FINAL REPORT

A New Generation: Farm Energy Conservation & Efficiency Initiative

Developed by Iowa State University Extension & Iowa Farm Bureau Federation

Funded by the Iowa Energy Center, Grant No. 09-03

July 1, 2009 – June 30, 2012

Principal Investigator: Mark Hanna, ISU Extension & Outreach

Introduction

The Iowa Energy Center awarded a three-year grant to Iowa State University Extension & Outreach and the Iowa Farm Bureau Federation beginning in 2009. The project, titled *A New Generation: Farm Energy Conservation and Efficiency Initiative*, brought together Iowa State University Extension educators, utility providers and agricultural agencies in a unified effort to address agricultural energy efficiency in Iowa. With guidance and input from these collaborators, Iowa State University Extension educators developed and implemented a farm energy conservation and efficiency program designed to improve knowledge and awareness of modern farm energy efficiency issues affecting Iowa's producers.

The project emphasized three fundamental goals. The first was to gather input and ongoing feedback from a task force of energy sector professionals who could contribute technical expertise and credibility to the project. With guidance from the task force, the second goal was to develop an updated series of farm energy efficiency fact sheets that could be used for educational programming. The third and final goal was for Iowa State University Extension educators to deliver the content from the fact sheets via webinar to Extension colleagues and energy service providers in Iowa.

ISU Farm Energy task force

Since its inception, the Farm Energy task force sought to strengthen relationships between Iowa State University Extension educators and energy efficiency stakeholders throughout Iowa. Early group meetings revealed opportunities to share knowledge and resources regarding farming practices in Iowa, farm-related energy demands, overall farm energy management and energy efficiency. Task force participants were selected based on technical expertise in agricultural and rural energy issues:

- Iowa State University Agriculture & Natural Resources Extension & Outreach
- Iowa State University Department of Ag & Biosystems Engineering
- Iowa Energy Center
- Iowa Farm Bureau Federation
- Iowa Association of Electric Cooperatives
- Consumers Energy rural electric cooperative
- Central Iowa Power Cooperatives
- Corn Belt Power Cooperative
- USDA Rural Development
- Alliant Energy
- MidAmerican Energy
- Iowa Office of Energy Independence

Mark Hanna, ISU Extension, speaking with Adam Kramer, task force representative for Alliant Energy.

The Farm Energy task force met three to four times per year from mid-2009 to mid-2012 and also communicated via e-mail to develop and refine a series of educational resources for utility service personnel, Extension field staff, agricultural agency staff and Iowa farmers. Specifically, group discussions identified a need for up-to-date educational resources about agricultural energy efficiency issues. With input from subject matter experts at Iowa State University, the task force generated a comprehensive list of agricultural energy efficiency and energy conservation topics to serve as a road map for the project (see Appendix A). This 'document tree' highlights the topics published from 2009 to 2012, as well as additional areas that may warrant further research. Contributing authors from Iowa State University and other institutions developed content for the fact sheet series with these topics in mind.

ISU Farm Energy fact sheets

The impetus for creating an updated series of farm energy efficiency fact sheets was to reinvigorate the energy 'literacy' and educational capacity of Iowa State University Extension educators and Farm Energy task force members. Data from USDA shows that direct energy consumption among Iowa's farms includes fossil fuel sources such as diesel, gasoline, propane, and electricity. Similarly, the primary indirect energy user for Iowa agriculture is nitrogen fertilizer. As statewide farm production practices are adapted to accommodate the rising cost of fossil fuels, there is an increasing need to address energy efficiency concerns for farm enterprises.

During the three-year project, a total of 24 farm energy efficiency fact sheets were published electronically (see Appendix B). By illustrating numerous topics in a brief, two-page format, the contributing authors were able to focus on their areas of expertise. Key topics address both livestock and crop farm enterprises, including energy efficiency considerations for swine production, grain drying, tractor operations and maintenance, and general farm energy management. Subject matter experts and Extension educators from Iowa State University and neighboring states served as co-authors, specifically:

Stuart Birrell, professor in Agricultural & Biosystems Engineering, Iowa State University
Greg Brenneman, Extension agricultural engineer, Iowa State University
Mike Brumm, professor emeritus in animal science, University of Nebraska-Lincoln
Mark Hanna, Extension agricultural engineer, Iowa State University
Jay Harmon, professor in Agricultural & Biosystems Engineering, Iowa State University
Charles Hurburgh, professor in Agricultural & Biosystems Engineering, Iowa State University
Dan Huyser, Extension agricultural engineer, Iowa State University
Dana Petersen, Farm Energy Extension program coordinator, Iowa State University
John E. Sawyer, professor in Agronomy & Extension soil fertility specialist, Iowa State University
Scott Sanford, Extension agricultural engineer, University of Wisconsin-Madison
Shawn Shouse, Extension agricultural engineer, Iowa State University
Hongwei Xin, professor in Agricultural & Biosystems Engineering, Iowa State University

Concepts from the fact sheets are summarized for easy reading in the “Farm Energy” column written by Dana Petersen, which appears in the monthly *Wallaces Farmer* magazine. These and other news articles related to the project are digitally archived online at http://farmenergy.exnet.iastate.edu. Each fact sheet from the Farm Energy series can also be downloaded free of charge from the web address above or from the ISU Extension online publication store at https://store.extension.iastate.edu/. The chronological list of fact sheet titles and corresponding reference numbers is as follows:

Reference number	Publication Title
PM 2089A	How Much Energy is Being Used on Your Farm?
PM 2089B	Electric Savings: Understanding Demand and 3-phase Motor Use
PM 2089C	Tracking the Energy Use on Your Farm
PM 2089D	Limiting Field Operations
PM 2089E	Energy Efficient Fans for Swine Production
PM 2089F	Managing High Temperature Grain Dryers for Energy Efficiency
PM 2089G	Ballasting Tractors for Fuel Efficiency
PM 2089H	Energy Efficient Fans for Poultry Production
PM 2089I	Energy Conservation in Corn Nitrogen Fertilization
PM 2089J	Sizing Minimum Ventilation to Save Heating Energy in Swine Housing
PM 2089K	Dryeration & Combination Drying for Increased Capacity & Efficiency
PM 2089L	Tractor Maintenance to Conserve Energy
PM 2089M	Shift Up and Throttle Back to Save Tractor Fuel
PM 2089N	Energy Fundamentals for Farm Lighting
PM 2089O	Fuel Efficiency Factors for Tractor Selection
PM 2089P	Conserve Heat Energy in the Farm Shop
PM 2089Q	Improving Corn Drying Efficiency
PM 2089R	Indoor Lighting for Livestock, Poultry and Farm Shop Facilities
PM 2089S	Estimating Payback for Energy Efficiency
PM 2089T	Managing Swine Ventilation Controller Settings to Save Energy
PM 2089U	Energy Consideration for Low-temperature Grain Drying
PM 2089V	Conserving Energy by Using Localized Heating in Swine Housing
PM 2089W	Energy Consumption for Row Crop Production
PM 2089X	Energy Efficiency for Dairy Milking Equipment

ISU Farm Energy outreach and education

To address the third goal of the project, Iowa State University Extension ag engineers Mark Hanna and Jay Harmon and coordinator Dana Petersen collaborated with Farm Energy task force members to present an annual farm energy efficiency professional development webinar. Each spring, beginning May 2010, Iowa State University Extension offered a farm energy efficiency webinar via Adobe Connect (embedded videos included in Appendix C). Spanning 2010 to 2012, each annual webinar hosted an average of 47 participants. These attendees included: investor-owned and cooperative utility employees statewide; Iowa State University Extension field specialists for ag engineering, farm management, agronomy, and livestock production; NRCS staff; and, other energy stakeholders.

Educational content for each webinar was drawn from the Farm Energy fact sheet series. This allowed presenters to illustrate the underlying technical concepts for the webinar audience. It also increased awareness among webinar participants that all Farm Energy fact sheets are publicly available as a resource for both them and their clients. Pre- and post-test surveys were the primary evaluation tools used in conjunction with the annual webinars. The analysis of approximately 200 completed surveys by evaluator Corry Bregendahl provided the following results:

- The percent of respondents who read or planned to read at least one Farm Energy publication increased from **88%** in 2010 to **93%** in 2012.
- The percent of respondents who referred or planned to refer clients or customers to at least one Farm Energy publication increased from **76%** in 2010 to **79%** in 2012.
- The percent of respondents who distributed or planned to distribute copies of at least one Farm Energy publication increased from **57%** in 2010 to **66%** in 2012.

In addition, the percent of respondents who were aware of the Farm Energy publication series *before* participating in the webinar increased from year to year, rising from **41%** in 2010 to **51%** in 2012. This ten percent increase suggests that the project not only increased its visibility from year to year but was also increasingly successful in reaching target audiences.

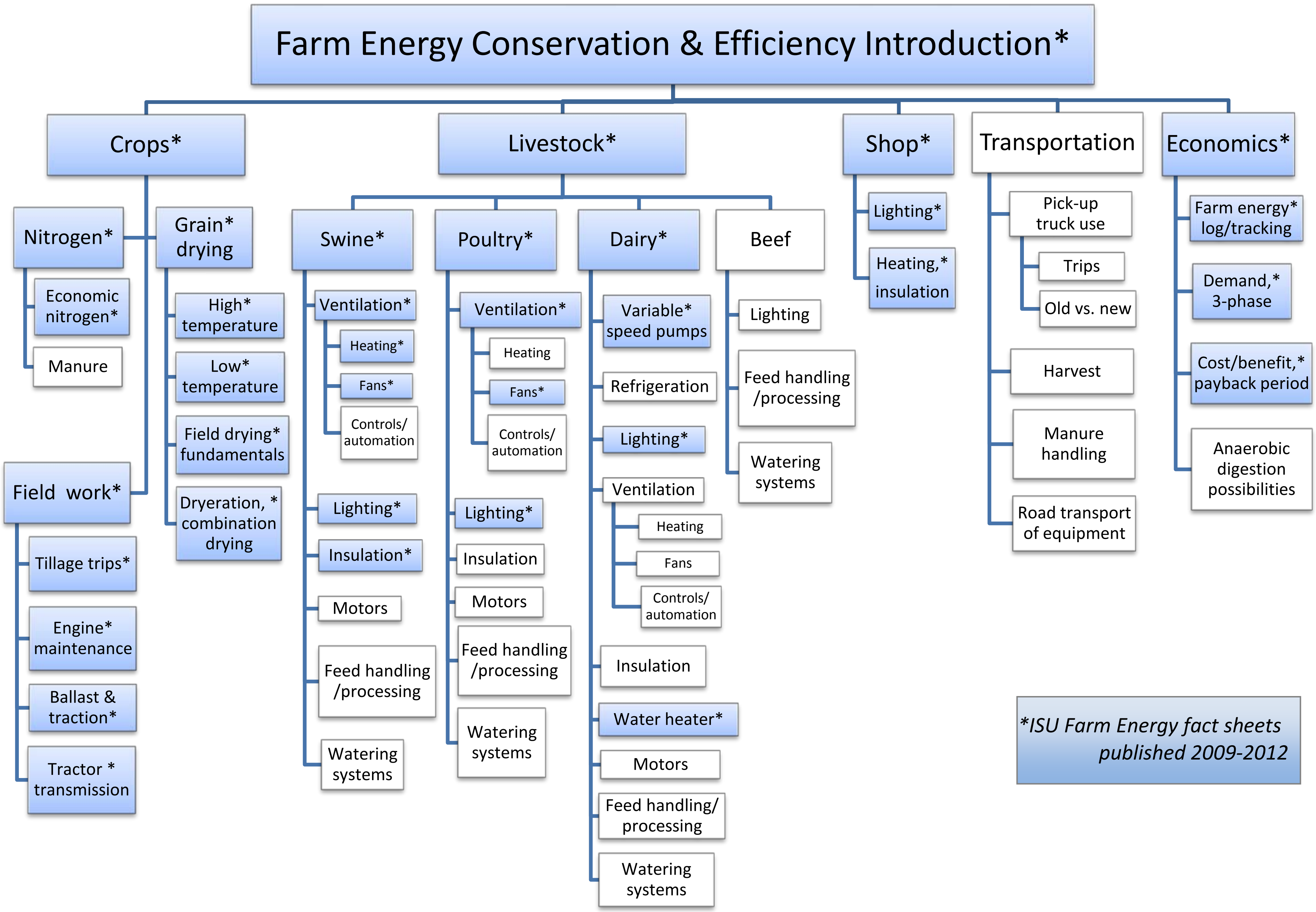
Another key outreach effort of the project utilized Iowa State University Extension & Outreach educational programming to connect directly with Iowa farmers. Mark Hanna and Dana Petersen collaborated with Extension field specialists to present farm energy efficiency topics each year during the annual Crop Advantage Series and Integrated Crop Management Conference, as well as a variety of field days hosted by Iowa Learning Farms and Iowa State University Extension & Outreach. Jay Harmon also presented an annual series of swine ventilation management workshops for Iowa producers in partnership with Extension livestock field specialists. These combined efforts brought updated farm energy efficiency and energy management information to nearly 1,500 farmers in Iowa from 2010 to 2012.

