ENERGY FACTS

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Corn Drying Using Crop Residues

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Corn drying is energy intensive and occurs during a 4-8 week period during the year. MSU grain drying tests in the late 1970's resulted in drying costs of 12-17 cents/bu (drying 25.5-15.5% moisture with propane).

Propane is the most common fuel for drying grain. It is easy to regulate, suitable for a range of burner sizes, permits a fairly wide heat modulation for a given heating unit and burns clean so that the products of combustion can be released into the air used for drying. However, propane prices will rise as natural gas is deregulated. It is possible that farmers may experience spot shortages due to high demand at harvest time.

Crop residues are renewable; corn residues are produced in proportion to the amount of corn dried. Large quantities of agricultural crop residues are used in several ways in Michigan, and some are disposed of at a loss to the producer. A potential shortage of economically priced energy adds value to collecting agricultural residues and converting them to energy.

In addition, tillage operations to incorporate crop residues require considerable energy. The amount used varies with the kind of implement and the number and kind of tillage operations. Reducing the number of tillage treatments and using implements more efficiently can significantly reduce energy requirements for crop production.

Considerations for Using Crop Residue

Any plant material found on the farmstead can be used as a fuel source. Typical crop residues include:

— Corn stover
— Corn cobs
— Corn screenings
— Wood chips
— Straw—wheat, oats, rye, barley
— Alfalfa (not good enough to feed)

Crop Residue Availability — Available crop residues are the plant materials that can be collected and converted to heat energy. Unavailable crop residues represent plant materials that are more difficult to collect, such as the lower stalk area or the root zone area of the crop. The available crop residues considered are corn stover (stalks, husks and leaves), corn cobs, wheat straw, and dry alfalfa. The average available residues of these crops in Michigan are shown in Table 1.

TABLE 1. Average available crop residue yields for Michigan.

Crop Residue	Yield (dry matter/acre)		
	Low	*Avg.*	*High*
Corn Stover (1.)	1,940	3,665	4,657
Corn Cobs (1.2)	580	1,095	1,391
Wheat Straw (1)	1,187	2,240	2,783
Alfalfa Hay (3)	4,000	4,900	12,000

[1]*Assuming residue harvest weigh equals grain harvest weight*
[2]*Assuming 23% of corn residue is corn cobs, 77% of corn residue is stover*
[3]*Total Production for harvest season*

Energy Aspects — In general, a pound of plant biomass dry matter yields about 8,000 BTU. Grain straw and alfalfa are about 15% moisture when harvested. Corn stover, at the time of grain harvest, has a moisture content about twice that of grain. At the time of grain harvest, corn cobs have a moisture content 10-20% greater than the moisture of the grain. The amount of moisture in the residue affects the available energy during combustion, as illustrated in Table 2. By comparison, a gallon of LP gas would yield approximately 80,000 BTU of available energy (assuming 85% burner efficiency). On the other hand, energy is required for collection and transportation of the crop residue. According to Extension Bulletin E-1123, "Crop Residue and Tillage Considerations in Energy Conservation," 3.1 gal of fuel/ton are needed to collect and transport wheat straw. Thus, the energy for collection and transport will require about 200 BTU/lb of crop residue.

Pros and Cons of Types of Residue

Corn stover—harvested after corn is stored for the next year; requires space for storage; may contain large amounts of dirt, which is undesirable

TABLE 2. **Crop residue available energy and collection energy as a function of crop residue moisture content.**

Residue Moisture, % w.b.	Collection Energy BTU/lb of residue	Available Energy,[1] BTU/lb of residue
10	200	4,963
15	220	4,645
20	230	4,326
25	250	4,008
30	270	3,689
35	300	3,371
40	330	3,052
45	370	2,734
50	410	2,415

[1]*Calculated assuming 8,000 BTU/lb dry matter; 1,100 BTU/lb water evaporated; 70% combustion efficiency.*

Corn cobs—clean fuel; harvestable in proportion to the amount of corn to be dried; if collected from combine with trailing wagon, will fields be dry enough?; if stored for next year, must be dried, or stored in a ventilated, crib-type structure.

Corn screenings—estimate volume increase for transportation; must be used that year because of moisture level and difficulty of drying; high moisture level may cause some difficulty in burner operation; size range critical for proper combustion

Wood chips—economical only when locally available; high moisture may be a problem unless chips are dried; size important for proper combustion.

