor should be more than happy to provide names and phone numbers of individuals who are using the company's product.

Certification and Safety Standards

Most burner designs are controlled by one of two standards established by the National Underwriters Laboratory (UL). UL 391 and UL 1482 examine the safety of solid-fuel type heating units (UL, 2008). Many models of biomass burners fall under the control of the Wood Heater Compliance Monitoring Program of the Environmental Protection Agency, which involves the testing and certification of wood stoves. All stoves classified as EPA-certified wood stoves must comply with specific particulate emission limits. A high air-to-fuel ratio may exempt some biomass burners from EPA certification (EPA, 2006). Check to ensure the stove is third-party certified safe, either by the UL or the EPA, and check with your insurance agent about coverage for corn stoves before purchasing a unit.

Types of Fuels

Manufacturers specify the types of fuels a particular burner is designed to use. Burners can be specified to burn wood pellets, corn or both. Other fuels, such as wheat, rye, cherry pits and waste paper pellets, have been burned successfully in biomass burners. Burning fuels other than those recommend by the manufacturer may affect performance and void the warranty.

Often, a type of burning aid is added to the fuel to help eliminate excess ash and burning residues. Crushed oyster shells or other calcium sources have been recommended by some manufacturers to provide a cleaner and more efficient burn of corn and to reduce clinker formation. Clinkers are hard masses of improperly burned fuel that can clog parts of the burner, reducing efficiency. Each manufacturer will have specific recommendations on how to reduce clinker formation and remove those that do occur. Some manufacturers recommend other types of additives and will void the warranty on their auger system if oyster shells are used.

Fuel quality also must be monitored if burning corn or wood pellets. Corn moisture content affects combustion. Buffington (2004) advises that the moisture content of corn should be no higher than 15.5 percent moisture, while Muske (2005) recommends the moisture content be 14 percent or less to ensure that the corn will both store and burn effectively. Others recommend that the corn moisture content be 12 percent or lower. The corn also should be clean and free of foreign materials, such as cob pieces and husks, to ensure proper combustion and flow of material in the stove. Dust content also can be an issue.

Muske has experimented with burning many different types of fuels in biomass burners. In his experience, he has found that wheat and oats produce large amounts of ash and sunflower and soybeans burn with an oily residue. He has found that barley burns well in the biomass burners and durum burns especially well.

Installation/Applications

Biomass burners often can be incorporated into existing heating systems. Biomass boilers or biomass furnaces can replace or supplement the existing heating source. Thermostat-based controllers are available and allow the biomass burner to adjust the burning rate to the heating needs. Some of the burner models will have an adjustable heat setting, but are not automatically controlled by a thermostat. An estimated 50 percent of biomass burners are installed in the living area of a home and 50 percent are installed in the basement. The basement is usually the best option because it will allow heat to rise and circulate through the entire house (Muske, 2005).

Having the installation of a biomass burner performed by a trained professional or having detailed installation instructions is important. Installation must meet all state, local and/or city codes and standards and insurer requirements. Generally, energy experts recommend that stoves have 3 to 4 inches of clearance when installed (Muske, 2005). The stove also may need to be installed on a noncombustible floor protector, such as ceramic tile.

A fresh outdoor air venting system is a component of nearly all biomass burners. This is to prevent creating negative pressure that pulls cold air into the area containing the burner and to increase the efficiency of the entire system. An exhaust pipe is required to remove the combustion gasses. These two piping systems need to extend outside the building.

Removing Ash

The burning chamber periodically will need to be cleaned of clinkers or ash after biomass is burned. A common recommendation is to remove the clinkers daily and remove the ash once a week, but frequency will vary depending on the fuel, the amount of fuel used and type of biomass burner. Clinkers are caused by unburned fuel or contaminants and can become very hard. They can cause problems with fuel feeding into the fire chamber if not removed. Generally, the homeowner would operate a burner continuously for one week, then shut it down and clean the stove and remove the ash (Muske, 2005). Depending on the efficiency and type of burner, about 15 pounds of ash will be produced when burning corn during the course of the heating season (Nichols, 2005).

Develop a plan for proper disposal of ash before purchasing a corn burner. Corn ash has some modest value as a fertilizer and as a liming agent, with no evidence of heavy metals or any other contaminants. The corn ash (after cooling) can be applied safely to garden areas, flower beds, lawns and fields. To ensure the safe handling of ash, use only noncombustible containers and store the ash outside. Never use paper or plastic bags for storage of ash.

Maintenance

Thorough maintenance is recommended about once a year, but timing will depend on operating conditions. Service the moving parts by oiling the hinges and blowing dust out of the blower motor. General cleaning of the outside stove surfaces also will help preserve its appearance. Inspect the chimney or stovepipe before the heating season to allow for necessary repairs before the stove is needed. Look for broken or cracked parts, bird nests and extensive soot buildup. Check the chimney or stovepipe regularly throughout the heating season. Cleaning of the chimney or stovepipe will depend on the amount of use. Maintenance should be done according to manufacturer specifications.