ISU Farm Energy final outcomes

Collaborations among Farm Energy task force members and Iowa State University Extension educators were critical to the overall success of the project. As Mark Hanna stated, “The task force infrastructure reminds our project partners of the larger goal—to help Iowans be better managers of farm energy.” Group meetings were filled with lively discussion and a shared enthusiasm for improving awareness of energy efficiency issues statewide. Before the three-year project came to a close, evaluator Corry Bregendahl conducted an in-depth interview with each member of the task force. From those interviews, the task force participants identified the following membership benefits and outcomes:

- Up-to-date knowledge about an expansive range of energy issues
- Stronger relationships with professionals within their industrial sector
- Greater effectiveness promoting energy efficiency programs
- Increased credibility among utility regulators
- New and different perspectives
- Greater exposure to a range of disciplines, knowledge, and energy related topics
- Improved job skills
- Access to a network of professionals to which they otherwise would not have access
- Improved decision making ability
- Improved customer service for clients
- A greater appreciation and respect for what Iowa State University Extension can offer
- Scientific validation for their work and recommendations

In conclusion, *A New Generation: Farm Energy Conservation and Efficiency Initiative* has built an excellent foundation for addressing contemporary farm energy efficiency and energy management issues. The up-to-date educational resources developed during the three-year project, particularly the Farm Energy fact sheet series and the corresponding webinars, serve to illustrate the wide variety of energy-related concerns that are currently impacting Iowa agriculture. The success of the task force collaboration and the ongoing support of Iowa State University Extension & Outreach highlight opportunities for future research and education.


Farm Energy Conservation & Efficiency Introduction*
Crops*
Nitrogen*
Economic nitrogen*
Manure
Grain* drying
High* temperature
Low* temperature
Field drying* fundamentals
Dryeration, * combination drying
Field work*
Tillage trips*
Engine* maintenance
Ballast & traction*
Tractor * transmission
Livestock*
Swine*
Ventilation*
Heating*
Fans*
Controls/ automation
Lighting*
Insulation*
Motors
Feed handling /processing
Watering systems
Poultry*
Ventilation*
Heating
Fans*
Controls/ automation
Lighting*
Insulation
Motors
Feed handling /processing
Watering systems
Dairy*
Variable* speed pumps
Refrigeration
Lighting*
Ventilation
Heating
Fans
Controls/ automation
Insulation
Water heater*
Motors
Feed handling/ processing
Watering systems
Beef
Lighting
Feed handling /processing
Watering systems
Shop*
Lighting*
Heating,* insulation
Transportation
Pick-up truck use
Trips
Old vs. new
Harvest
Manure handling
Road transport of equipment
Economics*
Farm energy* log/tracking
Demand,* 3-phase
Cost/benefit,* payback period
Anaerobic digestion possibilities
*ISU Farm Energy fact sheets published 2009-2012

How much energy is being used on your farm?

Equipment used in modern agricultural practices reduces labor, but consumes fuel and energy in the process. The first items that probably come to mind are diesel fuel being used in tractors, propane for grain drying, or the monthly electric bill. These are obvious and recurring expenses that may be several hundred or even thousands of dollars depending on farm size.

When analyzing energy use on the farm, it helps to think about different enterprises that are present. Iowa farms are diverse. Consider your own farming enterprises.

- What crops (corn, soybeans, alfalfa, pasture, others) are grown and in what quantities?
- Is there a livestock operation? Different animal species such as swine, beef, dairy, or poultry can have vastly different energy requirements depending on housing, environmental, and other needs.
- Think about how energy is being used within each enterprise. For example in contrast with corn or soybeans, tillage and planting is required only once every three to four years for alfalfa, however, multiple annual harvest operations are required.

Energy use within individual farming enterprises is beyond the scope of this publication, but will be covered in more detail within later publications in this series along with ideas for more efficient energy use.

Iowa agriculture's energy consumption

How do you compare to the rest of the state? Annually, Iowa agricultural producers spend nearly a billion dollars on energy for crop and livestock production. Figure 1 illustrates where the dollars are spent.

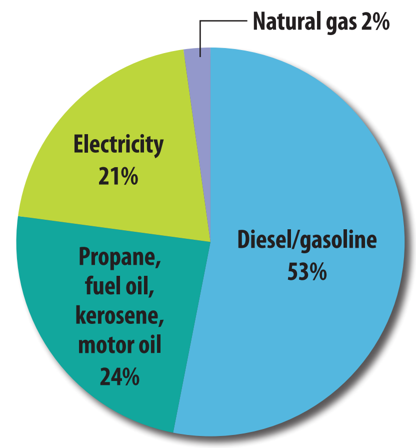


Figure 1. Energy expenses for Iowa agriculture. (Source: USDA Census of Agriculture 2007)

How do we compare to other states?

Agricultural producers in other states also are taking steps to reduce their energy use. As you can see in Figure 2, the energy use on farms in Wisconsin and Nebraska differs slightly from Iowa. Although electrical use is roughly equal, it's a larger percentage of total use in Wisconsin perhaps because of dairy. Natural gas and electricity are used on some irrigation wells in Nebraska. Iowa's somewhat greater propane use may be because of corn drying or perhaps heating of swine farrowing and nursery operations.

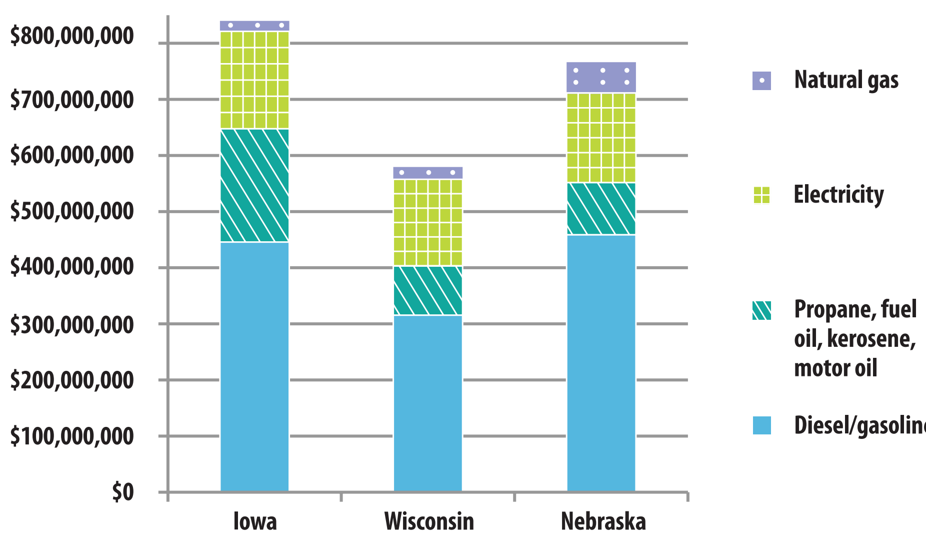


Figure 2. Energy expenses for Iowa, Wisconsin, and Nebraska by different energy sources. (Source: USDA Census of Agriculture 2007)

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PM 2089a November 2009




Energy costs are on the rise

Energy prices are volatile, but generally rise over time. Agricultural producers periodically feel the effects strongly.

During any specific period of time, costs of energy sources generally all increase or decrease as a group (see Figure 3). Do you want to be caught off guard when costs soar again?

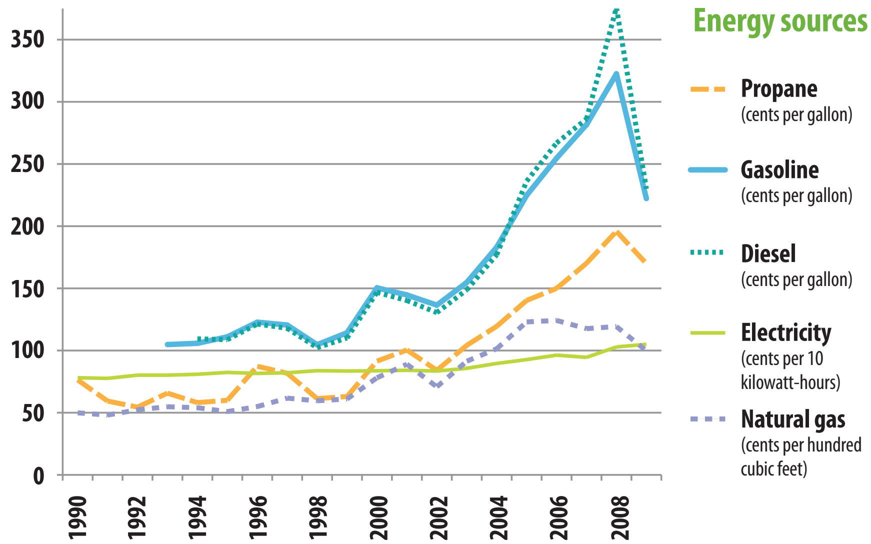

Figure 3. Energy sources and costs since 1990. (Source: Energy Information Administration)

How do I get started saving energy?

- Keep a log of the amount of energy used on your farm.
- Consult with a professional such as your local extension or energy provider.
- Consider a farm energy audit.

Farm energy log

A farm energy log is no different than tracking your spending to increase savings or counting calories to lose weight. It is important that the amount of energy used is tracked in addition to the cost. This is a simple procedure. You can start now or consider gathering past bills and entering old data. See sample energy log (Figure 4).

	January	December
Electricity		
kwh		
price per kwh		
Total		
Diesel		
gallons		
price per gallon		
Total		
Gasoline		
gallons		
price per gallon		
Total		
Propane		
gallons		
price per gallon		
Total		
Natural gas		
cubic feet		
price per cubic feet		
Total		
TOTAL ENERGY COST		

Figure 4. Example of a farm energy log.

Consult a professional

The Iowa State University Extension ag engineering, crops, livestock, and farm management professionals can provide assistance with enhancing the value of Iowa's agricultural industry, which includes energy savings. Your energy provider also offers assistance and resources to reduce energy use.

Farm energy audit

A farm energy audit will identify energy conservation and efficiency improvements within an agricultural production system (crops or livestock) and the various components of that system. If you are interested in an audit, contact your utility provider for more information.

Farm Energy Conservation and Efficiency Initiative

ISU Extension is working to enhance the efforts of farm energy conservation and efficiency with funding by the Iowa Energy Center. Extension and the Iowa Energy Center are cooperating with Iowa Farm Bureau Federation, Central Iowa Power Cooperative (CIPCO), the Iowa Association of Electric Cooperatives, Consumers Energy, Alliant Energy, MidAmerican Energy, Office of Energy Independence, USDA and other statewide partners in this effort .

This publication is part of a series of farm energy conservation and efficiency educational materials being developed through this initiative. The purpose is to increase farmers' awareness of opportunities for improving efficient use of farm energy. The initiative also helps farmers explore alternatives to reduce farm energy demand and to improve their farms' overall profitability in a rapidly changing energy environment.

For more information, go to www.extension.iastate.edu/store. See especially the topic environment – energy.

Prepared by Mark Hanna, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Jane Flammang, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension.

File: Energy 2–1

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Electric savings: understanding demand and 3-phase motor use

Did you know that sometimes a simple change in your practices can reduce your energy use and save money? For instance, the demand charges on your electric bill can be controlled by you. And understanding how 3-phase motors fit into your on-farm distribution can help you work with your utility to avoid supply problems.

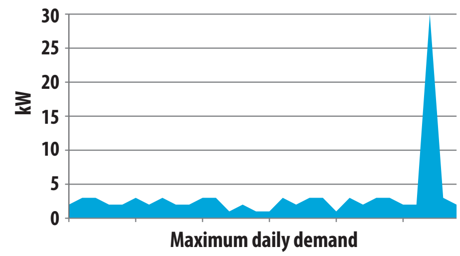
What is electrical demand?

Because of greater electrical load, some electric customers are on an "electrical demand" rate. Many people have trouble understanding this concept. With this rate, customers are charged not only for the amount of energy they use, measured in kilowatt-hours (kWh), but also the maximum amount of electrical energy they are using at any given time, measured in kilowatts (kW). This rate is essentially a charge for having the capability of drawing a greater electrical load. You could think of "demand" as the size of a garden hose. The more water (or kilowatts) you need at any given moment, the larger the hose (transformer, wires, etc) needs to be. It's like filling a 500 gallon sprayer tank with a ½ inch hose versus a 2 inch hose.

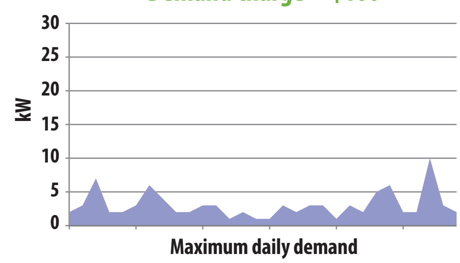
Utilities charge larger customers for demand because they are obligated to furnish adequate electricity for foreseeable demand that customers require. Even though electrical demand may be sporadic throughout a time period (e.g., summer residential air conditioning use or fall grain drying) the utility must have capacity to meet these demands. The cost for providing electricity is determined by both energy used (kWh) and infrastructure (i.e., generation and distribution) that must be present to meet your energy demand (kW). Energy and demand costs are lumped together for smaller users, but demand charges for larger businesses, including some farms, are charged separately. Users subject to demand charges can manage and lessen electric costs by knowing how these charges are assessed.