Straw—storage space requirements; fuel density; alternative markets; probably will be baled

Alfalfa—useful only if too much field exposure causes feed value to decrease; probably will be baled, but could be cubed for higher energy density

Soybean residue—collected either through flail chopping or windrow and baling; may be too much dirt for proper burner operation.

Other Considerations

Costs of collection, transportation and storage — The cost of collecting crop residues is often figured assuming that an extra trip over the fields is required to collect the residue. Studies have shown a cost of ½ to 1 cent/lb of biomass collected.

Soil Erosion — Soil erosion is a consideration mainly for corn residues. Corn residues on the soil surface help to reduce both wind and water erosion. Estimates of the corn residue necessary to stay within soil erosion tolerance limits vary in the range of 65-85%. It is reasonable to leave 80% of the corn residue on the soil, leaving only 20% of it usable for grain drying.

Fertilizer Replacement — Removing crop residues from the field not only has a potential effect on soil erosion, but also tilth and fertility. Crop residues returned to the soil help to maintain soil fertility by storing water and essential plant food elements. Corn stover (150 bu/acre) could return 100 lb of nitrogen, 11 lb of phosphorous and 77 lb of potassium per acre; wheat straw (60 bu/acre) could return 30 lb of nitrogen; 5 lb of phosphorous and 35 lb of potassium pei acre (see Extension Bulletin E-1123).

Labor Requirements — The convenience and density of the traditional fossil fuels cannot be overlooked. The drying process can be semi-automated, and thus continue with very little supervision, as long as wet grain is available. Using crop residues as an energy source for grain drying requires additional time from the dryer operator. Fuel must be added on a regular basis, clinkers and ash removed as necessary, and other operations done. This extra time may be readily available, and is often required when the farmer is rushing to complete the grain harvest. It might be desirable to harvest the crop residue during the summer or winter months, for use the following fall.

The MSU Crop Residue Furnace

Furnace System Construction and Operation — The Michigan State University furnace consists of two concentric steel cylinders. (See Figure 1).

A sloping grate is located at the bottom of the combustion chamber to support the fuel pile. An opening in the cylinder below the grate provides access to remove the undergrate ashes.

Fuel is pushed onto the sloping grate by an automatic auger feeder system. The system consists of an electric motor-driven feed wagon, a feed hopper and stoker-auger driven by a hydraulic motor.

The combustion air is forced into the furnace plenum between the two cylinders, where it is preheated. The primary air enters the fuel pile at the bottom of the grate where gasification and pyrolysis of the fuel takes place. The producer gases travel upwards into the secondary combustion zone of the furnace. Secondary air from the furnace plenum enters into the upper (secondary combustion) zone through two rows of tuyeres. The tuyeres cause a vortex

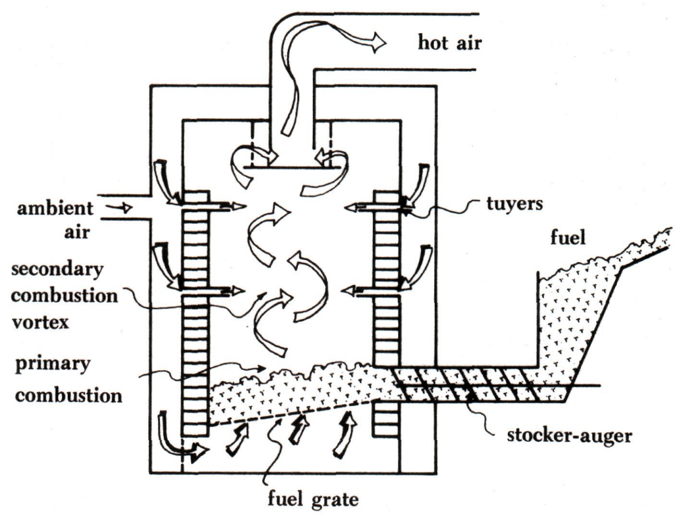

Figure 1. Schematic representation of MSU biomass furnace.

(spiral) and mixing of the flue gases. Unburned material or fly ash is centrifugally separated from the flame spiral. These particulates fall onto the top of the burning pile where they are reignited.

