

Radio Wave Grain Drying Systems: An Opportunity for Agricultural Cost Savings and Grain Quality Enhancement Through Energy Efficiency and Beneficial Electrification

Based on GDS Paper by: Bethany Reinholtz, CEM, CWEP GDS Associates, Inc.

MAY 2020

This article was developed in partnership by:



Business & Technology Surveillance

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ARTICLE SNAPSHOT

WHAT HAS CHANGED IN THE INDUSTRY?

Grain drying is a crucial part of the agricultural industry. Over the past 50 years, drying grain has primarily been accomplished with high heat grain dryers utilizing natural gas or liquid propane (LP) as the thermal energy source, accompanied by electricity driven power fans and motors. These drying systems can lead to large energy expenses for producers. Radio wave grain drying is an emerging technology that uses radio waves instead of heat to remove water from the inside out of individual grains. In addition to helping farmers reduce their grain drying energy costs, this beneficial electrification technology may also improve grain quality, e.g., by reducing over- and under-drying.

WHAT IS THE IMPACT ON COOPERATIVES?

The agricultural industry is prevalent in many areas served by electric cooperatives. Radio wave grain drying may present a beneficial electrification opportunity for substantial electricity loads that also delivers improved economic performance for agricultural members and communities.

WHAT DO COOPERATIVES NEED TO KNOW AND DO?

Radio wave grain drying systems are currently being tested on a small number of farms, and should results prove favorable, the technology could provide significant benefits for both cooperatives and their members. More testing under more diverse conditions will help accelerate what looks to be a major potential win for agriculture. Co-ops should follow available study data to determine if agricultural members should consider radio wave grain drying, and if so, to share the results of this beneficial electrification opportunity.

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Introduction

According to the U.S. Grains Council, in the 2018 growing season, the U.S. grew more than 14.42 billion bushels of corn.¹ Each year artificial drying is used on varying amounts of this grain in order to reduce moisture levels to a specific level (usually 13 to 15.5 percent depending on type of grain and amount of time in storage) for long-term storage without spoilage. In the northern Midwest of the

U.S., the cost of grain drying is the second or third largest expense in corn production after fertilizer or seed.² Unfortunately, there is no hard data available on total annual energy use or costs for grain drying in the U.S. However, the Propane Education and Research Council (PERC) estimates that about 80 percent of grain dryers in the U.S. use propane, and total annual agricultural propane use has been between 825 and 1,100 million gallons from 2010-2015 (Figure 1).³ Of this total, between 25 to 300 million gallons is used annually for grain drying.

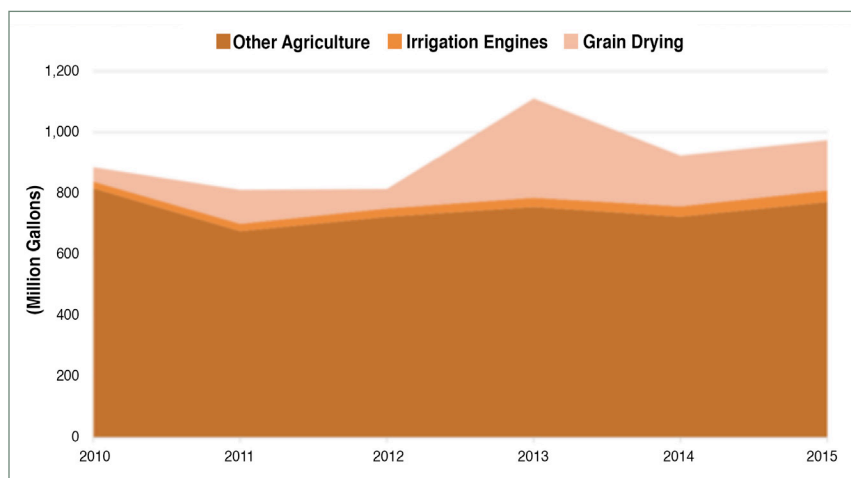


FIGURE 1: Annual U.S. Propane Demand in Agriculture
(Source: API Survey)

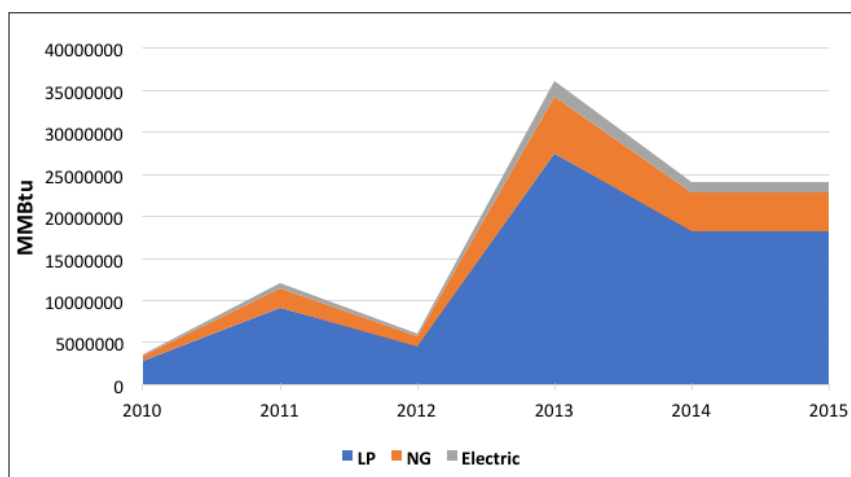


FIGURE 2: Estimated U.S. Energy Use for Grain Drying

Additionally, Iowa State University reports that 95 percent of grain drying energy use is from propane/natural gas and the remaining energy use is from electricity.⁴ Using this data, annual energy use related to grain drying from 2010-2015 has been estimated at between 3,600,000 – 36,100,000 MMBtu annually. At a propane rate of \$1.75/gallon, a natural gas rate of \$0.65/therm, and an electric rate of \$0.11/kWh, this is equal to an average of \$307 million dollars annually in energy costs.