As an example, a farmer decides that he/she wants to test three aeration fans on grain bins so he/she turns them all on at once. This occurs 2 days before the meter is read for the month of August. After letting them run for 20 minutes, they are all turned off. This action sets the demand charge for the entire month. In this instance, the maximum demand for the month was 30 kW (approx 3-10hp motors). The rest of the farm uses 1500 kWh during that month. If the demand charge is $10 per kW, this means that there would be an additional charge of $300 for the demand. During the time the fans were tested, only 10 kWh of electricity was used resulting in a kWh charge of $1 (10 cents per kWh). The demand charge could be reduced to $100 if one fan was tested at a time (reducing the demand to 10 kW). If the testing had occurred in the same monthly billing cycle when fans were used for drying, no charge would be levied during the prior month (August) for fan use.

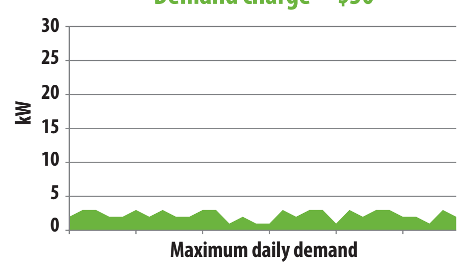
Testing all 3 fans at the same time
Peak Demand = 30kW
Demand charge = $300



Testing 1 fan at a time
Peak Demand = 10kW
Demand charge = $100



Fans not tested
Peak Demand = 3kW
Demand charge = $30



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Using 3–phase electrical motors

Single–phase electric motors have a practical upper power limit of approximately 10 horse-power (hp). This limit does not apply to 3-phase motors. Even in smaller sizes 3-phase electric motors ranging from 1 to 10 hp may cost less than single-phase motors of comparable size (although the need for phase conversion on single-phase lines adds to costs). Motors larger than 10 hp often are necessary for grain drying fans or on feed grinding equipment.

Only a small number of farms have 3-phase power available. Supplying 3-phase power is costly due to increased transformer distribution costs that cannot be adequately amortized with limited seasonal power usage such as fall grain drying or summer ventilation fans in livestock buildings. It's often cost prohibitive to install 3-phase service to the farm. In these cases phase-conversion devices are used.

Even in smaller motor sizes (e.g., 1 – 2 hp) it may be less costly to use the combination of a 3-phase motor and device to convert single- to 3-phase power. Although rotary and static converters have been used, recent developments in electronics have resulted in variable-frequency drive devices being used to both convert single- to 3-phase power and also to allow a much wider range of electrical motor speeds. Motors are ordinarily limited to shaft speeds of 3600, 1800, or 1200 rpm with power supplied at 60 Hz (cycles per second), however a variable frequency drive takes away this requirement of fixed speed. Variable frequency drives are attractive for use on larger hp motors because of the need for phase conversion. Use on lower hp ventilation fans currently is limited by cost, but may change if costs are driven down further.

Because of significantly increased power needed to be supplied and also the addition of phase converters your electrical power supplier should be consulted when adding significant electric motor loads on equipment such as drying fans or feed processors. Power quality on the distribution line can be affected by phase converters and the power supplier may restrict use of certain types to avoid line problems.

Photo courtesy of Sukup Manufacturing Co.

Let's test your electrical energy knowledge.

QUIZ

1. **True** or **False**
   Farmers can control their monthly electrical demand charges in an effort to reduce their overall energy use and costs.

2. **True** or **False**
   When choosing a new electric motor, there is little difference between installing a single-phase versus a 3-phase motor.

1. ANSWER: *True*
2. ANSWER: *False*

No endorsement of products or firms is intended, nor is criticism implied of those not mentioned.

Prepared by Mark Hanna, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Jane Flammang, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension.
Sponsored by the Iowa Energy Center.

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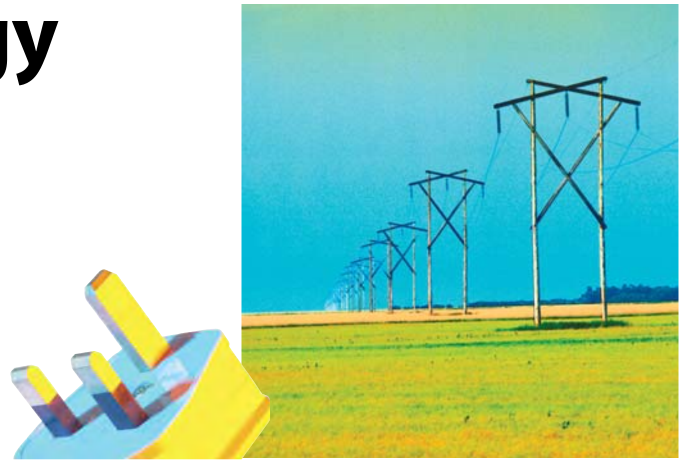
Tracking the energy use on your farm



You receive your energy bills. You read information about the importance of saving energy. You follow the tips to reduce energy use and costs. But how do you really measure your efforts? You might want to consider using an energy log. This is an easy and inexpensive method of tracking your energy use, studying costs, and comparing use and costs from month to month. We have provided a simple form (energy log) that you can download for use with Excel™, or simply print the log and enter by hand.

How do I use an energy log?

This is a simple format. For the more advanced user, rows and formulas can be added to customize your energy log.

Electricity

From your electric utility bill, enter the number of kWh used and your total cost for electricity. The form will automatically calculate your cost per kWh.

Diesel, gasoline, propane

Depending on the time of year and the amount used, you may not enter information for every month. Keep it simple. Only enter this information when you receive a bill. At that point, you can record gallons used and total cost. The Excel sheet will calculate your price per gallon for you.

Natural gas

Many farms are not on a natural gas line. This item may not be relevant to your farm. If you are a natural gas customer, record your use similar to electricity. Enter the cubic feet and the cost.

Total energy cost

Your monthly total energy cost will automatically be calculated. To the far right of this form, year-end total use and cost for each energy input will also be calculated.

Where do I find this information?

This might be a good time to review the materials provided by your utility companies on "how to read your bill." Contact your local provider with any questions regarding your bill or for help reading your bill in order to find the information necessary for the energy log.

	January	February	March	Total
Electricity				
kWh	4750	4314	4980	14044
price per kWh	$0.1000	$0.0948	$0.0900	
Total electric cost	$475	$409	$448	$1,332
Diesel				
gallons		892		892
price per gallon		$2.35		
Total diesel cost		$2,096		$2,096
Gasoline				
gallons				
price per gallon				
Total gasoline cost				
Propane				
gallons	613		834	1447
price per gallon	$1.30		$1.22	
Total propane cost	$796		$ 1,017	$1,813
Natural gas				
cubic feet				
price per cubic feet				
Total natural gas cost				
TOTAL ENERGY COST	$1,271	$2,505	$1,465	$5,241

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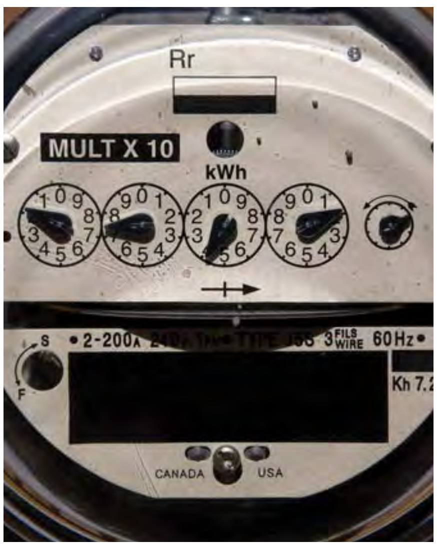
How much electricity DOES it use?

Although it's relatively easy to relate diesel or propane with a specific use such as tillage or crop drying, subdividing the total kilowatt hours (kWh) you used as listed on a monthly bill can be more challenging. What does leaving your lights on all day cost? How much does that fan motor use? The answers to these questions can be found pretty simply if you have some basic information. First of all, what is the wattage rating (W) of the item? Light bulbs generally have the wattage rating stamped on them. Other items, such as motors, can generally be assumed to use about 1 kW (1000 watts) per horsepower (hp). The other critical information needed is how long it is used.



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Swine – Example 1

As an example, your 1200 head swine finishing barn has fifty-six 100 W incandescent lights. Your normal practice is to turn the lights on when you enter the building at 7 am and turn them off after checking pigs in the evening at 5 pm. Your total electric usage is 4750 kWh for the month at a cost of $.10 per kWh. How much of this is due to the lights?

The basic equation is: kW x hours = kWh
Power usage = 56 lights x 100 W/light = 5600 W or 5.6 kW
On time = 7 am to 5 pm = 10 hours per day
Monthly usage = 5.6 kW x 10 hrs/day x 30 days/month = 1680 kWh
Monthly cost = 1680 kWh x $0.10/kWh = $168/month

An additional 3070 kWh (= 4750 kWh – 1680 kWh) are being used by other electrical devices. If you decided to try to cut back by only using the lights one hour in the morning, and one hour in the evening, how much could be saved?

Monthly usage = 5.6 kW x 2 hrs/day x 30 days/month = 336 kWh
Savings = 1680 kWh – 336 kWh = 1344 kWh or $134.40/month

Grain Drying – Example 2

Hours of "on" time for electric motors can be approximated to help sub-divide electrical usage. For example, a 20 hp motor on a grain drying fan is estimated to operate 15 hr/day for 24 days during a monthly billing period.

Power usage = 20 hp x 1kW/hp = 20 kW
On time = 15 hrs/day x 24 days = 360 hrs
Usage during the month = 20 kW x 360 hrs = 7200 kWh x .10 kWh = $720/month

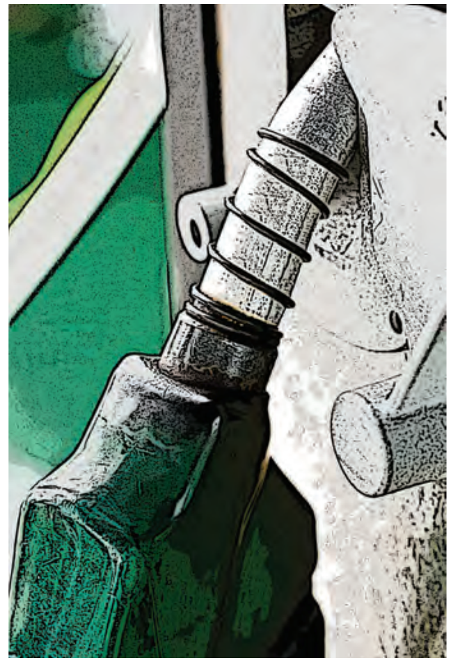
Fans – Example 3

If a minimum ventilation fan with a ½ hp motor runs continuously, what is the monthly electrical usage?

Power usage = ½ hp x 1 kW/hp = 0.5 kW
On time = 24 hrs/day x 30 days = 720 hrs
Monthly usage = 0.5 kW x 720 hrs = 360 kWh
Monthly cost = 360 kWh x $0.10/kWh = $36/ month

Limiting field operations

Maintaining equipment, proper ballasting and tire inflation, and selection of the proper tractor and gear setting all directly affect fuel savings during field operations and will be covered in this series. Individual savings in these categories are significant and can range from 3 – 5 percent up to 20 – 25 percent or more. An even larger impact, 100 percent fuel savings, results when equipment stays parked in the machine shed and a trip across the field is eliminated.



Certain field operations are required in modern crop production. Seed must be planted. Crop must be harvested. Some type of weed management strategy must be used. If chemical weed management is chosen this involves spraying. Approximate fuel required for many field operations are listed in PM 709, Fuel Required for Field Operations.

For row crops, tillage is the other major category of field activity in addition to planting, weed control, and harvesting. Approximately 2 to 2.5 gallons per acre of diesel fuel are necessary for planting, spraying, and harvesting. Combine use is a significant part of this total, planter use is intermediate, and each sprayer pass is a minor portion of it.

Figure 1 shows typical fuel use in corn and soybean production for some common tillage operations and a combined total for planting, spraying, and harvesting. Almost an equivalent amount of fuel is used for a single primary tillage operation with a chisel plow, subsoiler (ripper), or moldboard plow plus a single secondary tillage operation with a field cultivator or disk. Multiple secondary tillage operations can increase the total fuel for tillage requirement to 3 gallons per acre or more.