Fuel Requirements, Availability and Storage

Ensure you will have a reliable fuel supply before purchasing a burner because corn or other types of biomass with the appropriate characteristics may be difficult to obtain. Purchasing corn in large quantities often is necessary to secure the best price, so proper storage must be provided. Storage containers must be rodent-resistant. An outside hopper bin commonly is used for corn storage. Garbage cans or 55-gallon drums can be used for short-term storage for small quantities of biomass. Insect infestations are likely if corn is stored during warmer temperatures. For this reason, all hoppers and storage containers should be emptied at the end of the heating season. Fuel transportation, storage and handling costs must be included in the heating cost.

The amount of fuel that will be used depends on many variables, including the size of the area to be heated, the heat output and the quality of the fuel. An average 1,500-square-foot home in North Dakota should use around 80 million British thermal units (BTU) of heat for a 150-day heating season. A pound of corn has about 6,800 BTU, so you will need roughly 80 pounds of corn to heat each day (80 million divided by 6,800 divided by 150). That is about 12 gallons or 2½ 5-gallon buckets worth of corn every day.

Depending on the size, model and combustion rate of the biomass burner, the hopper must be refilled daily or every few days. Hopper sizes can vary from 100 to 500 lbs.

If the stove runs out of fuel, it must be relit, which is an inconvenience, although some stoves have automatic ignition systems. Consider adding a battery backup system to keep the fuel supply auger operating in case of power failure.

Energy Content and Cost of Fuel

While cost savings are expected using biomass fuels, it is important to use a valid cost comparison tool to ensure cost savings. North Dakota State University Extension service has a cost comparison chart that enables quick fuel cost comparisons. Units of corn and other agricultural commodities are measured in pounds or bushels, wood pellets are measured in pounds or tons, and fuel oil or propane is often measured in gallons. Because of this, conversions must be made to accurately compare the energy content of each fuel. For biomass, the energy content is commonly expressed in BTU per pound. A BTU or British thermal unit is defined as the quantity of heat energy required to increase the temperature of one pound of water by one degree Fahrenheit.

When comparing fuels, using accurate values for the energy contents of each commodity is important. Buffington (2004) explains that the moisture content and burning efficiency is often not taken into account. This creates inflated results for the energy contents. The energy content for corn is about 8,000 to 8,500 BTU per pound of dry matter. Corn with 15 percent moisture then would have only about 6800 BTU/pound (8,000 x .85). Research conducted by the Agricultural Utilization Research Institute determined the energy contents of several common agricultural energy sources. Some of the results of the study are listed in Table 2. With any agricultural product, the quality and energy characteristics will vary significantly with growing conditions, how the product was handled and the moisture content.

The heating efficiencies of the burners must be considered. Heating efficiency refers to the amount of heat produced compared with the potential heat in the fuel. If all the energy of the fuel were converted to heat energy, the burner would have a heating efficiency of 100 percent. Biomass heaters will not convert all of the fuel energy into heat, so the energy content of the fuel must be reduced for accurate comparison. Some fuels can be converted to heat more efficiently than others and some burning units can convert fuel more efficiently.

Table 1. List of equivalent heating values for corn (adapted from Buffington, 2004).

Fuel	Energy Content	Pounds of Shelled Corn	Bushels of Shelled Corn
1 ton of hard coal (nonlignite)	14,000 BTU/lb	3,500	63
1 ton of lignite coal	6,600 BTU/lb	1,650	29
1 gallon of kerosene	125,000 BTU/Gal	16	0.3
1 gallon of No. 2 fuel oil	135,000 BTU/Gal	17	0.3
1,000 ft^3 of natural gas	1,000,000 BTU	125	2.2
1 gallon of propane	92,000 BTU/Gal	12	0.2
1 full cord of firewood	24,000,000 BTU/cord	3,000	54
1 ton of wood pellets	8,200 BTU/lb	2,050	37
1,000 kwh of electricity	3,413 BTU/kwh	427	8
1 bushel 15% moisture corn	8,000 BTU/lb	56	1

Table 2. Heating values of various agricultural products (AURI, 2005).