Accelerated grain drying in the U.S. over the last 50 years has primarily been accomplished with high heat grain dryers which typically utilize natural gas or liquid propane (LP) as the thermal energy source. These dryers also require some electricity to power fans and motors on the systems. This can lead to large energy expenses for producers. In addition to often high energy costs, high heat dryers can produce uneven drying can lead to over-drying or under-drying, which has the potential to damage grain (cracks, fissures, etc.), all of which can lead to lower commodity prices and resulting profit losses for the farm. This paper discusses current grain drying technologies, efficiencies of these systems, and a potential new grain drying technology that may lead to an opportunity for improved grain drying, reduced grain drying costs, and improved grain quality.

¹ Corn Production and Exports. **U.S. Grains Council.**

² Plastina, A. **Estimated crop production costs in Iowa** (A1-20). *Ag Decision Maker - Iowa State University Extension* (2017).

³ Caldarera, M. **Propane in the Agriculture Market.**

⁴ Hanna, H. **Grain Drying Energy Use.**

If the moisture level of the grain is too high or too low, the farmer will receive a lower price than if the grain was at optimal moisture value.

The Importance of Optimal Grain Drying

Prices for grains, such as corn and soybeans, vary not just by volume (e.g., bushels, for corn), but also by density and quality. However, the price paid per bushel is dependent on several factors that relate to grain drying. These are: a) the average moisture content; b) other grain damage, such as cracks and fissures resulting from over- or under-drying; c) nutritional value, which degrades at drying temperatures above 250°F; and d) germination and viability (i.e., for seed corn).

Grains are bought and sold by bushel. A bushel is a volume measurement for grain created many years ago to facilitate fair grain trade. Although grain is referred to in terms of bushels in the United States, it is referenced

and traded on the basis of weight (tons or metric tons) throughout the rest of the world. To facilitate the trading of grain, the USDA created weight standards for each grain, so that grain could be weighed to determine the number of bushels rather than trying to make volume measurements. The test weight concept was developed by the grain trade as a means of accounting for the varying densities of grain caused by weather and/or production practices.⁵ Therefore, before grain is sold, the moisture level of the grain is tested, and in this way, grain is sold at the same price per bushel regardless of the water content.

Drying grain refers to evaporation of water from grains. If the grain is overdried, the weight is lower than at optimal moisture and the farmer is paid a lower price per bushel. If the moisture of the grain is too high, the payment per bushel will be lowered and the farmer will not receive as high a price as if the bushel meets the optimal moisture value of dry grain for that commodity. The maximum moisture value of various stored grain can be seen in Table 1. These values assume good quality, clean grain that is stored in aerated storage bins.

Furthermore, grain is often stored for many months. If not dried properly prior to storage, high moisture content in grain can lead to mold, mildew, and spoilage of the crop. For these reasons alone, proper grain drying is crucial. According to a 1990 survey of extension specialists throughout the United States, stored grain losses exceeded \$500 million for the year. Most of these losses resulted from infestation by several species of insects and damage by numerous molds and mycotoxins.⁷

The nutritional content and germination of the grain can also be a factor in grain value, while not factors that affect price paid per bushel. This is because many farms utilize some or all of their dried grain to feed their livestock and seed corn growers may be utilizing their own

TABLE 1: Maximum Moisture Content of Various Stored Grains⁶

Grain Type & Storage Time	Maximum Moisture Content for Safe Storage, %
Shelled corn or sorghum	
Sold as #2 grain by spring	15 1/2
Stored 6-12 months	14
Stored more than a year	13
Soybeans	
Sold by spring	14
Stored up to 1 year	12
Stored more than 1 year	11
Wheat, oats, barley	
Stored up to 6 months	14
Stored more than 6 months	13
Sunflower	
Stored up to 6 months	10
Stored more than 6 months	8
Flaxseed	
Stored up to 6 months	9
Stored more than 6 months	7
Edible beans	
Stored up to 6 months	16
Stored more than 6 months	14

⁵ Lindsey, A., **Bushels, Test Weights, and Calculations**. Ohio State University Extension.
⁶ McKenzie, B., **Managing Dry Grain in Storage**, Purdue University Extension.
⁷ **Stored Grain Losses Due to Insects and Molds and the Importance of Proper Grain Management**. University of Minnesota.

TABLE 2: Maximum Drying Temperatures (°F) for Selected Grains

Grain	Dryer Type				Seed
	Cont. Flow Dryer	Recirculating Batch Dryer	Column Batch Dryer	Bin Batch Dryer	
Wheat and Durum	150□	150□	135□	120□	110□
Malting Barley	120□	120□	110□	110□	110□
Soybeans (non-food)	130□	130□	110□	110□	110□
Oats	150□	150□	135□	120□	110□
Rye	150□	150□	135□	120□	110□
Sunflower	200□	200□	180□	120□	110□
Flaxseed	180□	180□	160□	120□	110□
Corn	200□	200□	180□	120□	110□
Mustard and Rape	150□	150□	130□	110□	110□
Pinto Beans, Navy Beans	90□	90□	90□	90□	90□

seed for their fields. While nutritional quality of livestock feed is unaffected by temperatures up to 250°F, other studies have shown reductions in nutrient availability and quality. In addition, a number of tests on drying seed grains show that germination drops rapidly as the seed kernel temperature goes above 120°F.⁸ For this reason, the temperature inside a dryer must be carefully monitored to ensure nutrition and germination are not affected.