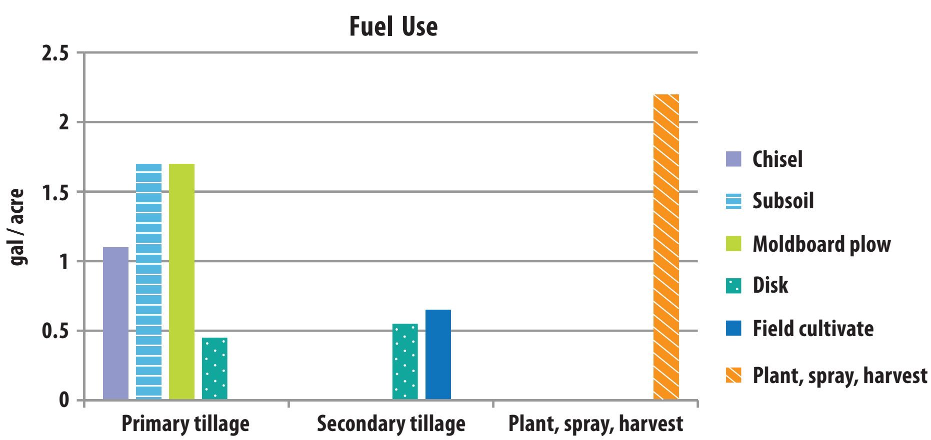


Figure 1. Fuel used for various operations in row crop production.

Selecting the right amount of tillage is a critical decision for farm energy use and profitability. Similar to other farm management decisions such as nitrogen fertilizer use for corn, or ventilation rate in a livestock confinement, overuse wastes energy but underuse can lower profitability. A key is to carefully consider potential for gross revenue returns to tillage operations, (i.e., crop yield), in comparison to fuel, labor, and machinery costs for doing tillage. Put another way, are tillage passes beyond a no-till management scheme returning costs of fuel, labor, and machinery that are required of the tillage?

(Continued on back page)

Iowa State University
University Extension

PM 2089d   January 2010



(Continued from front page)

Although soil type and moisture affect the relative ease of no-till, successful no-tillers are present in most counties. For many crop producers, whether or not no-till (or at least reducing tillage practices) is acceptable also may depend on comfort with the overall management scheme of a no-till system. Planting corn into significant amounts of residue calls for more attention to planter adjustment, fertilizer application, and weed management practices.

Eliminating tillage passes prior to soybean planting is a good place to start in making a transition to very reduced or no tillage. Numerous university field trials throughout Iowa over several years suggest that soybeans don't respond much if at all to tillage (Figure 2). Energy, labor, and equipment costs cannot be recouped without a reliable yield response.

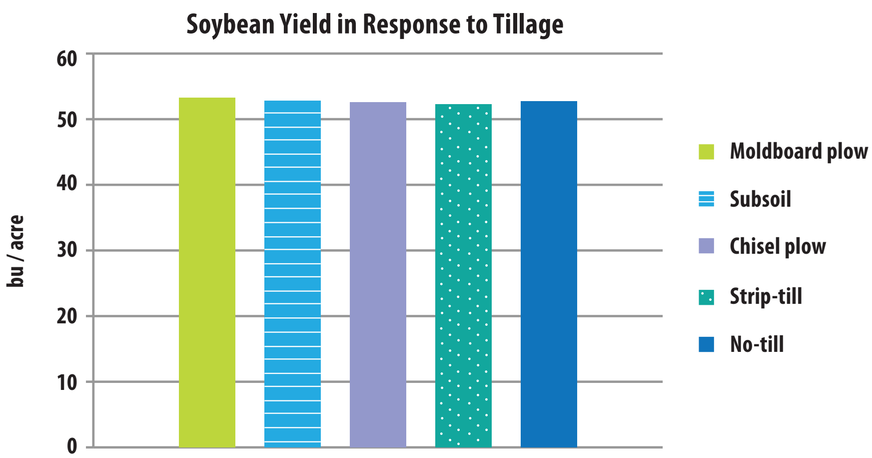


Figure 2. Soybean yield response to tillage (average of six ISU university farm locations across Iowa, 2003 – 2007, Al-Kaisi and Hanna).

Additional information to help with a transition to reduced or no tillage includes:

PM 1901D, *Considerations in selecting no-till – Resource Conservation Practices*
PM 1901C, *Consider the strip-tillage alternative – Resource Conservation Practices*
PM 1492J, *Adjustment and operation of planters in systems with high levels of surface crop residue*

If tillage is deemed necessary, consider raising up the tillage implement. The amount of fuel required for many tillage operations beyond those in the first 2 to 4 inches is directly related to depth of operation (see Figure 3).

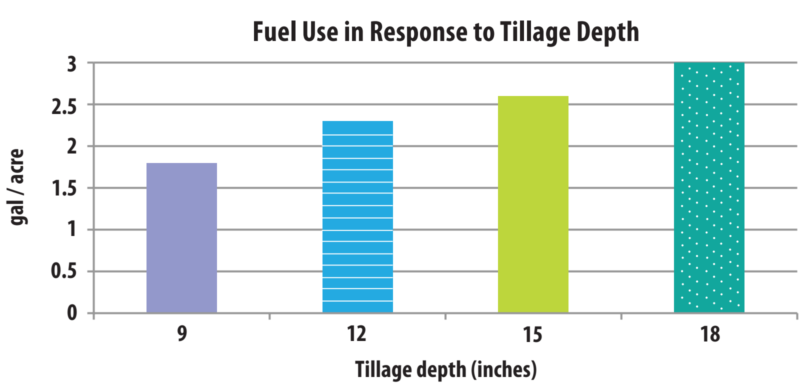


Figure 3. Diesel fuel used at different depths for subsoiler operation (Shinners, 1989).

Forage field operations

Tillage operations to establish crops such as alfalfa can be evaluated, but most harvest operations (cutting, windrowing, baling or chopping) are necessary and occur multiple times during the season for alfalfa or grass. Sharp knives can significantly lower fuel use, particularly on a forage chopper.

Prepared by Mark Hanna, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Jane Flammang, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Energy efficient fans for swine production

Fans are an important component of mechanically ventilated facilities. They are the driving force behind the exchange of air that is necessary to create a healthy environment for animals and associated farm employees. Other components of the ventilation system, such as the inlets and controllers, are essential to create a properly functioning system which is also energy efficient.

Fans impact energy usage in two different ways. They not only use energy to operate, but the management of fans greatly impacts the efficiency of the heating energy used within the building. Fan management is crucial in winter because over-ventilating exhausts heating energy needlessly. Swine housing systems often use variable speed fans which generally use the same amount of energy at a reduced speed as they do at full speed.

Quantifying quality

To understand the principles of fan selection, it's important to understand the following terms:

Air delivery: Air delivery is the amount of air that a fan will move under different conditions. This term is expressed as volume of air movement per unit time. The standard unit is cubic feet per minute (cfm).

Static pressure: Static pressure is the difference in pressure that a ventilation fan creates between the inside and outside of a mechanically ventilated structure. Static pressure may be measured using a manometer (Figure 1). Fans are used to create a vacuum within a building by exhausting air. The indoor environment, having a lower pressure than

outdoors, will draw air in through inlets (Figure 2). This is called a negative pressure system. In most animal housing situations, the static pressure operates between 0.04 and 0.08 inches of water. A free hanging fan, such as a stirring fan, will operate with no static pressure.

Fan efficiency: Fan efficiency is the amount of air delivery that a fan will provide per unit of electricity used, given in cubic feet per minute per watt (cfm/W). In general, small fans are less efficient than larger fans. Efficiencies range from about 5 cfm/W to 25 cfm/W.

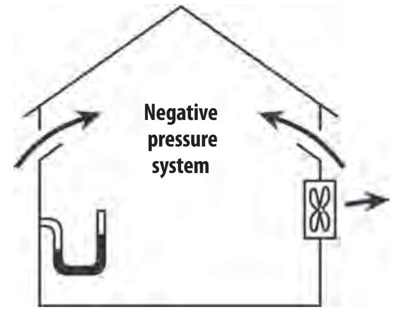

Figure 2. Negative pressure system with inlets and an exhaust fan.

Fan rating

Fans should be rated by an independent lab to show air delivery and efficiency as a function of static pressure. This information will be presented by using either a graph or table. An example appears in Table 1. Accessories on the fan such as guards, shutters, and discharge cones impact performance and should be noted when examining test data. Test results are available from the Bioenvironmental and Structural Systems (BESS) lab at the University of Illinois (www.bess.uiuc.edu).

A common mistake is to select fans based on fan diameter. Never assume that two fans of equal size will perform the same since different motors, curvature of blades and other attributes greatly influence the performance. For instance, it has been found through testing of several 24-inch fans that the air delivery (at 0.10 inches of water) ranged from 4,090 to 7,270 cfm, and the efficiency ranged from 9.9 to 17.1 cfm/W.

Table 1. Example fan data for a 24-inch fan with shutter, guard, and discharge cone (BESS Lab)

Static pressure Inches of water	**Speed** Rpm	**Airflow** cfm	**Efficiency** cfm/W
0.00	1101	6490	16.1
0.05	1094	6090	14.7
0.10	1089	5740	13.4
0.15	1083	5250	12.2
0.20	1082	4760	10.8
0.25	1082	3950	9.0
0.30	1088	2330	5.6

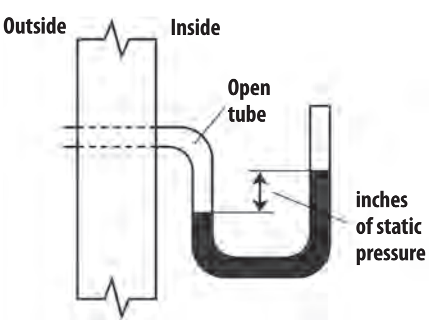

Figure 1. Static pressure as measured with a manometer.

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PM 2089e March 2010




Selection criteria

Mechanical ventilation systems are generally composed of multiple fans which are staged on as temperature rises. In most systems this begins with small fans, and larger fans are added to increase the air delivery. Fans should be selected based on air delivery and efficiency ratings at 0.10 inches of water. The shaded area of Table 1 illustrates the data that should be used for fan comparisons and selection. Efficiency is another criterion that should be considered. Table 2 shows median and upper quartile test results for efficiency ratings by fan size. Choose fans which are within the upper quartile of rated fan efficiencies. Many utility companies provide rebates for efficient fans that meet target efficiency. ***Check with your electrical supplier for rebate requirements before purchasing fans.***

Table 2. Fan test results for efficiency based on fan size and 0.10 inches of H_20 (BESS lab)

Diameter of fan	Efficiency rating	
Inches	Median rating cfm/W	Top ¼ rating cfm/W
<16	7.9	8.7
16 to 20	10.3	11.2
22 to 35	13.0	14.6
36 to 46	15.9	17.2
48 to 56	18.9	20.4
>56	20.1	21.5

Summary

Good quality fans are essential for proper performance of mechanically ventilated swine facilities. Inefficient fans can add to production cost in two ways. The most obvious cost is wasted energy that is expended while using an inefficient fan. Other costs can be due to poor air quality in the building due to under-ventilation or wasted heat due to over-ventilation. Fans that are inefficient or mismanaged may allow air quality to diminish and therefore stress animals. Stressed animals are more susceptible to disease and also have less-than-optimal animal growth and feed conversion. Management and proper staging of fans is also an important part of an energy efficient system and will be dealt with in other fact sheets.

Improper fan maintenance can negate energy savings from proper fan selection. Simple routine maintenance steps include:

- **Regular cleaning and maintenance of fan blades and shutters**
- **Maintain discharge cones**
- **Check belt tension regularly**
- **Check with utility provider for rebates when replacing or upgrading fans**


Factors affecting fan performance

The configuration in which a fan is installed and the manner in which it is maintained **greatly affect its performance**. Guards generally decrease the fan performance less than 5 percent, and should always be left in place because they protect workers from the fan and the fan from objects. Shutters reduce fan performance 10-25 percent but are necessary for periods when the fan is not operating. Dirty shutters and blades can reduce air delivery by as much as 40 percent. Regular cleaning and maintenance will keep shutters operating at their manufactured level of efficiency. Well maintained discharge cones increase fan efficiency by 15 percent or more. If belt-driven fans are used, check belt tension regularly. Loose belts will cause the fan to be less efficient and effective, perhaps by as much as 50 percent. An over-tight belt will cause undue wear on bearings. Fan ratings are based on a fan that is in a new condition and should include all accessories which will be used in your application.

Prepared by Jay Harmon, professor, ag and biosystems engineering; Mark Hanna, extension ag engineer and biosystems engineering; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Managing High-Temperature Grain Dryers for Energy Efficiency

High-temperature grain dryers, whether continuous flow or batch flow, are capable of high-speed grain drying to accommodate increasing grain yields and farm sizes statewide. Dryer design and dryer management are both key to achieving maximum grain drying energy efficiency.

Graphic courtesy of GSI

Wet holding

Wet grain holding capacity allows drying to continue through temporary stops in harvesting (overnight, rainy days, and breakdowns). At minimum, the wet holding capacity should equal the difference between the daily harvest amount and the amount that can be dried during daily harvest hours (approximately 4-8 hours of harvest capacity). Some producers plan for a full day of harvest capacity in wet holding. Greater capacity may cause problems with the allowable storage time for the wet grain.

Wet holding bins should have aeration rates of 0.5 to 1.0 cubic feet per minute per bushel (cfm/bu) of capacity to keep grain cool.

