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Energy Costs for Corn Drying and Cooling

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The purpose of this brief article is to provide enough information so that readers can estimate costs for drying and cooling corn. More information about managing dryers and storage can be found on the University of Minnesota Biosystems and Agricultural Engineering extension postharvest web page at http://www.bae.umn.edu/extens/postharvest.

Figure 1. Estimates of energy used for gas fired drying.

Burner: 0.02 gallons LPG per bushel per percentage point of moisture removed (For dryers that use natural gas, the equivalent number would be about 1.84 cubic feet of natural gas per bushel per percentage point of moisture removed or 0.0184 hundred cubic feet [ccf] of natural gas per bushel per percentage point of moisture removed.)

Fans: approximately 0.01 kWh electricity per bushel per percentage point

Gas-fired drying

Energy use per bushel per percentage point of moisture removed for gas-fired drying varies widely among dryers, but the value is fairly consistent for a particular dryer that is managed in a similar way from one year to the next. The best source of information on energy use for drying is actual records on quantity of grain dried, amount of moisture removed, and energy use to remove that moisture. Managers of gas-fired dryers are encouraged to collect the information that is necessary to calculate annual drying costs. In some cases, it might be desirable to install extra gas and/or electric meters to obtain the necessary data.

When better information is lacking, you can use the information in Figure 1 to get a rough estimate of energy use for gas fired drying. These figures do not take into account the energy savings that would result from recirculation of part of the dryer's exhaust air. (Note that LPG stands for liquefied petroleum gas, which is mostly propane.)

Some of the factors that affect energy use by gas-fired dryers are:

- Type of dryer/dryer design. This is the most important factor. Energy use is affected by things like airflow per bushel, direction of airflow relative to grain direction, grain depth or column thickness, grain stirring or mixing, operating temperature, rapid cooling in the dryer vs. slow cooling in a separate bin, and use of partial exhaust air recirculation. Unfortunately, we don't have good data for specific types or brands of dryers, and currently there is no organization that conducts independent tests on energy use by dryers.

- Outdoor weather. As you'd expect, dryers use less energy in warm, dry weather, and more energy in cold weather. Gas use is roughly proportional to the number of degrees the air is heated. For example, heating air from 0 to 240°F takes about 20% more gas than heating air from 40 to 240°F. Offsetting the energy savings for heating drying air during warm conditions, however, are the following factors: Warm air is less dense than cold air, so fans move less air, which tends to reduce drying capacity when outdoor air is warm; Warm outdoor air usually holds more moisture than colder air, which also tends to reduce drying capacity; And less moisture is lost during cooling when outdoor air is warm, because moisture loss is a function of the difference between the temperature of the hot grain and outdoor air.

- Initial and final corn moisture. It takes slightly more gas per point of moisture removed at low moisture contents than it does at higher ones, and of course it takes more gas per bushel for more total points of moisture removed. This means anything that can be done to get corn out of the dryer sooner (for example, use of dryeration or combination drying; see www.bae.umn.edu/extens/postharvest for more information on these topics) is going to improve efficiency of gas use as well as total gas use. Drying grain further than necessary (overdrying) for safe storage, marketing, or the grain's final use increases energy use, reduces weight of grain available for sale, increases breakage susceptibility of grain kernels, and reduces overall profits. Careful management and/or high quality moisture sensors and dryer controls can reduce problems with overdrying.

- Corn hybrid. Researchers and farmers are finding that there are differences among hybrids in energy requirements for artificial drying. Unfortunately, we don't know enough, yet, to recommend one hybrid over another on this basis. Corn yield trials, though, do indicate that some high-yielding hybrids have consistently lower harvest moisture. Using these hybrids would reduce drying costs.

- Column thickness/corn depth in dryer. The more corn that drying air has to pass through before exhausting from the dryer, the more saturated the air will be, and the lower gas use per bushel will be. Increasing grain depth or column thickness also increases moisture variation when the dryer is unloaded and increasing grain depth also tends to reduce dryer capacity. Loss of dryer capacity with increasing grain depth is especially critical for in-bin continuous flow dryers, which usually give the best combination of capacity and efficiency with grain depths of four to six feet.

- Drying air temperature. In theory, drying is more efficient at higher drying temperatures because it takes less energy to evaporate water at higher temperatures. In reality, the effect of drying temperature on energy efficiency probably depends on things like airflow per bushel and grain depth or column thickness. We do know, however, that reducing drying air temperature reduces dryer capacity (bushels dried per hour) and improves grain quality (fewer cracked and broken kernels, better test weight, and less starch damage).

- Airflow. Increasing airflow per bushel increases drying rate and it tends to decrease moisture variation in the dried grain, but increasing airflow also increases gas use per bushel.

Natural-air drying

Energy use for natural-air drying (electricity to operate drying fans) is very weather and airflow dependent, but it can be predicted for given weather conditions and airflow. (For more information about natural-air drying systems, see www.bae.umn.edu/extens/postharvest.) The best source of information on energy use for natural-air drying is several years of farm records for moisture removed, bushels dried, and electricity used. The more years of records, the better, because energy use per bushel can vary greatly from one year to the next. University of Minnesota drying studies, based on many years of weather data, indicate that the following electric energy use values are reasonable averages for 21% moisture corn dried to 16% when the drying bin is equipped with a fan that can supply 1.0 cfm/bushel (one cubic foot of air per minute per bushel of grain in the bin).