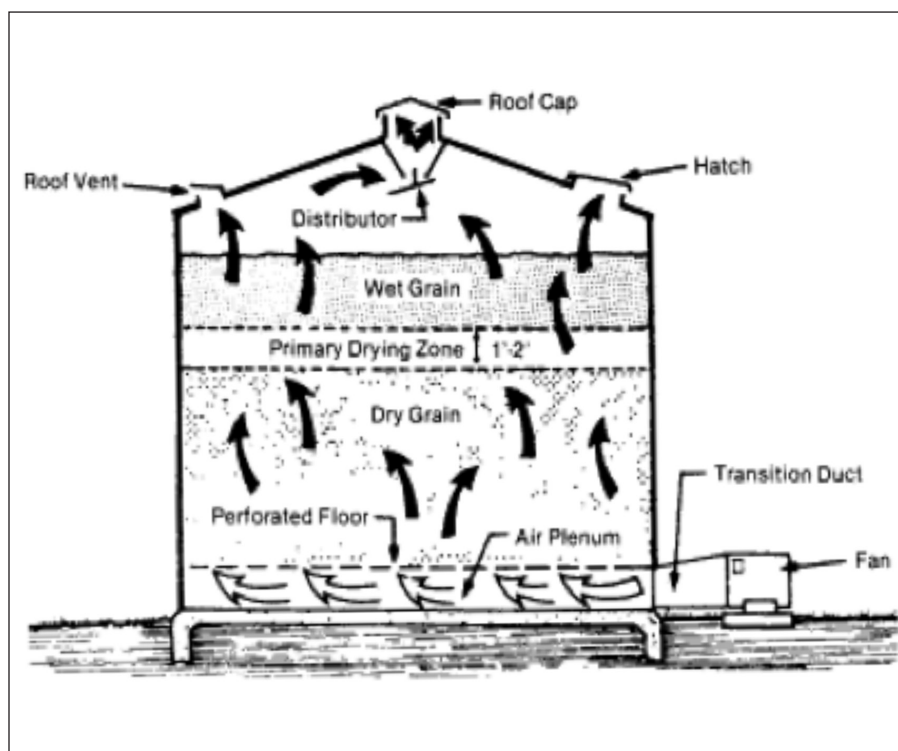
Maximum recommended drying air temperatures for selected grains can be seen in Table 2 (all temperatures are in °F).⁹ According to the University of Guelph, drying corn at temperatures over 45°C (113°F) will cause losses in viability and induce protein and carbohydrate reactions, which reduce nutrient availability and quality.¹⁰

Types of Grain Dryers in Use Today

There are many types of grain dryers on the market and the majority of them use liquid propane (LP) or natural gas to heat the grain using thermal energy during the drying process. Systems are also often accompanied by electric fans and motors.

LOW TEMPERATURE OR AMBIENT AIR DRYING

Low temperature or ambient air drying removes moisture, because the relative humidity of the input air is less than the air blown into the dryer. Air heating reduces air relative humidity and produces an even greater moisture difference between air and grain, causing a faster moisture removal process. Low temperature air drying systems typically use electricity for energy and do not utilize natural gas or liquid propane. Air movement through a natural air drying bin can be seen in Figure 3.

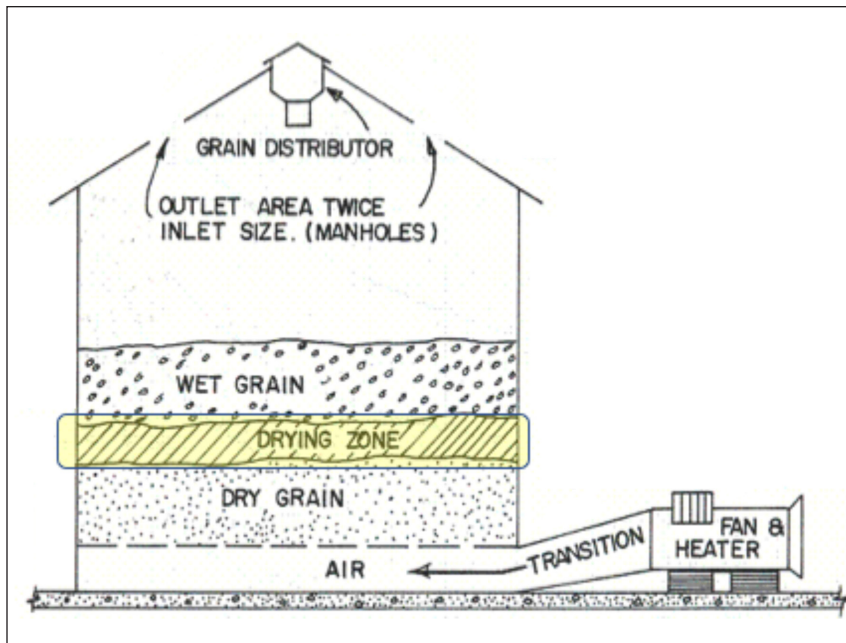
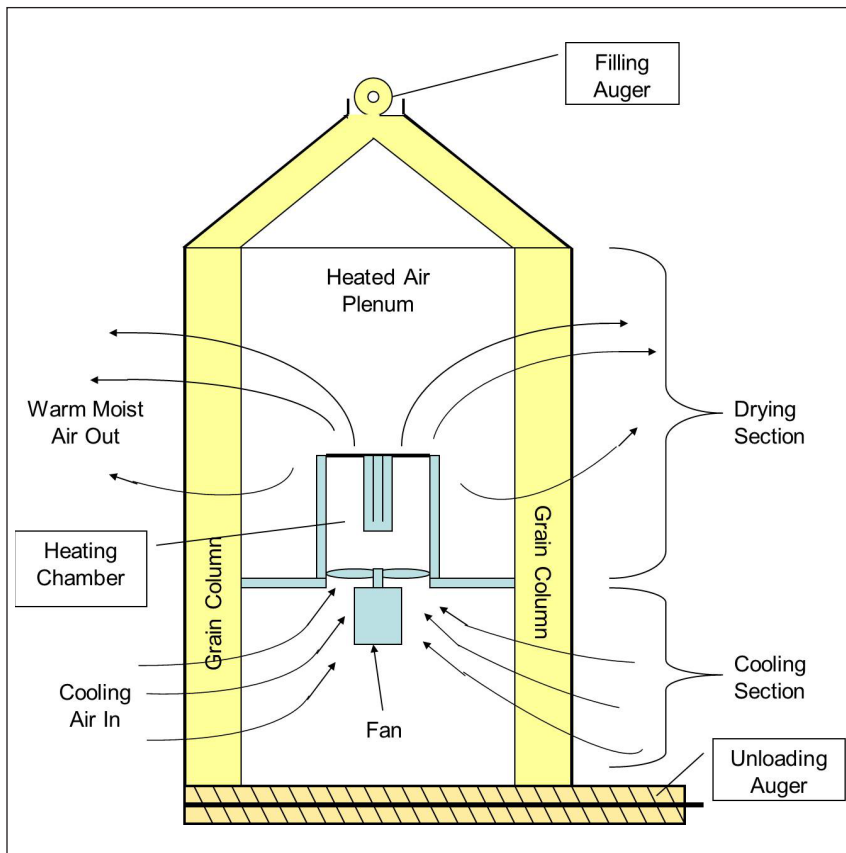
**FIGURE 3: A Natural Air-Drying Bin System¹¹**