If wet holding bins are not emptied every day, they should be equipped with hopper bottoms or power sweep augers that remove grain from the bottom of the bin so that no wet grain is trapped for extended periods. Additional calculations for wet holding capacity and other topics can be found in the *Grain Drying, Handling and Storage Handbook* (MWPS-13) available from Midwest Plan Service.

Drying temperature

Drying rate and drying fuel efficiency both increase with increasing drying temperature. High temperature dryers for corn typically use temperatures of 120 to 180 degrees Fahrenheit. Risks of grain discoloration and quality loss increase above 200 degrees. Seed grains, specialty grains, and in-bin dryers may have lower temperature limits.

Column dryers equipped with multiple heating zones can utilize higher drying air temperatures in the upper zones where moisture is being removed faster and lower temperatures in the final drying zone. This variable temperature approach can maximize energy efficiency while protecting grain quality.

Adequate airflow

Airflow rate is the primary key to drying rate. Factors that reduce airflow rate with the same electrical input rob your system of efficiency.

Accumulation of fines on drying floors and screens reduces airflow. Use proper combine settings, grain cleaners, gentle handling, and frequent checking and cleaning to minimize fines accumulation.

Grain resistance to airflow is directly proportional to the depth (thickness) of grain. But fan performance drops faster as airflow resistance increases. Excess grain depth or improper matching of fans to the drying system can hinder drying rate and efficiency.

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PM 2089f May 2010




Cooling

High temperature drying systems often cool the grain quickly before leaving the dryer. Rapid cooling of hot grain can lead to increased seed coat cracking and increased damage with further handling. Delayed cooling can reduce the harmful effects of rapid cooling and can increase dryer throughput and efficiency.

Transferring hot, dried grain to a separate cooling bin allows a batch dryer to be refilled sooner, increasing drying rate by as much as 33%. From either continuous flow or batch dryers, if dried grain is transferred while it's hot, the drying process can be stopped at 1-1.5 points above the target moisture content. This extra moisture is removed in the cooling process. Using this method, energy savings of 10-15% can be achieved. Be aware that significant condensation can occur in the cooling bin. Transfer the cooled grain to a separate storage bin or equip the cooling bin to manage the extra condensation.

Delayed cooling can be improved further by allowing the hot grain to "steep" for several hours in a process called dryeration. This process allows removal of 2-3 points of moisture in the delayed cooling process and energy savings of up to 25%.

Prepared by Shawn Shouse, extension ag engineer; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative. Sponsored by the Iowa Energy Center.

Heat recovery

Even when delayed cooling is not possible, energy savings are possible by recapturing heat energy from the cooling process. Recirculating the cooling air and even the drying air from the final portion of the drying phase into the drying airstream can create energy savings of 10-20%. Some continuous flow dryers are equipped to capture cooling air by reversing the airflow through the cooling section. Other dryers can be equipped with shrouds and ductwork to achieve this same effect. Bin roof dryers achieve this cooling heat capture by cooling grain on the floor and adding the cooling air to the drying air plenum.

Mixing the drying grain

Exposing the wettest grain to the highest air temperatures maximizes drying efficiency. In bin systems, this effect is achieved by stirring the grain. In column dryers, flow diverters or inverters can channel the wetter outside grain back to the inside of the drying column. Mixed flow column dryers may use both grain mixing and an extended configuration air plenum to achieve higher efficiency.

Controls and sensing

As additional efficiencies are sought, close attention to controls and moisture and temperature sensing becomes increasingly important. Check and calibrate your moisture meters and temperature sensors frequently. Consider additional sensing equipment and automated controls to avoid over-drying and finished grain moisture variability.

Energy management

If you are thinking about installing a high-temperature grain drying system or upgrading existing equipment, contact your local energy providers to discuss the potential changes in your energy demand and consumption. Also, inquire if there are any energy audit services or rebate incentives available for your project.

Managing for energy efficiency

- Maintain airflow by cleaning screens and floors, watching combine settings and grain damage, and matching fans and grain depth for optimum performance
- Use higher drying temperature within the recommended range for your dryer to increase fuel efficiency
- Calibrate your moisture meter and temperature sensors often to increase reliability and avoid over-drying

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Ballasting tractors for fuel efficiency

Most tractor operators know proper ballasting is important to transfer as much engine power as possible to the drawbar. Exactly how to accomplish this ballasting, however, frequently remains a mystery. Too little weight or ballast results in excessive drive wheel slippage and an obvious waste of fuel. Conversely, carrying too much ballast on a tractor dramatically lowers wheel slip but results in greater rolling resistance as the tractor sinks too far into the soil, causing wheels to be constantly climbing out of a deep rut.

Many larger modern tractors have an option to display wheel slippage to the operator. To maximize transfer of power from drive axles to the drawbar, optimum amounts of wheel slippage depend on the soil surface. On firm, untilled soil, wheel slip should be in a range of about 6–13%. More slippage is allowed on a tilled surface, 8–16%, with slightly more yet on a non-cohesive sandy soil. Conversely, optimal wheel slip is about 4–8% on concrete. Checking wheel slippage on tractors equipped to display this information provides an easy check to determine if the tractor is optimally applying fuel and horsepower to the drawbar.

If tractor wheel slip is outside these suggested ranges for operation with drawbar loads, check the operator's manual for ballasting suggestions or consult the following procedure. Total gross tractor weight required for optimal ballasting is a function of tractor type (two-wheel drive, mechanical front wheel assist/drive, four-wheel drive) and travel speed in the field (Table 1).

Table 1. Gross tractor weight, lb/Hp

Speed, mi / hr	< 4.5	5	> 5.5
Tractor type			
2WD & MFD (lb/Hp)	130	120	110
4WD (lb/Hp)	110	100	90

Since only wheels on powered axles supply traction, it's also important to distribute ballast properly between front and rear axles. Optimal weight split between axles is affected by tractor style and whether the attached implement is pulled or mounted (Table 2). Equipment such as manure tank wagons and grain carts have significant tongue weight and can be considered "fully mounted" drawbar loads when calculating the proper weight split between front and rear axles because they add weight to the tractor's rear axle similar to fully mounted implements.

Table 2. Front-to-rear axle weight ratio as percentage of total weight

Tractor type	Towed / drawbar % Front / % Rear	Semi-mounted % Front / % Rear	Fully-mounted % Front / % Rear
2WD	25/75	30/70	35/65
MFD	35/65	35/65	40/60
4WD	55/45	55/45	60/40

An important exception to the ballasting procedure described above occurs when lighter drawbar loads are used that require less than half of the available tractor power. Examples include a pull-behind sprayer, a small planter, or a field cultivator that does not require much horsepower. Ballast previously added for primary tillage or heavy drawbar loads simply adds to tractor weight, increases rolling resistance and can increase fuel use. Although adding and

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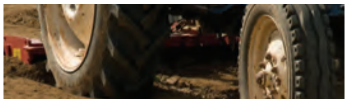

removing cast iron ballast can be daunting, with proper equipment to support weights, a semiannual weight management strategy may be appropriate. Ballast is removed in late spring for lighter drawbar work such as planting and spraying, and also summer PTO operations such as mowing or baling with light drawbar loads. Ballast is then added to the tractor prior to fall tillage operations which require more of the tractor's engine power to be transferred to the drawbar.

Total tractor weights and percentage weight splits between front and rear axles shown in Tables 1 and 2 are only a guide. Because tractor fuel and power efficiency are optimized over a range of wheel slippages, fuel use is not likely to increase substantially with a 5% deviation from these values, but increased fuel use may become evident if weights differ by 10% or more. **NOTE:** if slippage cannot be easily checked and tractor axle weights are not known, they should be measured to gain confidence that fuel is not being wasted. Total tractor weight as well as the weight being carried on each axle can be conveniently checked on commercial scales at a grain elevator or co-op (Figure 1).

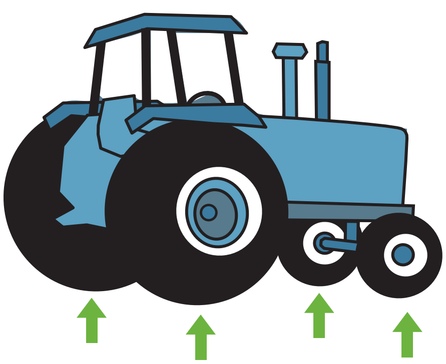

Figure 1. Tractor weight should be checked on both front and rear axles.

Prepared by Mark Hanna, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

Tire inflation

Besides proper ballasting, it's important to know axle weight in order to calculate the load each tire carries. Correct tire inflation pressure for the load carried can be found from load and inflation tables available on the tire manufacturer's web site or in the equipment operator's manual. Correct inflation pressure for a given weight depends on tire size, whether the tire is used as a single or dual, and if the tire will be used at high speed (e.g. greater than 25 mi/h).

Because underinflated tires wear sidewalls quickly, a natural tendency is to overinflate tires for a given load. Unfortunately, over-inflation reduces contact of the tire's lugs with the soil and results in excessive slippage and increased fuel use. Figure 2 shows fuel used for primary fall tillage operations with five different tractors when tires were inflated at a relatively high 24 psi inflation pressure and also with tires inflated at 14 psi pressure, which was more appropriate for the load these tires were carrying.

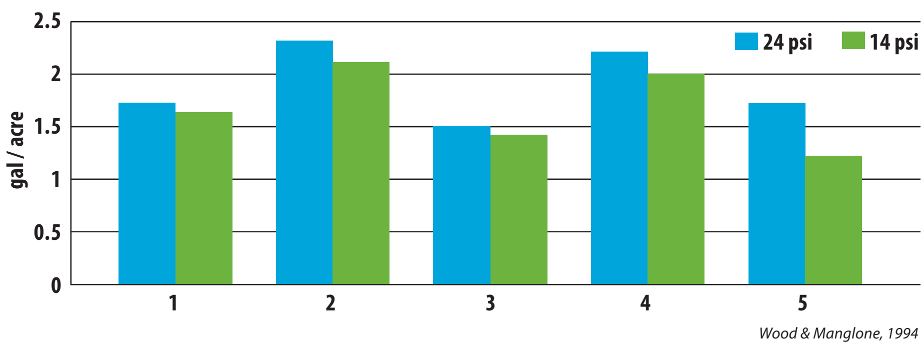

Figure 2. Fuel used during fall tillage by five tractors with tires inflated at either 24 psi or 14 psi.

Summary

Tractor fuel efficiency, time spent in the field, and tractor engine hours used can be adversely affected by either using too much ballast, causing excessive rolling resistance, or too little ballast, causing excessive tractor wheel slip. As an example, wheel slippage is usually not noticeable to the operator's naked eye until it's above 20%. Correct wheel slip in soil generally produces visible lug marks, but with distinct crumbling of the soil near the tire centerline indicating some slippage of lugs in the soil. If lug marks are distinct across the tread width without evidence of some soil crumbling, excess ballast is being used.

Checklist

- **Know the proper weight that should be carried on the front and rear axles of the tractor in order to efficiently transfer engine horsepower to drive wheels. Ensure weight being carried by the tractor is in this range by checking these weights on a scale.**
- **Check tractor slippage and consider reducing tractor ballast during periods when the tractor will be used with lighter drawbar loads.**
- **Use a good tire inflation gauge capable of readings within 1 – 2 psi and manage inflation pressure according to tire load and tractor use conditions.**

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Quantifying quality

To understand the principles of fan selection, some basic terms must be understood. These include the following:

Air delivery: Air delivery is the amount of air that a fan will move at different conditions. This term is expressed as volume of air movement per unit time. The standard unit is cubic feet per minute (cfm).

Static pressure: Static pressure is the difference in pressure that a ventilation fan creates between the inside and outside of a mechanically ventilated structure. Static pressure may be measured using a manometer (Figure 1). Fans are used to create a vacuum within a building by exhausting air. The indoor environment, having a lower pressure than outdoors, will draw air in through inlets (Figure 2). This is called a negative pressure system. In most animal housing situations, the static pressure operates between 0.04 and 0.08 inches of water. A free hanging fan, such as a stirring fan, will operate with no static pressure.

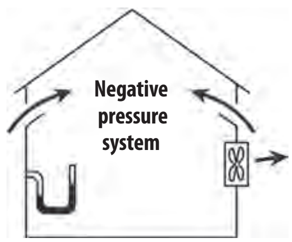

Figure 2. Negative pressure system with inlets and an exhaust fan.

Fan efficiency: Fan efficiency is the amount of air delivery that a fan will provide per unit of electric power used, given in cubic feet per minute per watt (cfm/W). In general, small fans are less efficient than larger fans. Efficiencies range from about 5 cfm/W to 25 cfm/W.

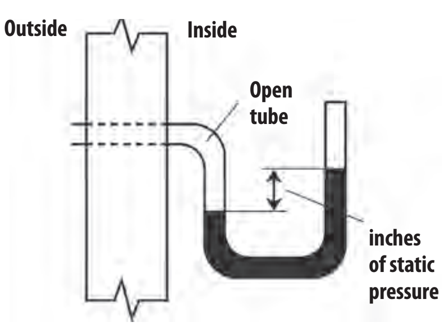

Figure 1. Static pressure as measured with a manometer.