The flow of hot air from the top of the cylinders ensures that smoke and other volatile gases do not escape through the feed auger or other leaks. The exhaust flue gases are blended with the ambient air to achieve the desired temperature for air supplied to the dryer fan intake.

Experimental Results — The dryer system was used to dry 2,750 bu of corn from an average initial moisture content of 26% to 15% (w.b.). The biomass burner was connected to a Shivvers, in-bin counter-flow drying system. Table 3 shows the results from several corn drying tests.

Table 3 contains the standardized energy consumption and operating costs for the different fuels and fuel feeding rates, based upon a corn yield of 100 bu/acre dried from 26% to 15.5% MC. Average standardized specific energy consumption was 3,846 BTU/lb of water removed. Average drying capacity and operating costs were 59 bu/hr and 11.5 cent/bu; the operating costs for the propane-fueled Shivvers System were 16.1 cent/bu. Thus, the drying costs for the biomass furnace system were lower than for the equivalent system fueled by propane (if the investment and labor costs are excluded). However, capital investment for the biomass system is substantially higher than for propane fueled systems.

Build Your Own Furnace Ideas

Generally, the construction material used for small, low temperature furnaces is low carbon steel with welded seams and riveted joints. When higher temperatures are used (i.e., in commercial and industrial furnaces) alloy steels containing chromium and nickel are also used. To withstand higher temperatures, ceramic coatings or aluminum steel are used. For farm-type furnaces where the drying temperature is held to 150-250°F, low carbon steel appears to be satisfactory. The firebox is normally lined with high temperature firebrick and includes a smoke shelf of cast iron or high temperature steel depending on the design. The low carbon steel should be at least 3/16" thick and flue passages greater then 1½" wide. To prevent the flue passages from getting too hot, it is necessary to force air across the outer surface as well as the inner surface.

The airflow required through a heat exchanger can be calculated by considering the maximum heat output and the temperature drop across the heat exchanger which prevents surfaces from exceeding 250°F. The minimum amount of heating surface required is approximately 20 times the grate area. The steel heat absorption rate is about 3,000 BTU/hr/sq ft of surface.

The amount of cast iron grate area required is generally estimated at 1 sq ft for each 20 lb of fuel burned/hour. In any event, the burning rate is limited to about 50 lb of fuel/hour/sq ft of grate area. The furnace volume is limited to 30,000 BTU/ft^3.

The effects of burner operations on smoke emissions may be an important consideration in public health issues. Efficient furnaces are those which burn the smoke and gas pollutants at high temperature in the range of 1,500 to 2,000°F. These are also the furnaces which minimize air pollution from the stack.

Commercially Available Burner Units

SUKUP MFG., Sheffield, IA 50475

The SUKUP CROP RESIDUE BURNER is lined with fire brick to produce high combustion temperatures necessary for efficient burning as well as to prevent the metal from warping under the high heat generated. The heat chamber is about 3 ft in diameter and 8 ft tall. The

TABLE 3. Standardized energy consumption and operating costs for different fuels and fuel rates for concentric vortex-cell furnaces I and II (1981 and 1982).[1]

Fuel Type	Fuel Moisture Content % w.b.	Fuel Feed Rate dry lb/hr	Total Required dry lb/acre	Electricity kWh/acre	Drying Rate dry bu/hr	Specific Energy Consumption BTU/lb H_{2O}	Drying Costs[2] ¢/bu
1982							
Wood chips	19.3	214	284	14	65	3,592	8.1
Wood chips	45.0	216	336	17	55	4,242	13.5
Corn cobs	10.1	207	336	15	60	3,785	6.4
1981							
Wood chips	44.3	181	321	19	49	4,061	13.0
Wood chips	44.3	258	317	13	75	3,969	11.7
Wood chips	48.9	276	369	14	65	4,627	15.6
Corn	14.5	176	315	19	48	3,977	14.5
Corn-wood chips	35.9	112	186	17	53	2,530	9.3

[1]*Based on corn yield of 100 bu/acre dried from 26 to 15.5% MCWB.*

[2]*Wood chips valued at 2.03¢/lb wet, corn at 4.91¢/lb, corn cobs at 1.59¢/lb, corn-wood chips mixture at 3.01¢/lb and electricity at 7¢/kWh.*

furnace can directly heat the air used for drying grain. It is equipped with a thermostat control and damper system to help control the temperature of the heated air to the grain bin. It will produce up to 3 million BTU/hr.