⁸ Grain Drying, Dr. Kenneth J. Hellevang, PE, NDSU Extension Service, October 2013

⁹ Ibid.

¹⁰ A.G. Meiering, H.J. Hoefkes & L. Otten (1977) **Particulate Emission in Corn Drying**, *Journal of the Air Pollution Control Association*, 27:6, 548-552, DOI: 10.1080/00022470.1977.10470454

¹¹ EPD 397: Mcglammery, 5/3/2010. **Reducing Energy Use in the Grain Drying Process**. Eric A. Anderson

FIGURE 4: Bin Dryer¹²FIGURE 5: Continuous Flow Grain Dryer¹⁴

MECHANIZED GRAIN DRYING

Mechanized grain drying requires airflow to carry evaporated water away from the grain. The market is dominated by two types of dryers:

1. Batch:
 - a. Low Temperature, and
 - b. High Temperature
2. Continuous flow, which typically run at high temperatures.

Low temperature drying or drying using air heated 10°F over ambient air temperatures, is limited to grain with input moisture of about 24 percent. Low temperature drying is more prevalent in areas with low humidity and when grain needs less than 3 percent moisture removal. Sometimes, electrical resistance heaters are used for low temperature drying rather than gas-fired heaters.

High temperature bin drying uses a heater fan to raise grain temperatures from 120-160°F. Continuous cross flow dryers use high temperatures, heating grain to around 180-210°F. High temperature grain dryers evaporate more water at a faster rate than low temperature dryers, and therefore, require higher air flow rates. A drawing of a bin dryer can be seen in Figure 4.

Continuous flow dryers are used in production systems that require high capacity processing (measured in bushels per hour).

There are often trade-offs of grain quality between the continuous flow, high temperature type dryers (see Figure 5) and batch, low temperature type systems. Low temperature systems require longer residence time in the dryer, which often produces higher quality grain kernels. A high temperature system, when a lot of thermal energy is spent on grain in a short time, can stress the kernels and lead to cracking. Cracking is amplified by rapid cooling and can lead to lower quality grain, which in turn leads to lower price paid per bushel.¹³

¹² <http://tifton.uga.edu/eng/publications/grain%20soybean%20drying/grain%20and%20soybean%20drying.htm>

¹³ Grain Drying Systems, Dr. Dirk Maier.

¹⁴ <https://fyi.extension.wisc.edu/energy/grain-drying-and-storage/energy-conservation-for-continuous-flow-dryers>

It is estimated that it can take 1,000 Btu to 3,000 Btu to remove one pound of water from corn grain.

Energy use of technology for grain drying is primarily determined by the harvest conditions.

Grain Dryer Energy Efficiency of Current Technologies

Energy performance of grain drying is measured in Btu/pound of water removed. The professional world of grain dryer energy auditing is complicated because no dryer performance standards exist, and documented dryer performance data is limited and unorganized. Most of the existing efficiency data is from grain dryer manufacturers and is based on simulations from proprietary software. To date, there are no large third-party studies of grain dryer energy efficiency to use as a baseline and to verify manufacturer claims of efficiency. Further, there is little available information on the science and applied performance of different dryer systems as a function of highly variable real-world conditions, such as grain moisture content, ambient temperature, humidity and wind during drying, and other factors.

Energy consumption during grain drying occurs during grain handling and drying. There are claims that the rules of physics dictate that it takes *at least* 1,000 Btu to remove one pound of water from corn grain.¹⁵ Academic “back of the envelope” calculations when calculating continuous flow grain dryer efficiency reveal high capacity dryers use approximately 1,500-3,000 Btu/lb. of water removed, but deviations from this number may occur depending on dryer design, capacity, age, and

maintenance.¹⁶ These estimates are shown in Table 3, with lower values being more energy efficient.

Cross flow, high temperature dryers use about 0.02 gallons of propane/bushel/% moisture removed, 0.018 Therms of natural gas/bushel/% moisture removed, and 0.01 kWh of electricity/bushel/% moisture removed (see Table 4).¹⁸

Energy use of technology for grain drying is primarily determined by the harvest conditions, including the number of bushels to be dried, the moisture content of the grain, humidity and temperature during drying, and the efficiency of the drying process. A very wet harvest season may require significantly greater energy use for drying, resulting in higher costs for farmers drying crops.