Fan rating

Fans should be rated by an independent lab to show air delivery and efficiency as a function of static pressure. This information will be presented by using either a graph or table. An example appears in Table 1. Accessories on the fan such as guards, shutters, and discharge cones impact performance and should be noted when examining test data. Test results are available from the Bioenvironmental and Structural Systems (BESS) lab at the University of Illinois (www.bess.uiuc.edu).

A common mistake is to select fans based on fan diameter. Never assume that two fans of equal size will perform the same since different motors, curvature of blades and other attributes greatly influence the performance. For instance, it has been found through testing of several 50-inch fans that the air delivery (at 0.10 inches of water) ranged from 18,000 to 28,600 cfm, and the efficiency ranged from 14.3 to 24.5 cfm/W.

Table 1. Example fan data for a 50-inch fan with shutter, guard, and discharge cone (BESS Lab)

Static pressure Inches of water	Speed rpm	Airflow cfm	Efficiency cfm/W
0.00	540	29,500	27.4
0.05	537	27,600	24.4
0.10	535	25,400	21.5
0.15	534	22,900	18.5
0.20	533	19,600	15.5
0.25	533	15,800	12.5
0.30	534	6,500	5.3

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PM 2089h August 2010



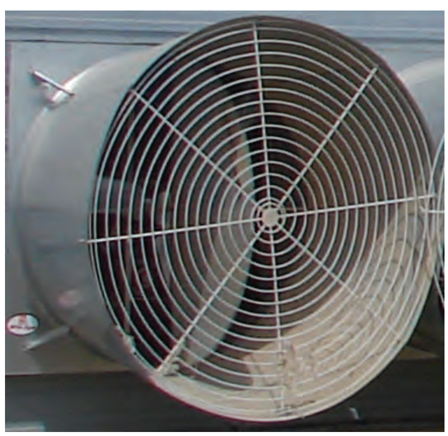

Selection criteria

Mechanical ventilation systems are generally composed of multiple fans which are staged on as temperature rises. In some systems this begins with small fans and larger fans are added to increase the air delivery. Fans should be selected based on air delivery and efficiency ratings at 0.10 inches of water. The shaded area of Table 1 illustrates the data that should be used for fan comparisons and selection. Efficiency is another criterion that should be considered. Table 2 shows median and upper quartile test results for efficiency ratings by fan size. Choose fans which are within the upper quartile of rated fan efficiencies. Many utility companies provide rebates for efficient fans that meet target efficiency. ***Check with your electrical supplier for rebate requirements before purchasing fans.***

Table 2. Fan test results for efficiency based on fan size and 0.10 inches of H_20 (BESS lab)

Diameter of fan	Efficiency rating	
Inches	**Median rating** cfm/W	**Top ¼ rating** cfm/W
<16	7.9	8.7
16 to 20	10.3	11.2
22 to 35	13.0	14.6
36 to 46	15.9	17.2
48 to 56	18.9	20.4
>56	20.1	21.5


Factors affecting fan performance



The configuration in which a fan is installed and the manner in which it is maintained **greatly affect its performance**. Guards generally decrease the fan performance less than 5 percent and should always be left in place because they protect workers from the fan and the fan from objects. Shutters reduce fan performance from 10 to 25 percent but are necessary for periods when the fan is not operating. Dirty shutters and blades can reduce air delivery by as much as 40 percent. Regular cleaning and maintenance keep shutters operating at their manufactured level of efficiency. Well maintained discharge cones increase fan efficiency by 15 percent or more. If belt-driven fans are used, check belt tension regularly. Loose belts will cause the fan to be less efficient and effective, perhaps by as much as 50 percent. An over-tight belt will cause undue wear on bearings. Fan ratings are based on a fan that is in a new condition and should include all accessories which will be used in your application.

Improper fan maintenance can negate energy savings from proper fan selection. Simple routine maintenance steps include:

- **Regular cleaning and maintenance of fan blades and shutters**
- **Maintain discharge cones**
- **Check belt tension regularly**
- **Check with utility provider for rebates when replacing or upgrading fans**

Summary

Good quality fans are essential for proper performance of mechanically ventilated poultry facilities. Inefficient fans can add to production cost in two ways. The most obvious cost is wasted energy that is expended while using an inefficient fan. Other costs can be due to poor air quality in the building due to under-ventilation or wasted heat due to over-ventilation. Fans that are inefficient or mismanaged may allow air quality to diminish and therefore stress animals. Stressed birds are more susceptible to disease as well as have less-than-optimal growth and feed conversion. Management and proper staging of fans is also an important part of an energy efficient system and will be dealt with in other fact sheets.

Prepared by Jay Harmon, professor, ag and biosystems engineering; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Energy Conservation in Corn Nitrogen Fertilization

Iowa has a strong tradition of crop production, especially corn. Achieving optimum corn yields requires nitrogen (N) fertilization in most crop rotations. Unlike buying diesel for tractors, fertilizer energy is not directly purchased; but the energy consumed during the production of N fertilizer is considerable. In particular, the amount of natural gas used to produce N fertilizer means that pricing is affected by the supply and price of natural gas.

At recommended rates, N fertilizer application is the largest energy input for corn production. This publication will address the utilization of N (and other) fertilizers to maximize returns on energy consumed in N manufacturing, transportation, and application for corn production.

Energy use in nitrogen fertilizer manufacture

Nitrogen fertilizers are predominantly produced using the Haber-Bosch process. Nitrogen gas (N_2) is combined with hydrogen (H_2) to form ammonia (NH_3). Nitrogen gas comes from the air and hydrogen typically from natural gas. Production of N fertilizers is very energy intensive and natural gas is the main energy source. Combining the N and H to form NH_3 requires considerable natural gas, both as the hydrogen feedstock and as energy for heat required during the process. Other fertilizers containing N are predominantly made from ammonia, including:

- Urea – $CO(NH_2)_2$
- Ammonium nitrate – NH_4NO_3
- Urea-ammonium nitrate solutions
- Ammoniated phosphates – MAP ($NH_4H_2PO_4$); DAP [$(NH_4)_2HPO_4$]

Due to the consumption of natural gas as an energy source and as feedstock in ammonia production, the price of N fertilizer is typically related to supply and price of natural gas. A modern ammonia production plant requires net energy consumption of approximately 29.7 million BTUs per ton of N (Kongshaug and Jenssen). Upgrading ammonia to other N fertilizers requires even more energy: 35.9 million and 31.4 million BTUs per ton for urea and urea/ammonium nitrate manufacture, respectively.

Table 1. Energy required to manufacture N fertilizer, and equivalent amount of energy expressed per 100 cubic feet of natural gas (per ton) or gallons of diesel fuel (per lb).

	Millions of BTUs/ton N	Natural gas equivalent ccf/ton N	Diesel fuel equivalent gal/lb N
Modern			
Ammonia	29.7	29.7	0.107
Urea	35.9	35.9	0.129
Urea ammonium nitrate (UAN)	31.4	31.4	0.113
Ammonia average, 1998	39.8	39.8	0.143

Older ammonia production plants are less efficient. In 1998, the average U.S. plant required 39.8 million BTUs per ton N. Efficiency gains in production of ammonia have improved the energy use for N fertilizers and corn N fertilization as newer technology has become available.

Energy use in phosphorus and potassium fertilizer manufacture

Phosphorus and potassium (K) are also important fertilizers for corn production. The energy use in modern manufacturing technology of commonly used P and K fertilizers is much less than N. In fact, the net energy balance for the production of MAP and DAP show that the accumulated energy produced is greater than energy consumed (-14.1 GJ/mt P_2O_5 or -0.044 gal diesel fuel equivalent per lb P_2O_5) (Kongshaug and Jenssen). This occurs due to several processes in manufacturing that release energy. Net energy consumption (balance) in manufacturing potassium chloride (muriate of potash) is 2.5 GJ/mt K_2O or 0.008 gal diesel fuel energy equivalent per lb K_2O. At typical K application rates for corn, the diesel fuel equivalent per acre is quite low compared to N fertilization, even considering additional energy for transport and application.

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PM 2089i September 2010




Corn N fertilization requirement

Production of optimal corn yields requires N fertilization in most crop rotations. For example, the yield increase due to N application rate for corn following soybean (SC) and corn following corn (CC) is shown in Figure 1. Soybean in the cropping rotation results in a soil system that supplies greater crop-available N. Therefore, the rotation of SC is more efficient with fertilizer N use due to higher yield and lower N application rate requirement. This has important implications for energy use in corn production. The typical corn yield advantage for SC is 15% greater than for CC, and the N rate is 30 to 50 lb N/acre lower.

Nitrogen rate recommendations in states across much of the Corn Belt come from the online Corn Nitrogen Rate Calculator [http://extension.agron.iastate.edu/soilfertility/nrate.aspx]. Crop rotation and economics (price of nitrogen and corn) determine recommended rates, referred to as the **M**aximum economic **R**eturn **T**o **N**itrogen (MRTN). For example, at a 0.10 N:corn price ratio (example $0.35/lb N:$3.50/bu corn), suggested rates for Iowa corn production are 125 lb N/acre with SC (Figure 2) and 177 lb N/acre with CC (Figure 3). Corn grown in rotation with forage legumes, such as established alfalfa, has an even greater advantage as there is little to no N fertilization need in the first year, and reduced rate requirement for the second year of corn.

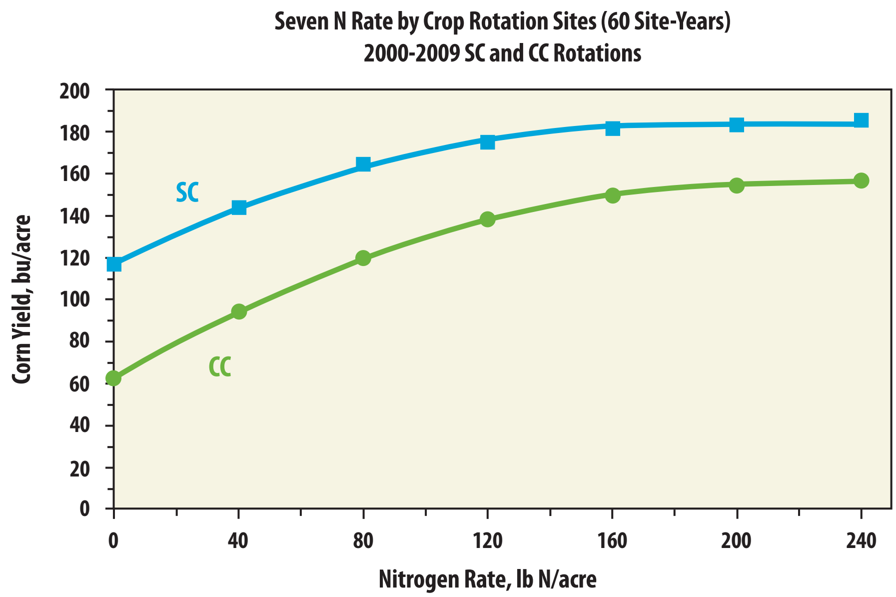

Figure 1. Corn yield response to fertilizer N application rate for seven sites across Iowa in 2000-2009, corn following soybean (SC) and corn following corn (CC). Data from J.E. Sawyer and D.W. Barker, Iowa State University, Department of Agronomy.

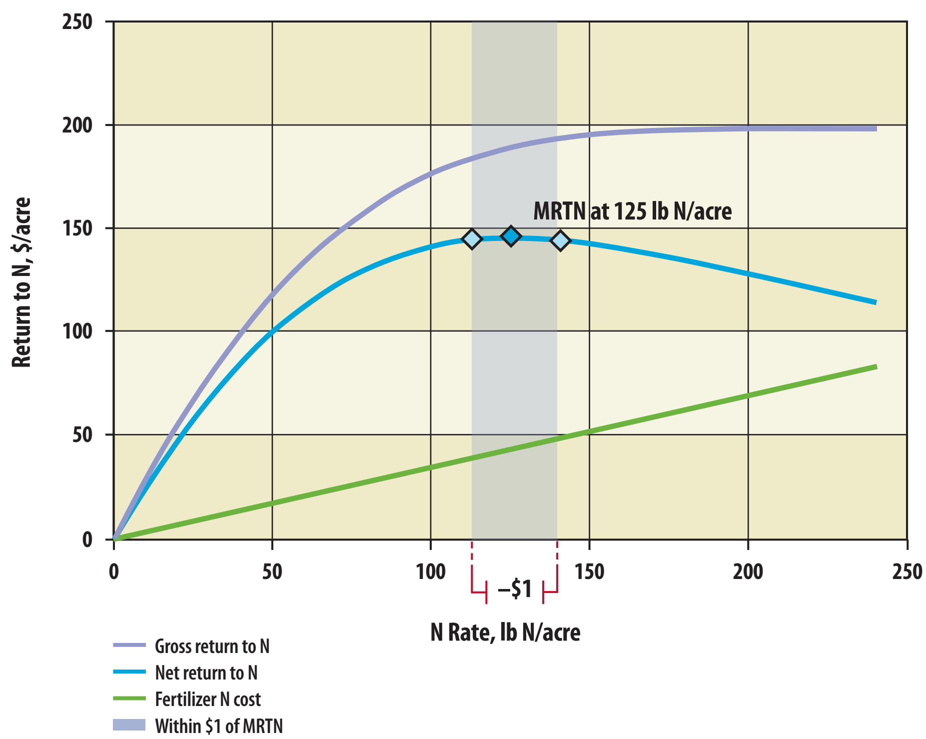

Figure 2. Recommended N rate (MRTN) for corn following soybean in Iowa with N at $0.35/lb N and corn at $3.50/bu (Corn Nitrogen Rate Calculator, 2009).