Product	Moisture Content (Wet Basis)	BTU/lb (As Is)	BTU/lb (Dry-matter Basis)
Corn – shelled	13.4%	6,924	8,100
Corn – high oil	12.5%	7,398	8,480
Hardwood pellet	7.1%	7,955	8,573
Soybeans	10.3%	8,783	10,230
Sugar beet pulp	9.7%	6,597	7,345
Sunflower hulls	8.7%	8,474	9,654
Wheat	10.4%	7,159	8,063

The heating efficiency of heating units often is measured in terms of either combustion efficiency or annual fuel utilization efficiency (AFUE). Pierce (1998) explains that the combustion efficiency is an instantaneous measurement of how well the system is converting fuel energy into heat. The AFUE averages the efficiency during the entire heating season, accounting for losses that occur when the heating unit is starting or cooling or heat escapes with the exhaust (Pierce, 1998). Buffington (2004) estimates that corn burns with an overall thermal efficiency of about 75 percent. This is compared with about 85 percent combustion efficiency for propane. Typically, the AFUE is about 85 percent of the combustion efficiency (Pierce, 2000). The AFUE is required by federal law to be included with the "energy efficiency guide" attached to new heating units. The system with the highest AFUE will be the most economical to operate if the price of each heating fuel is the same. By using the equivalent heating values shown in Table 1, the price per unit of fuel, the heating efficiency and the cost of different heating systems can be compared.

A comparison of fuel costs for corn and propane can be completed using the formulas in Table 3 *(see page 6)*. First, a ratio to compare the two fuels being compared is determined. Then, using that ratio, the most cost effective fuel source can be determined.

The purchase, shipping and installation cost must be considered in addition to fuel cost. Many different models of biomass burners are available in residential, commercial and industrial sizes. The residential-sized models have heat outputs in the range of about 50,000 to 170,000 BTU/hour. The commercial models range from 100,000 to 500,000 BTU/hour and the industrial models are even larger. BTU/hour is the amount of BTU created by the stove in one hour's time. The price range for residential-sized models is about $1,000 to $6,000, depending on the heat output and additional features. Shipping, delivery and installation costs may be extra. Table 5 compares purchase prices for a few commonly available biomass burners.

Table 6 gives an example cost comparison between heating with corn and propane that includes the cost of an average stove or heating unit and labor costs.

Several manufacturers and/or retailers of corn and wood pellet burners are listed in Table 7.

Table 3. Calculations for fuel cost comparisons of propane and biomass.

Fuel ratio (gallons/bushel) = $\dfrac{\text{Corn heat content (Btu/lb)} \times \text{56 lb/bushel} \times \text{corn burner efficiency}}{\text{Propane heat content (BTU/gallon)} \times \text{propane heater efficiency}}$

Equivalent corn price ($/bu) = Fuel ratio (gallon/bushel) x Propane price ($/gallon)

Example: Comparing 15 percent moisture corn with a heating efficiency of 75 percent (0.75) and a heat content of 6,800 BTU/pound with propane that has a heating efficiency of 85 percent (0.85) and a heat content of 91,600 BTU/gallon

$$\textbf{Fuel Ratio (gallons/bushel)} = \frac{6{,}800\ \frac{\text{BTU}}{\text{lb}} \times 56\ \frac{\text{lbs}}{\text{bu}} \times .75}{91{,}600\ \frac{\text{BTU}}{\text{gal}} \times .85} = 3.668\ \frac{\text{gal}}{\text{bu}}$$

Equivalent corn price ($/bu) = 3.668 gallons/bushel X $2.20/gallon = **$8.07**

Corn at $8.07/bushel equals propane at $2.20/gallon.

Conclusion: If the price of propane is $2.20, then burning corn would be more cost effective unless the price per bushel of corn is more than $8.07.

Table 4. Comparable corn and propane prices for heating, assuming a moisture content of 15 percent for the corn.

Propane Price ($/gallon)	Comparable Corn Price ($/bushel)
$0.50	$1.83
$1.00	$3.67
$1.20	$4.40
$1.40	$5.14
$1.60	$5.87
$1.80	$6.60
$2.00	$7.34
$2.20	$8.07
$2.40	$8.80
$2.60	$9.54

Table 5. Price and size comparison of common biomass burners.*

Type of Burner	Manufacturer	Burner Model	Maximum Heat Output BTU/hr	Price	Source
Stove	Northern Tool and Equipment	Northstar	55,000	$1,500	www.northerntool.com (800) 533-5545
Stove	LMF Manufacturing	Iroquois	50,000	$1,860	www.americasheat.com (800) 582-4317
Stove	American Energy Systems	Countryside Pedestal	50,000	$2,890	www.hearthdirect.com (800) 495-3196
Stove	Snow-Flame Corn Stoves	No. 5000	40,000	$2,300	www.snowflame.com
Furnace	American Energy Systems	Magnum 7500	78,000	$3,348	www.hearthdirect.com (800) 495-3196
Furnace	LMF Manufacturing	BM 620-9	100,000	$3,100	www.americasheat.com (800) 582-4317
Boiler	LMB Manufacturing	AHB 100/170	100,000 170,000	$4,500	www.americasheat.com (800) 582-4317
Boiler	LDJ Manufacturing	A-maize-in heat 991-10	165,000	$5,300	www.ldjamaizeingheat.com 1-866-535.7667

*Prices intended as approximation only and may not reflect current prices. Specifications are taken from given Web sites and reported as manufacturers' claims. Web sites were accessed June 6, 2008.