There are also trade-offs in energy costs when comparing various drying systems. Low-temperature systems generally use less Btu’s per point of moisture removed. However, low-temperature systems use more Btu’s of electricity versus gas, as there is generally higher fan and motor usage in a low temperature system, than high temperature systems. What does this do to drying costs? The answer depends on the unit cost of electricity, natural gas, and LP. **Figure 6** titled, “Energy Efficiency and Energy Cost,” assembled by Scott Sanford of UW-Madison’s Biological Systems Engineering Department, illustrates the variations in drying costs that exist between the currently commercially available drying systems.¹⁹

TABLE 3: Estimated Efficiency of Corn Dryer Systems¹⁷

Dryer Type	Thermal Efficiency (Btu/lb. water removed)	% Gas	% Electric
Combination High/Low Temperature	1200	75	25
No Heat Bin Dryer	1500	0	100
Low Temperature Bin Dryer	1650	0	100
Continuous Flow Dryer In Bin Dryer	2000	98	2
Mixed Flow Dryer	2050	98	2
High Temperature Batch Bin Dryer	2430	98	2
Batch Cross-Flow Dryer	2450	98	2
Continuous Cross Flow Dryer	2500+ (3200 typical)	98	2

Table 4: Cross Flow, High Temperature Dryers — Average Fuel Use per % Moisture Removed

Energy Source	Use per % Incremental Cost	Unit
Propane	0.02	Gallon
Natural gas	0.018	Therm
Electricity	0.01	kWh

¹⁵ Grain Dryer Selection & Energy Efficiency Presentation by Kenneth Hellevang, Ph.D., P.E., NDSU
¹⁶ Reduce Grain Drying Costs This Fall, Scott Sanford, University of Wisconsin, Biological Systems Engineering.
¹⁷ Ibid.
¹⁸ Ibid.
¹⁹ Reducing Grain Drying Costs, Scott Sanford, Sr. Outreach Specialist, University of Wisconsin.

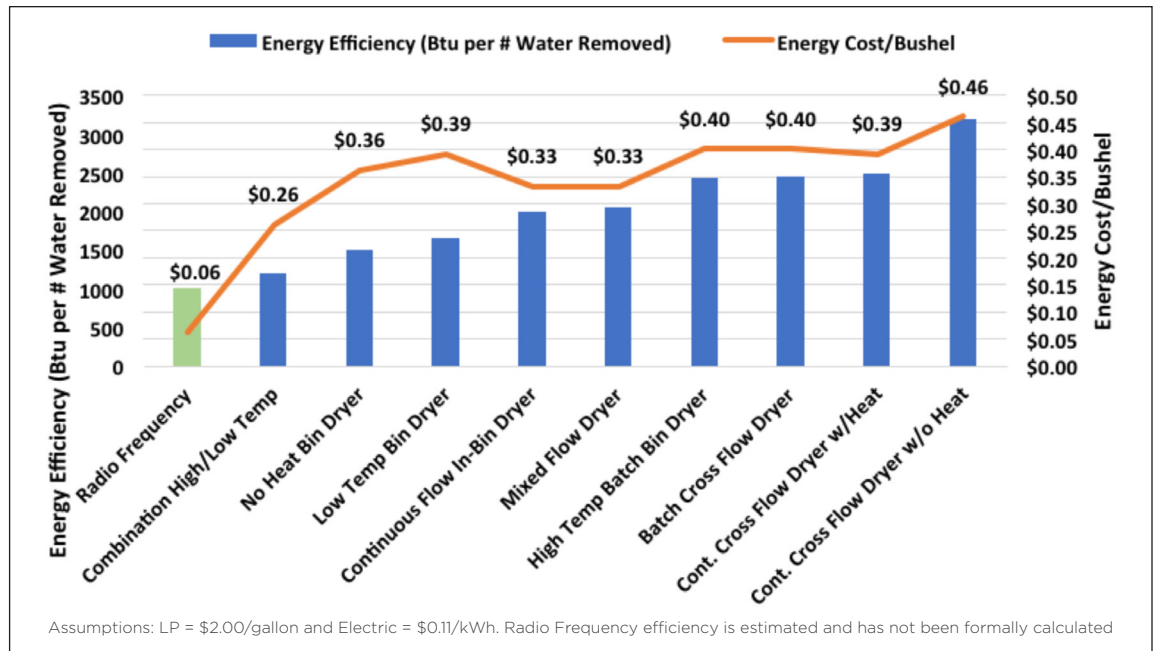


FIGURE 6: Energy Efficiency and Energy Cost for Drying Corn from 25% to 15% in Various Grain Drying Systems

Having the right-sized system and maintaining that system is essential.

Increases in efficiency of 10 to 20 percent are achieved with recirculating cooling air, and up to 30 percent with also circulating part of the drying air.

Measures to Improve Efficiency of Traditional Drying Systems

Preparation and planning are key to an efficient drying system. Having the right-sized system and maintaining that system is essential. To prevent system overload, it is important the grain drying system has ample capacity to handle the amount of grain coming off the field. Newly purchased grain dryers may require calibration by the grain dealership.

It is also important to conduct regular checks and maintenance on the system, during drying and off-season. Moisture sensors and thermostats should be calibrated every year; clogs and dirt need to be removed from drying screens, fans and grain handling systems; fan burners should be tested to ensure efficient fuel combustion; gas controls and regulators should be tested (by a professional); and bearings and belts should be maintained properly. It is recommended to clean the grain dryer before using to improve dryer efficiency.