Nitrogen fertilizer application has a large impact on energy use in corn production and using recommended N rates minimizes energy consumption. While applying N rates below optimum would further reduce energy input, yield loss would occur, thereby reducing economic return. Applying more N than is optimal wastes energy because corn yield does not increase above the maximum response (Figure 1), and is therefore an economic and energy loss. In addition, there is increased potential for nitrate loss to tile drainage and groundwater. It makes economic, environmental, and energy sense to apply recommended and not excessive N rates.

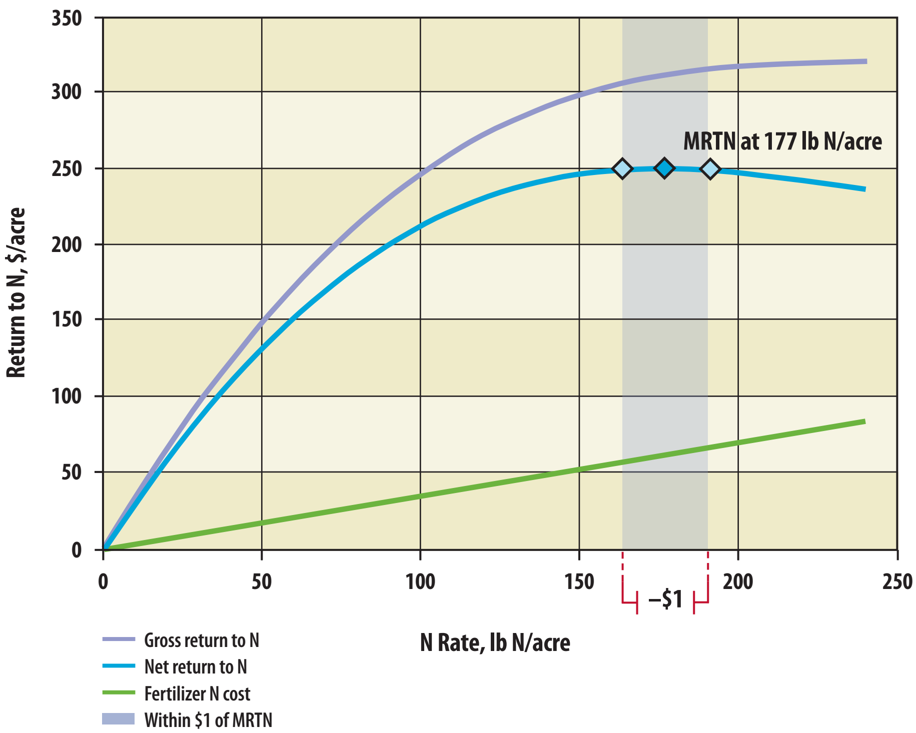

Figure 3. Recommended N rate (MRTN) for corn following corn in Iowa with N at $0.35/lb N and corn at $3.50/bu (Corn Nitrogen Rate Calculator, 2009).

Energy use in nitrogen fertilizer application for corn

As mentioned above, at recommended rates, N fertilizer application is the largest energy input into corn production. For example, with SC at 125 lb N/acre applied as ammonia, the diesel fuel energy equivalent for N manufacture is 13.3 gal and with CC at 177 lb N/acre is 18.9 gal. There is additional energy use in fertilizer transport and application. For ammonia, the energy for transportation is roughly 1,100 BTU/lb N and for application 1,000 BTU/lb N (Hoeft and Siemens). Energy for transport and application varies somewhat for different fertilizer products due to analysis and method of application. For the rate examples above in each rotation, and N application as ammonia, the energy use for transport and application is much lower than for manufacturing. For SC at 125 lb N/acre is 1.9 gal diesel fuel equivalent and for CC at 177 lb N/acre is 2.7 gal diesel fuel equivalent. The total energy use as diesel fuel equivalent for corn N fertilization is then 15.2 gal for 125 lb N/acre and 21.6 gal for 177 lb N/acre.

As illustrated, optimal use of N fertilizer can have a sizeable positive impact on energy consumption for corn production. In addition, rotating corn with forage legumes can greatly reduce the energy input due to N supply from the rotation where sunlight and the symbiotic relationship between Rhizobia sp. and the forage legume crop provides the energy input (via sunlight and photosynthesis) for the N supplied to a future corn crop.

Summary

Optimal use and management of N (and other) fertilizers is important to maximize return to the energy consumed in the manufacture, transportation, and application for corn production. Efficiency gains can be achieved by avoiding losses during and after field application, applying recommended rates, and substituting manure and legume N where energy has already been captured. Choice of N application rate is important for maximizing economic return and minimizing environmental loss. It is also important for maximizing net energy return through crop capture of sunlight and grain/stover production. For additional information, see Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn (PM 2015). [http://www.extension.iastate.edu/Publications/PM2015.pdf]

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Prepared by John E. Sawyer, extension soil fertility specialist and professor of agronomy; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Sizing minimum ventilation to save heating energy in swine housing

Wasted heating energy is a costly problem for producers, and ventilation accounts for 80–90 percent of the heat lost in swine housing during the winter. Air exchange is critical to providing a healthy environment that fosters efficient pig growth by reducing humidity and noxious gases like ammonia and carbon dioxide. Since under-ventilation creates an unhealthy environment and over-ventilation wastes valuable heating energy, finding the right balance is the key to energy savings and efficiency.

Wean-to-finish buildings provide one of the greatest challenges to efficient heating. A good target for liquefied petroleum (LP) usage is two gallons per pig space per year. Actual usage will depend upon what time of year the weaned pigs are started in the building. Figure 1 shows that over-ventilating by as little as 10% can increase annual LP consumption by 27%. Likewise, over-ventilating by 40% can double LP consumption. Over-ventilating is more common than expected since it is difficult to know just how much air is actually being exchanged.

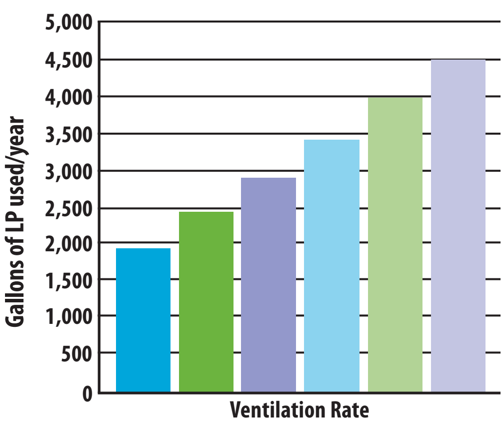

Figure 1. Over-ventilation of a 1000-head wean-to-finish facility significantly increases estimated LP usage.

Proper | 20 % Over | 40 % Over
10 % Over | 30 % Over | 50 % Over

To size minimum ventilation, refer to the rules of thumb that appear in Table 1. As an example, a 1,000-head wean-to-finish building with newly placed pigs should be ventilated at 1,500 cfm (1,000 pigs x 1.5 cfm/pig) during the coldest weather. This rate must be adjusted as the pigs get larger. It seems simple enough to pick a fan rated at 1,500 cfm. However, to meet the changing needs of the pigs and to minimize the number of fans required, a controller is used to slow down the fan speed, which causes it to deliver less air. These fans, often called "variable speed" fans, can be used to fine tune the ventilation rate and save heating costs by reducing LP fuel consumption.

Table 1. Rules of thumb for swine ventilation (adapted from Midwest Plan Service).

		Ventilation Rate (cfm/head)	
Production Phase	**Weight (lbs)**	**Winter Minimum**	**Hot Weather**
Sow and Litter	450	20	500
Nursery	12-30	1.5 to 2	25
Nursery	30-75	3	35
Finishing	75-150	7	75
Finishing	150 to Market	10	120
Gestating sow	400	14	250

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Air delivery

There are limits to how much a fan can be slowed down using variable speed and still be effective. Figure 2 shows how a 24" fan tested at BESS Labs performs with varied voltage. The important thing to notice is that half voltage does not yield half air flow. For instance, full voltage at 0.10 inches of water will deliver 7,000 cfm but at 120V only about 700 cfm is delivered. Fans that receive less than half voltage are likely to require replacement more frequently because the electric motor will run hot. Fans operating at low speed also cannot operate against much pressure so it is important to protect fans facing prevailing winds. Figure 3 shows one method of protection.

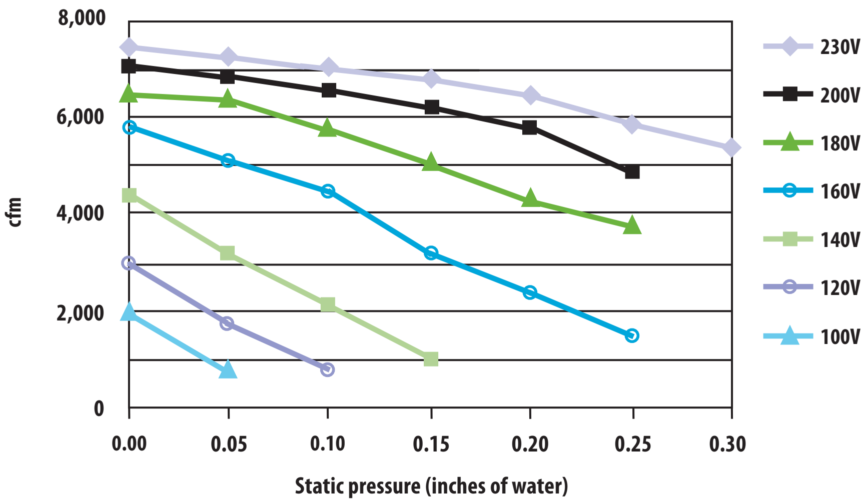

Figure 2. Flow rate for a 24" fan for various voltages. **BESS Lab**

Figure 3. Variable speed fan with wind protector.

When selecting fans for variable speed usage, it is good practice to not expect them to deliver less than half their rated airflow at 0.10 inches of water. For instance, in the 1,000-head example above, 1,500 cfm is needed and a selected fan might be rated at 3,000 cfm. This fan can therefore be used with a variable speed controller to deliver half its rated amount. An additional fan would be required once the pigs grow beyond 75 lbs and require more air.

Prepared by Jay Harmon, professor, ag and biosystems engineering; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

The management of variable speed fans is a complex prospect. Controllers have settings for the minimum speed but the percentage of fan speed is not necessarily related to the percentage of the full air flow rate. However, using the percentage of fan speed as a guideline of full air flow is a good initial approximation. This percentage can then be adjusted based on room conditions. If relative humidity or gases are too high, the percentage can be increased. If the air quality is good, lowering the percentage may be appropriate. With experience, this becomes easier. Further usage of controllers will be addressed in another fact sheet.

Summary

Ventilation is necessary for a healthy production environment but can also be costly in terms of demand for heating energy. Using variable speed fans can help to maintain good air quality while limiting heating fuel usage.

Important points to remember:

- **Size variable speed fans to run no lower than half of the full speed rated capacity.**
- **Adjust the speed based on air quality. If the relative humidity is higher than 60% or ammonia seems high, increase the speed. If the relatively humidity and gases are low, try reducing the fan speed slightly.**
- **The energy cost of wasted heat exiting the building is far greater than the electricity required to operate variable speed fans.**
- **Protect variable speed fans from prevailing winds.**
- **Understand your controller and how it interacts with variable speed fans.**

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Dryeration and combination drying for increased capacity and efficiency

In years when artificial corn drying is necessary, the grain dryer is often the bottleneck that limits harvest rate. Two management strategies, dryeration and combination drying, can help you increase the drying rate from your high-temperature (above 120 degrees F) corn dryer.

Stop high-temperature drying sooner to increase dryer capacity/efficiency

In both dryeration and combination drying, the drying process in the high-temperature dryer is stopped at a grain moisture content higher than the final target moisture content. This allows more bushels per hour to be moved through the high-temperature dryer, increasing drying capacity. At the same time, delayed cooling of the grain allows the drying process to finish with less fuel input, increasing drying energy efficiency.

Delayed cooling is the key

In a high-temperature dryer, moisture is being removed from corn kernels faster than the moisture can equalize within the kernel. At the end of high-temperature drying, the moisture in the center of the kernel is still higher than around the outside of the kernel. Delaying the cooling process 4 -12 hours (dryeration) allows kernel moisture to equalize, moving this extra core moisture toward the surface of the kernel where it is more easily removed. Cooling the corn after this resting period, sometimes called "steeping" or "tempering" time, removes an extra 0.2 to 0.25 points of moisture from the corn for each 10 degrees of temperature change (2-3 points of moisture for typical high-temperature dryers) compared to immediate cooling.