Table 6. Example cost of corn heating vs. cost of propane heating.

About 80 Million BTU are required per year to heat a 1,500-ft^2 well-insulated house in North Dakota, assuming 56 pounds (lb) of corn per bushel (bu), labor costs of $10/hour, corn prices of $5 per bushel and propane costs of $2.20 per gallon (gal).

Heating with corn

■ **Cost of corn**

$$\frac{6{,}800 \text{ BTU}}{\text{lb}} \times \frac{56}{\text{bu}} = \frac{380{,}000 \text{ BTU}}{\text{bu}} \times 75\% \text{ efficient} = 285{,}600 \text{ useable } \frac{\text{BTU}}{\text{bu}}$$

$$\frac{80{,}000{,}000 \text{ BTU}}{\text{year}} \times \frac{1 \text{ bu}}{285{,}600 \text{ useable BTU}} = \frac{280 \text{ bu}}{\text{year}} \times \frac{\$5}{\text{bu}} = \$1{,}400/\text{year}$$

■ **Cost of corn furnace**

$$\text{Furnace} = \frac{\$3{,}100}{10 \text{ yr approx life}} = \frac{\$310}{\text{year}}$$

■ **Labor cost**

$$\frac{150 \text{ heating days}}{\text{year}} \times \frac{10 \text{ minutes}}{\text{day}} \times \frac{\$10}{\text{hour}} \times \frac{1 \text{ hour}}{60 \text{ minutes}} = \$250/\text{year}$$

■ **Total cost = $1,400 (corn) + $310 (furnace) + $250 (labor) = $1,960 per year**

Heating with propane

■ **Cost of propane fuel**

$$\frac{92{,}000 \text{ BTU}}{\text{gal}} \times 85\% \text{ efficiency} = 78{,}200 \text{ useable } \frac{\text{BTU}}{\text{gal}}$$

$$\frac{80{,}000{,}000 \text{ BTU}}{\text{year}} \times \frac{1 \text{ gal}}{78{,}200 \text{ useable BTU}} = \frac{1023 \text{ gal}}{\text{year}} \times \frac{\$2.20}{\text{gal}} = \$2{,}250/\text{year}$$

■ **Cost of propane furnace**

$$\text{Furnace} = \frac{\$3{,}100}{15 \text{ yr approx life}} = \frac{\$200}{\text{year}}$$

■ **Total cost = $2,250 (propane) + $200 (furnace) = $2,450 per year**

Features to look for when selecting a corn stove:

- Easy access for ash removal
- Large fuel hopper
- Capability to burn multiple fuels
- Burners that do not require calcium additives
- Battery backup for feeding system
- Automatic ignition
- Stove is UL approved

Table 7. Manufacturers of biomass burners with contact information.

Company Name	Address	Phone	Website
LMF Manufacturing	Lock Haven, Pa.	(800) 582-4317	www.americasheat.com
American Energy Systems Inc	Hutchinson, Minn.	(800) 495-3196	www.americanenergysystems.com
Ja-Ran Enterprises	Lexington, Mich.	(810) 359-7985	www.ja-ran.com
Alternative Heating Systems	Fithian, Ill.	(218) 548-1190	www.corn-stoves.com
Grain Stoves Inc.	Blyth, Ontario	(888) 320-4042	www.grainstovesinc.com
Bixby Energy Systems	Rogers, Minn.	(877) 500-2800	www.bixbyenergy.com
Golden Grain Stoves	Sterling, Colo.	(800) 634-6097	www.goldengrainstove.com
Harman Stove Co.	Halifax, Pa.	(717) 362-1422	www.harmanstoves.com
Even Temp - St. Croix Stoves	Waco, Neb.	1-800-331-8862	www.eventempinc.com
LDJ manufacturing	Pella, Iowa	1-866-535-7667	www.ldjamaizeingheat.com
Snow-Flame, Inc.	Mills River, N.C.	1-828-891-1006	www.cornenergysystems.com
Northern Tool and Equipment	Burnsville, Minn.	1-800-533-5545	www.northerntool.com

Sources of Additional Information

For information on issues related to energy, visit the NDSU Extension energy homepage at *www.ndsu.edu/energy*.

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For more information about energy from the NDSU Extension Service:

www.ndsu.edu/energy

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North Dakota DEPARTMENT OF COMMERCE
Office of Renewable Energy & Energy Efficiency

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