Grain handling before and after drying can also impact dryer efficiency. Field drying corn for as long as possible allows Mother Nature

to remove moisture, but it is important for a producer to monitor stalk quality during field drying to prevent harvest hiccups. While a low- or no-cost method for initial grain drying, the longer the grain is left in the field, the dirtier it tends to become, which makes grain drying less efficient. Added dirt and “bees wings” contain moisture that can increase fuel consumption during the drying process. Bees wings or chaff are the light flaky part of the corn that binds the kernels to the cob and are part of the dust generated while drying grain.

Post-drying, grain may be moved hot at a higher moisture than the target moisture content and allowed to steep to remove the last one to two points of moisture. Along the same theme, grain may be dried in stages, referred to as “dryeration,” to increase energy efficiency. Energy savings can also be obtained from a grain dryer with air-recirculation or heat recovery capabilities. Dryers that recirculate only the cooling air show an energy efficiency increase of 10 to 20 percent compared to equivalent dryers without air recirculation. Units capable of recirculating both the cooling and part of the drying air may improve energy efficiency up to 30 percent.²⁰

²⁰ Hellevang <http://www.ag.ndsu.edu/pubs/plantsci/smgrains/ae701-3.htm>

Insights on Grain Dryer Energy Use on Wisconsin and Minnesota Farms

A brief review of grain dryer energy usage across 20 farms in Wisconsin and Minnesota resulted in several interesting findings:

- The average age of the grain dryers in this small study was just over 18 years. Typical life expectancy for traditional grain drying technology is 20 to 25 years. This means that many of the current dryers are getting towards the end of useful life and are likely to be replaced within the next 5 to 7 years.
- An overall average efficiency of almost 3,000 Btu/lb. of water removed was discovered. The average energy efficiency of only the horizontal continuous cross flow dryers from this review was 2,932 Btu/lb. of water removed. This puts the overall average on the high side of the estimates from Iowa State University and the University of Wisconsin.
- Next, the average cost to dry grain on these farms was \$0.14/bushel, ranging from a low of \$0.02/bushel in a mixed flow dryer using very low-cost natural gas, to a high of \$0.32/bushel in a portable dryer using LP. Horizontal continuous cross flow dryers in this small study averaged \$0.13/bushel.

This small review of grain dryers includes all types of dryers from natural air dryers to batch bin dryers to horizontal continuous cross flow dryers to mixed flow dryers. It should also be noted that almost all farms in this review remove, in a typical year, 7 to 8 points from their corn, with corn entering dryers at about 21 to 22 percent and drying corn down to about 14 to 15 percent for final holding/storage.

Selecting a new grain dryer is an expensive proposition for a farm, and the choice is especially complicated when considering the following variables:

- The poor economic state that the agricultural sector has been in for the last few years;
- Increased challenges of growing crops with changing weather patterns;
- Fluctuating fuel prices; and

- Uncertain performance of even standard dryer technology under real-world conditions.

Selecting what type of dryer to purchase when it comes time to replacing an existing dryer is a big decision. In addition to looking at the energy efficiency of the dryers in this small study group, cost estimates for various types of new grain dryers were reviewed. Actual quotes for new dryers from equipment dealers reveal price estimates from around \$60,000 for a Shivers system retrofit with the ability to dry about 600 bushel per hour to almost \$400,000 for a new tower dryer with the ability to dry up to 5,000 bushel per hour, with many dryers with capacities of 1,000 to 2,500 bushel per hour falling in the \$150,000 to \$300,000 range. For context, the 2018 average corn yield in the U.S. was 176.6 bushel/acre, so a system of this capacity would be typical for a typical cash crop grain farm in the U.S. Although most cropland was operated by farms with less than 600 crop acres in the early 1980s, today most cropland is on farms with at least 1,100 acres, and many farms are 5 and 10 times that size.²¹ It should also be noted that the above examples are all farm-scale grain dryers. Large capacity commercial grain dryer sold to a grain elevator or grain cooperative are much larger, have a much higher price tag, and have similar cost per unit of drying capacity.

Radio Wave Grain Drying — A New Technology

While farmers have used heated air to dry grain for decades, some researchers have recently been exploring an entirely different approach that they believe can deliver major cost reductions and improvement in grain quality: using radio waves. Similar to the microwave in your kitchen, radio wave drying involves directly exciting water molecules within the grain. Radio waves penetrate the entire grain causing the water to move out from the inside. Due to highly limited heating of the grain, the water leaves the grain as a vapor instead of as steam, with the grain remaining relatively cool, e.g., exiting the dryer at 70 °F to 85°F.

Typical life expectancy for traditional grain drying technology is 20 to 25 years.

Selecting what type of dryer to purchase is a big decision, since prices can range from \$60,000 to nearly \$400,000.

²¹ Farm Size and the Organization of U.S. Crop Farming.

Radio wave drying would be a novel technology for grain drying, but there is precedent. Radio waves are used for drying in the industrial sector for a variety of applications including ceramics, foam, fiberglass, wood, paper, and other materials.

As of early 2020, three radio wave grain dryers have been installed and are operational at sites in the U.S. and Canada, and a fourth dryer is in the process of being installed. The systems are currently being tested by DryMAX, the equipment manufacturer.

POTENTIAL BENEFITS OF RADIO WAVE GRAIN DRYING

Proponents of radio wave grain drying indicate a range of potential benefits, including lower drying costs, energy savings and emissions reductions, higher grain quality which may lead to higher commodity value, and improved farm logistics. See, for example [Figure 8](#), which is a list of benefits prepared by DryMAX.