STORMOR INC., P.O. Box 198, Freemont, NE 68025

The STORMOR CROP RESIDUE FURNACE is designed for on the farm use. Furnace design uses a heat exchanger, which indirectly heats the air that is blown through the grain. The heat chamber is 8 ft wide, 7 ft high and 7 ft deep, making it capable of burning round bales 6 ft diameter x 6 ft or anything smaller. In this indirect fire system, there is no flame or combustion by-products entering the grain. The burner is capable of producing 900,000 BTU/hr.

MESSERSMITH MFG., P.O. Box 324, Escanaba, MI 49829

The MESSERSMITH INDUSTRIAL CONVERSION BURNER is designed to burn sawdust, wood chips, and biomass waste products semi-automatically. It will provide from 500,000 to 4,000,000 BTU, depending upon the type of fuel and the rate of operation. An auger in the bottom of the fuel hopper moves the fuel to the burner system and spreads the fuel over specially-designed cast iron grates. Combustion is aided by forced air under and over the fire. The electronic control of this unit: 1) keeps enough fuel on the grates for a pilot burn when the furnace is not calling for heat, 2) enables you to adjust the amount of fuel that is being fed into the furnace, 3) monitors the flow of fuel in the auger and 4) protects the motors from overload. The unit is marketed with standard augers and grates. Special augers and additional grates can be ordered.

MULTIPLE ENERGY CORP., P.O. Box 1304, Columbus, NE 68601

The CROP RESIDUE BURNER was designed to furnish heat energy to raise the temperature of a drying airstream to a desired level for drying corn or small grains. The burner is made to attach to a centrifugal fan which must be designed to withstand the drying operating temperatures normally encountered (120-180°F). The heat output of the burner is controlled by a thermostat located in the airstream entering the drying bin. The fuel is automatically injected into the burner from a hopper tank by means of a small auger. The auger motor is energized whenever the burner needs additional fuel. Nearly all of the heat energy of the fuel is used in this direct-fired unit since even the products of combustion are injected into the drying airstream.

STOCKDALES GRAIN EQUIPMENT, Route #3, Iowa Falls, IA 50126

The CORN-FUELED FURNACE uses an indirect heating method, and will burn corn screenings or other grain unfit for consumption. It is automated with gauges and controls that display temperature and efficiency factors. The circulating exhaust system recaptures heat from the outside skin of the furnace. Because it has few moving parts, the furnace is relatively maintenance-free, and it burns a farm fuel that is replenished every year.

WATERWIDE SYSTEMS, P.O. Box 4, Haumoana, New Zealand

The WATERWIDE BURNER is a unique direct-fired design that first turns all the solid fuel into biogas. The gas is then burned at high temperatures to ensure total, pollution free combustion. This unit has almost total combustion efficiency—higher than oil and coal fired systems—so there is no chimney or ash pan. The company indicates that grain can be dried with no contamination, and that noxious sulphur fallout associated with other burners does not occur.

Safety with Biomass Fuels

On-farm, small-scale utilization of biomass fuels is still in the developmental stages. Building construction and the equipment for producing, processing and/or using these biomass fuels should adhere to appropriate codes and standards. These include building codes, Environmental Protection Agency regulations, National Fire Protection Assn. codes and standards, Occupational Safety and Health Administration regulations, and insurance requirements.

Some Hazards — Biomass-straw, corn fodder, etc. can be burned in specially constructed furnaces to dry grains, heat livestock buildings, etc. Corncobs, wood chips, or combustible cubes from other biomass materials may also be used. Equip the furnace system with automated controls to achieve maximum efficiency and to maintain temperatures within a safe range. Secure screen guard over the chimney top to prevent escape of hot ashes.

—Have a fire extinguisher available. A minimum of a 10 lb dry chemical, class ABC or BC fire extinguisher is recommended.

—Stay clear of components such as augers, feed rolls and similar devices that may have to be upgraded to permit the machine to function.

—Install and maintain carbon dioxide fire extinguishers and smoke and heat detectors.

—Use hydraulic motors to minimize fire hazards. Ground all wiring and metal hydraulic lines.

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