Figure 2. Natural air energy use values for 21% moisture corn dried to 16% with 1.0 cfm/bushel

October 1 harvest: 0.75 kWh/bu
October 15 harvest: 1.0 kWh/bu
November 1 harvest: 1.25 kWh/bu

Here are some factors that affect energy use in natural-air drying.

- Weather. Energy use per bushel can be twice as large in a cool, wet fall as in a warm dry one. Adding some supplemental heat (to heat drying air beyond outdoor temperatures) would speed drying in cool years, but supplemental heat greatly increases total energy use and cost. Contrary to popular belief, spoilage in natural-air dryers is actually less likely in cool weather because molds grow slower at low temperatures.

- Airflow. We suggest following the drying recommendations contained in “Natural-Air Corn Drying in the Upper Midwest” (available online at www.bae.umn.edu/extens/postharvest). If lower than recommended airflows are used, the risk of spoilage increases. If greater than recommended airflows are used, energy use per bushel increases.

- Grain depth. You can deliver the same airflow per bushel with smaller fans in large diameter, shallow bins compared to narrow diameter, deep bins. Although large diameter, shallow bins are initially more expensive than narrow, deep bins, energy savings more than make up the difference over the life of the bin.
- Layer filling, which involves filling a bin a few feet at a time over a period of several weeks, can also save energy in natural-air drying. The first layers put into the bin dry rapidly because airflow per bushel is quite high in a partly filled bin. Because these layers dry rapidly, layer filling also allows a person to start filling the bin with wetter corn.

- Corn hybrid. Hybrids that mature earlier and dry down faster in the field can be harvested and dried earlier in the fall when energy use per bushel is lower.

Combination drying

In combination drying, a gas-fired dryer is used to dry corn from a high harvest moisture down to about 21% moisture and then a natural-air dryer is used to dry the corn to a safe storage moisture. Use the energy values given earlier to arrive at a total energy cost for combination drying. (See www.bae.umn.edu/extens/postharvest for more information about combination drying.)

Cooling and aeration

Energy use for aeration to cool hot grain from a gas-fired dryer (hot corn that is transferred directly into storage should be cooled to outdoor temperatures within about 24 hours after it leaves the dryer) or to cool grain for winter storage depends primarily on the size of the fan motor and the number of hours of fan operation. Time required to move a cooling front through a bin of grain (called a cooling cycle) depends on airflow per bushel. (See www.bae.umn.edu/extens/postharvest for more information about dryeration and about storage management.) A rough estimate of the number of hours required to cool grain can be calculated as follows:

Cooling time, hours = 15 / (airflow in cfm/bu)

To reduce the temperature of stored grain from harvest temperature to the temperature recommended for winter storage (20 to 30F in the upper Midwest), it is best to cool the grain in stages - reducing the temperature 10 to 15 degrees F at a time. Complete cooling of a bin of grain can require two to four cooling cycles.

Motors on grain drying and aeration fans usually draw about 1 kW of electrical power per rated horsepower. Total kWh of electric energy use is the product of kW of electrical power drawn by the fan motor and the number of hours of fan operation. Thus, electric energy use by fan motors is approximately:

Fan energy use, kWh = Motor power, hp x 1.0 kW/hp x time of operation, hours

Example energy cost calculations

Example 1. Estimate energy cost per bushel for gas-fired drying corn from 21% to 16% moisture when LPG costs $1.00/gal and electricity costs $0.07/kWh.

Points removed = 21% - 16% = 5 points moisture removed

Energy cost =
5 points x 0.02 gal LPG per bu per point x $1.00/gal
+ 5 points x 0.01 kWh per bu per point x $0.07/kWh
= 0.1 gal/bu x $1.00/gal + 0.05 kWh/bu x $0.07/kWh
= $0.10/bu (LPG) + $0.0035/bu (elec) = <u>$0.1035/bu</u>

Example 2. Estimate the average energy cost for drying 21% moisture corn harvested October 15 and dried at 1.0 cfm/bu in a natural-air dryer in Minnesota when electricity costs $0.07/kWh.

Energy cost = 1.0 kWh/bu x $0.07/kWh = <u>$0.07/bu</u>

Example 3. Estimate the cost per bushel to aerate a 10,000 bu bin of corn using a 1/3-hp fan that delivers an airflow of about 0.15 cfm/bu. Assume that it takes four cooling cycles to completely cool the grain and that electricity costs $0.07/kWh.

Time for cooling cycle = 15/0.15 cfm/bu = 100 hours

Total fan operation time =
4 cycles x 100 hours/cycle = 400 hours

Energy use = 0.33 hp x 1.0 kW/hp x 400 hours = 133 kWh

Energy cost = 133 kWh x $0.07/kWh = $9.33

Energy cost per bushel = $9.33/10,000 bu = <u>$0.00093/bu</u>

Other drying costs

Although energy costs for grain drying are very important, don't forget to consider other grain drying costs when comparing drying systems. The total amount for the other costs of owning and operating a grain dryer can sometimes be at least as much as the cost for energy. Other costs include things like equipment costs for dryers, holding bins, conveyors, and controls (depreciation, taxes, insurance, maintenance, and repairs) and labor to operate drying systems. Additional factors that might be harder to quantify are quality of dried grain (quality is usually better for slower, lower-temperature systems), lost marketing opportunities for grain that is not dried immediately after harvest, and the value of storage space that you get with in-storage drying systems.

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