Three major potential benefits that may be of particular importance to farmers and electric cooperatives include:

Lower Energy Cost for Drying

Radio waves can efficiently deliver energy to the water molecules, causing them to exit the grain as vapor. In contrast, conventional drying makes the grain hot and dry on the outside, while the interior remains relatively cold and wet. Because the dry outer layer acts as an insulating barrier and reduces the conduction heat transfer to the middle of the grain, the process is somewhat inefficient.²²

Initial studies by DryMAX indicate significantly reduced energy costs. For example, they indicate that removing 6 percent moisture from soybeans will cost about \$0.017/bushel, and a full-scale 36kW radio wave dryer can remove 6 points at a rate of 1,600 bushels/hour. Initial studies evaluating the removal of 10 points from corn indicate a cost of about \$0.05/bushel. Additional tests on corn indicate that removal of 7 to 8 points may cost as little as \$0.015-0.03/bushel.²³ A cost per kWh of \$0.0873 was used



FIGURE 7: Example of a Tower Style Radio Wave Grain Dryer (Source: [DryMax website](#))

in these studies. It was previously noted that the small review of Wisconsin and Minnesota grain dryers revealed that the average cost to remove 6 to 8 points from corn in a high temperature continuous cross flow dryer was \$0.13/bushel, as shown in [Figure 6](#). If the results from the initial tests from the radio wave grain dryer hold true, a significant savings of up over \$0.10/bushel is possible.

Importantly, this energy cost savings may not involve higher equipment cost than for conventional dryers. As previously noted, the cost of a new commercially available propane or methane grain dryer can range from \$60,000 to \$400,000 for systems with 600 to 5,000 bushel per hour capacity at 5-point removal. The estimated initial cost of a tower style radio wave grain dryer, per DryMAX, is about \$350,000, which is within the range of currently available grain dryer models.

Higher Product Quality, Delivering Higher Commodity Value

Radio wave grain drying may increase grain quality relative to conventional drying, considering each of the quality metrics discussed earlier. Some of these relate directly to higher commodity value, while others are promising but less clearly connected.

Both over- and under-drying grain can directly lead to a lower price paid per bushel. Overdried grain results in undue weight loss, resulting in a lower price per bushel. Under-dried grain can lead to price penalties, as a grain

If the results from the initial tests from the radio wave grain dryer hold true, a significant savings of up over \$0.10/bushel is possible.

²² [Differences Between Radio Frequency and Conventional Heating.](#)

²³ Electrify Indiana Rural BE Opportunities Panel, [DryMAX Drying, A New Look at Water Removal.](#)

elevator may have to re-dry the grain to attain a moisture level suitable for long-term storage. Also, unlike with conventional dryers, radio wave drying avoids the high temperature differential between the interior and exterior of the grain, resulting in lower cracking.

The relatively minimal heating accompanying radio wave grain drying can also reduce the issue of lower germination and viability, as germination rates can be reduced with drying temperatures as low as 120°F.

DRYMAX

Radio Frequency Grain Drying

ADVANTAGES

Industry Disruptive Firsts

1. **NO CONTAMINATION** - Propane gas is embedded in cracks in grains during heat drying. *DryMAX eliminates contamination from combustible fuels entering food supply.*
2. **NUTRITION SAVED** - Most nutritional value in grain or food is lost using high heat methods. *Our gentle process reduces breakdown, retaining ALL nutritional value!*
3. **QUALITY** - Volatiles are exhausted in heat fumes causing food producers to use unnatural additives. *Volatiles such as taste and smell are kept using RF.*
4. **PRESERVATION** - Grains immediately begin to rot after harvest due to mold, bacteria, insects and moisture. *Our process kills living matter. No more mold, mildew, insects or other forms of loss. Long storage times.*
5. **PREMIUM PRICES** - Farmers lose revenues due to many post harvest grain maladies (Food grade grains, nuts, animal feed...) *Expect higher revenue from better quality products. The market will reward farmers for drying with DryMAX.*
6. **GERMINATION** - Seed providers see results. *Higher seed germination due to lower temps. DryMAX technology shows 98%+ germination rate.*
7. **LOWER COSTS** - Propane drying cost is \$.20-40/bushel. *DryMAX drying cost is \$.04-.08/bushel*
8. **FAST HARVEST** - Crops left in field to dry are vulnerable to mold, weather and insect damage. Typical losses are 2-4% of crop per week left in field. *Harvest immediately into holding bins to eliminate losses.*
9. **EFFICIENCY** - Bottlenecks, wasted trips, grain moving, storage issues. *DryMAX Lowers cost of transport, grain moving - increases farmers net*
10. **NO CO2 POLLUTION, NO PROPANE SHORTAGES** - 1.4 Billion gallons of Propane are used to dry grains annually. *Electrical platform reduces risk from volatile Propane supply. DryMAX seeks to eliminate all forms of pollution.*

www.drymaxsolutions.com/advantages.html

FIGURE 8: DryMax Performance Improvement Claims

Radio wave grain drying could be the future of grain drying for farms, improving their bottom line and being a new opportunity for beneficial electrification.

Beneficial Electrification Opportunity

Of particular interest to electric cooperatives, radio wave grain drying technology could provide an opportunity for beneficial electrification in an industry that is typically thought of as not having a lot of options in moving from natural gas or propane to electricity. Grain drying equipment, and thus energy use needed for grain drying, has seen minimal changes in the last 10+ years. Even with the changes that have been introduced for improved efficiency in conventional grain drying, the newest dryers are still high temperature dryers that require significant quantities of natural gas or LP, and can lead to grain that is over- or under-dried that may be of lower quality than desired. Radio wave grain drying would utilize electricity as the energy source for drying with little to no heat input required, thus shifting the energy used for grain drying from thermal energy to electrical energy.

TESTING, VALIDATING AND OPTIMIZING RADIO WAVE GRAIN DRYING TECHNOLOGY

A grain dryer without heat that is not a natural air dryer is certainly different than anything the market has seen previously. This new technology also has the potential to change how we have been thinking about grain drying for the last 50 years.

Many questions arise including: How, and how well, does this technology work under theoretical, laboratory and real-world conditions? What kind of costs are associated with radio wave drying?

A new grain dryer with the potential to significantly reduce energy costs and increase product quality and value could lead to a large impact for an industry that often faces challenging economic conditions.

While radio wave grain drying looks promising for farms, this technology needs more study to prove itself not only for grains, but also in additional potential applications of the dryer for other agricultural products, such as the drying of hemp, hops, biomass, and other products. With additional research and development, radio wave grain drying could

lead to significant improvements in cost and performance for agriculture.

However, before this technology can be encouraged at the farm level, third-party unbiased studies on the overall efficiency of radio wave grain dryers and commercially available dryers needs to be completed across a range of real-world conditions and a variety of crops. Furthermore, additional studies on the improved grain quality need to be completed to verify claims made by DryMAX. Radio wave grain drying could be the future of grain drying for farms and not only improve the farm's bottom line, but also be a new opportunity for beneficial electrification in the agricultural sector.

A variety of R&D activities are needed to assess the commercial and technical merit of radio wave grain drying technology, including:

- Validating the one manufacturer's technology currently on the market today under a range of conditions and a range of crops;
- Assessing the impacts not just on energy efficiency of removing water, but also on the quality metrics listed earlier (e.g., grain viability, nutritional content, uniformity of drying; over & under-drying; cracking; burning; destruction of pathogens; killing of insects, etc.)
- Improving the understanding of the underlying science and technology to determine optimal characteristics of radio wave technology for grain drying applications;
- Baseline fuel-based systems on the above metrics.

Conclusion

Drying grain is essential for long-term storage of high-quality grain across the U.S. Grain drying is also a significant cost to farmers, with grain drying being the second or third highest expense for corn producers in the upper Midwest of the U.S. Large amounts of natural gas and propane are currently used annually for drying grain. The costs associated with propane can be highly volatile, and thus, unpredictable for a farm, as can methane to a lesser degree.

There are numerous aging grain dryers across U.S. farms, as dryers generally have a useful life of around 20 to 25 years before needing to be replaced. Without existing dryer performance standards, and with limited and unorganized documented dryer performance data, understanding which type of dryer is the most efficient option is challenging for a producer looking to replace an aging dryer.

The new technology of radio wave grain dryers may offer an opportunity to reduce energy costs and improve grain quality in an industry that has seen minimal change in over 10 years. It may also offer an opportunity for beneficial electrification in a sector thought to have limited options for electrification. To gain a better understanding of the true performance of

existing grain drying technology, a third-party field study on the energy efficiency of existing commercially available grain drying units is recommended. Further, additional installations of radio wave grain dryers and third-party studies on the new radio wave grain dryers is needed to get a full understanding of the energy efficiency of these units in the field, potential for improved grain quality from using these units, and the potential impact these units may have on electric use in the agricultural sector. To date, there are no third-party studies being conducted on this new technology for drying grain, and any data that can be acquired and shared with producers, electric cooperatives and others in the industry would benefit all. ■

ABOUT GDS ASSOCIATES, INC. AND THE PRINCIPAL INVESTIGATOR

GDS Associates, Inc. (GDS) is a multi-service energy consulting firm with an extensive history of services for the energy efficiency and renewable energy industries. GDS has provided numerous studies in the agricultural sector and recently completed an agricultural energy use study for the state of Minnesota. GDS also works in the areas of energy programs and policy, as well as conducts site specific energy audits in the agricultural sector. GDS has worked with thousands of farmers and has conducted hundreds of energy audits on all types of grain drying systems over the last 20 years.

Bethany Reinholtz, the principal investigator for this study, oversees several agricultural energy efficiency programs nationwide. Her expertise includes advising farm owner/operators on sustainability in farming including energy and water efficiency and renewable energy opportunities and providing assistance with state, federal and utility incentives and project implementation. Bethany has been with GDS for over 10 years and provides farmers, manufacturers, and other agricultural professionals consultation on the latest and most innovative agricultural systems. Bethany also conducts renewable energy assessments and feasibility studies and assists producers with completing REAP grant applications as well as other renewable energy program incentive applications. Bethany received her master's degree from the University of Wisconsin-Green Bay in Environmental Science and Policy, emphasizing renewable energy and resource management and is a certified energy manager (CEM) and a certified water efficiency professional (CWEP) through the Association of Energy Engineers (AEE). Bethany is also a certified farm, greenhouse, grain drying, and irrigation auditor through Michigan State University, a certified solar electric site assessor through the MREA since 2010, and a Technical Service Provider (TSP) for the USDA-NRCS for CAP 128, Agriculture Energy

Continued on next page

ABOUT GDS ASSOCIATES, INC. AND THE PRINCIPAL INVESTIGATOR (CONT.)

Management Plans. She has spent a large amount of time working as an energy advisor for various state and utility energy efficiency programs, providing profitable energy and water saving advice for many different types of agribusinesses including dairy, controlled environment agriculture, poultry, swine, aquaculture, and grain drying. Bethany works on program design and implementation, conducts on-site energy audits, calculates baseline energy use and potential savings, and helps owners and operators be sustainable.

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- To find more resources on business and technology issues for cooperatives, visit our [website](#).

DISTRIBUTED ENERGY RESOURCES WORK GROUP

The Distributed Energy Resources (DER) Work Group, part of NRECA's Business and Technology Strategies department, is focused on identifying the opportunities and challenges presented by the continued evolution of distributed generation, energy storage, energy efficiency and demand response resources. For more information, please visit www.cooperative.com, and for the current work by the Business and Technology Strategies department of NRECA, please see our [Portfolio](#).

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