Drying capacity can increase 50 -70% with dryeration. Drying energy efficiency can increase 15 -30%. Additional benefits of delayed cooling are reduced stress cracking of kernels during cooling, reduced kernel brittleness, and improved millability.

Planning for dryeration

Systems designed for dryeration must have the ability to transfer hot grain from the dryer and hold it for several hours before cooling. This is best done in a dedicated cooling bin with full floor aeration. Because condensation occurs on the bin sidewall and nearby grain during delayed cooling in cold weather, delayed cooling in storage bins is not recommended.

For batch loading and unloading, use two cooling bins so that one bin is steeping and cooling while the other bin is loading. Convenient operation results when each cooling bin is sized for one day's drying capacity. Size the cooling fans to cool the bin in about 12 hours. This requires approximately one cubic feet per minute of airflow per bushel of grain to be cooled (cfm/bu).

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Consider sizing cooling bins for up to 1.5 times your current drying capacity to allow for expansion and the fact that drying capacity increases with dryeration. Good grain handling equipment and layout is critical for dryeration.

Manage your dryeration by transferring hot grain from the dryer at a moisture content 2-3 points higher than the final target moisture. Allow the first grain into the cooling bin to steep for at least 4, and preferably 6-12 hours before starting the cooling fan. Once grain is cooled, move it to storage bins. Monitor the final grain moisture content and adjust drying times as necessary. Avoid immediate bin cooling of grain as this removes 1-2 points less moisture than delayed cooling with dryeration and does not provide as much protection against cracking.

Dryeration requires additional grain handling equipment and additional management time, but can result in significant increases in drying capacity and energy efficiency.

Combination high-temp./ low-temp. drying

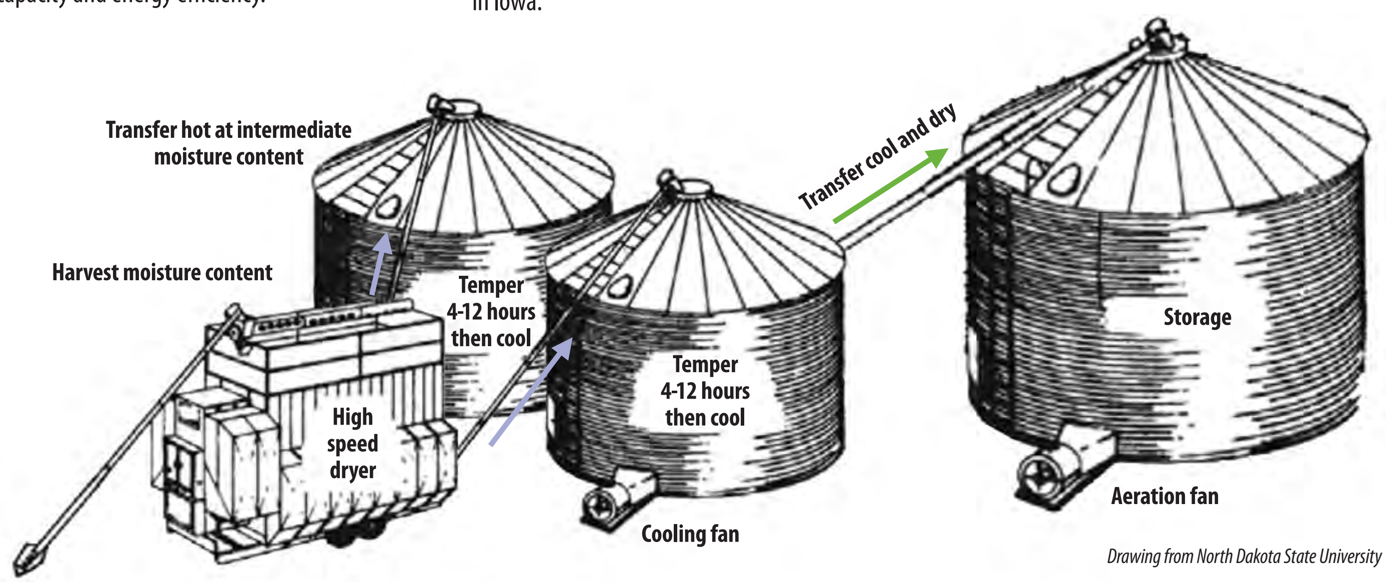
Another adaptation of delayed cooling combines high-temperature and low-temperature drying systems. This combination works particularly well for corn harvested at a moisture content too high for reliable low-temperature drying alone.

For combination drying, the high-temperature dryer must be equipped to transfer hot grain to a low-temperature drying bin.

In this system, corn is dried in the high-temperature dryer to a moisture content of 22% or less. The partially dried hot corn is transferred to a low-temperature drying bin where the fans are started immediately to cool and finish drying the corn. Immediate cooling in the low-temperature bin reduces the risk of condensation but still removes an additional point of moisture during cooling. The resulting moisture content of 21% or less is generally safe for low-temperature drying in Iowa.

Combination drying can reduce drying energy use by up to 50%. Drying capacity can be doubled or even tripled compared to conventional high-temperature drying alone. Because combination drying relies on low-temperature drying in addition to high-temperature drying, more electricity is used in place of natural gas or propane, and more drying system investment is required.

When considering any changes to your grain drying system, start first with an energy audit to determine your energy efficiency and opportunity for improvement. Consult a qualified engineer or system planner for equipment selection and sizing. More information on grain drying systems is available from your Extension Ag Engineer and in the Midwest Plan Service Grain Drying, Handling and Storage Handbook available at www.mwps.org.



Dryeration example: high-temperature dryer system with two tempering bins. Tempering bins are filled in alternating order, making sure hot grain has at least 4 hours of time to temper before exposure to cooling air. After tempering and cooling, transfer grain to storage bin.

Prepared by Shawn Shouse, extension ag engineer; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative. Sponsored by the Iowa Energy Center.

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Tractor maintenance to conserve energy

Machinery represents a significant portion of capital costs, second only to land in many farming operations. A well-kept fleet of machinery improves the ability to respond to changing field conditions and other seasonal needs. Past surveys of tractor owners indicate that most are aware of routine maintenance schedules and wish to follow them to protect their equipment investment. Machinery test data supports filter replacement and other general maintenance. When performed at intervals no greater than those listed in operation manuals, the fuel savings are measurable.

Engine maintenance

Efficient combustion of fuel and air inside the tractor's engine directly affects the availability of engine power and fuel efficiency. Filters, usually both primary and secondary, are used to collect small particles and impurities to protect close machine tolerances inside the engine from wear. To maintain a proper fuel and air mixture in the engine cylinders, filters must be replaced on a periodic basis as restricted flow starts to impact combustion efficiency.

In a previous study by ag engineers at the University of Missouri, farmers were invited to bring their tractors to one of six field days at implement dealers around the state. The result was test data on 99 tractors using a power-take-off (PTO) dynamometer. Each tractor was first tested "as is" to determine maximum horsepower available through the PTO shaft. A subsequent test was conducted after replacing the existing air and fuel filters on the tractor with new filters.

After the filters were replaced, average tractor power output increased by 3.5% without further modifications. Filters were replaced on all tractors tested regardless of whether the filters were near the end of useful service life or had been recently replaced. Self-reported oil change intervals and engine oil samples collected and subsequently tested suggest that most tractor operators were following recommended periodic maintenance procedures.

Tests on the 99 tractors indicate that scrupulously following air and fuel filter maintenance procedures results in a 3.5% power increase. Manufacturer representatives confirmed that a 3–4% power increase was normal and expected during filter replacement. Consistent filter replacement maintains the tractor's power output, which is noteworthy since a new tractor currently costs approximately $700 per horsepower depending on its size and options. Making an additional 3.5% of power available on a 200 hp tractor is equivalent to adding 7 hp—a value of nearly $5000 when considering the initial cost of a new replacement tractor.

Alternatively, fuel flow from the throttle could be reduced 3.5% to produce an equal power level after the filters were replaced. Fuel use savings per tractor on smaller (~ 140 hp) tractors being used at the time was estimated to be 105 gallons/year. Larger tractors would be expected to save proportionately more depending on use.

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As further evidence of the importance of filter maintenance, combustion power output is directly related to air pressure available to fill the combustion cylinder. A vacuum drop of 0.5 psi air pressure across an air filter results in 3.5% less air entering the cylinder in a naturally aspirated engine. The relationship in a turbocharged diesel engine is more complex, but results in a similar trend if oxygen is limited for combustion.

Combustion efficiency is significantly affected by maintaining engine operating temperature within a certain range. In addition, engine wear increases rapidly if lubricating oil breaks down at high temperatures or water condenses at lower temperatures and reacts with sulfur compounds to create corrosion. Engine operating temperature should be carefully monitored. Thermostats on many engines open around 180°F, but consult the operation manual. Cooling system maintenance should include periodic inspection and replacement of coolant and possible replacement of the engine thermostat if it is defective in maintaining proper engine temperature.

Letting a diesel tractor engine idle for a few minutes following hard work allows circulation of cooling oil. Before idling for 8–10 minutes, check the operator's manual. Newer tractors may require 3–5 minutes of idling or less. Road transport at a lower engine speed before shut off may eliminate the need for cool down idling. Ten minutes of excess idling consumes a half gallon of fuel or more on a larger tractor used for tillage.

Fuel supply

Diesel fuel forms waxy, solid crystals at low air temperatures common during cold weather operation. The temperature at which diesel begins to "cloud" as solids begin to form depends on the diesel refining process. Unfortunately, refining that lowers the cloud point for cold-weather diesel operation also slightly reduces the energy content per gallon of fuel. The result is common use of #2 diesel fuel during warm weather operation, but switching to #1 diesel during cold weather. Using #1 diesel reduces the potential for plugging filters or fuel injection systems due to its lower cloud point, but fuel energy per gallon is also slightly reduced. Fuel supplies should be switched from #2 to #1 as the climate cools in late fall, but back again to #2 when air temperature warms for springtime operations. If a supply of #2 fuel must be carried into colder weather, fuel additives are available.

A tractor engine block heater is commonly used to warm the engine and aid starting for cold weather operations such as snow clearing or livestock chores. Conserve energy by plugging the heater into a timer to heat the engine for 2–3 hours before starting rather than operating the heater overnight. Also keep the fuel tank relatively full during cold weather. If air inside the tank is cooled below its saturation point (dew point), vapor condenses into water and may cause potential fuel problems.

To reduce fuel loss due to evaporation, use white or aluminum-colored paint on above-ground fuel storage tanks unless another color is required by local fire code. Shade or paint that reflects solar radiation helps to reduce fuel evaporation. Use a vacuum and pressure-relief valve on large fuel supply tanks to reduce evaporation loss due to pressure changes inside the tank. For onboard fuel tanks, use a vented or unvented fuel cap per manufacturer recommendations.

Summary points:

- Be vigilant in following air and fuel filter replacement as well as other engine maintenance procedures. Staying current on filter replacement saves 3–4% of fuel or more.
- Observe engine temperature and air filter/pressure indicators during operation for any significant changes that might affect fuel economy.
- Avoid excessive idling to cool engine.
- Use a timer with an engine block heater to avoid unnecessary heating.
- Protect fuel from evaporative losses and select appropriate fuel for summer/winter operation.

Prepared by Mark Hanna, extension ag engineer and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative. Sponsored by the Iowa Energy Center.

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Shift up and throttle back to save tractor fuel

Diesel fuel is the largest direct energy purchase for Iowa farmers. Tractor operation accounts for much of this. Higher horsepower tractors that do a large percentage of their work as drawbar pull on tillage and seeding implements must efficiently transfer power from the engine to the drive wheels through a transmission. Speed and torque available from the engine crankshaft is changed to a combination of drive axle speed and torque.

Drawbar tractor operations such as chisel plowing, field cultivating, planting, and spraying require different amounts of drawbar pull or force, depending on the size of the implement and soil conditions. Although a specific amount of power is available from any given tractor, various load requirements of farm operations frequently result in the tractor being only partially loaded for the amount of drawbar power available.

Power and friction

Fortunately, fuel economy of diesel engines is very forgiving for partial drawbar load operation if the transmission is shifted to a higher gear and the fuel supply throttle is adjusted to reduce fuel use. When the engine speed (rpm) is greater than necessary, the excessive friction robs power from the engine. Therefore, a high throttle setting actually decreases the total "useful" power produced by the engine.

The concept of shifting up and reducing throttle setting to reduce engine speed for fuel savings is similar to what occurs with truck or automotive transmissions during highway travel. At slower starting speeds when greater force and higher torque is needed at the drive wheels to overcome inertia and accelerate the vehicle, the transmission transmits greater torque from the engine by reducing axle speed in a lower transmission gear. Once greater force is no longer required to accelerate the vehicle as it comes up to speed, engine power is shifted to higher transmission gears and the throttle (foot accelerator) is reduced.

New technology

Sophisticated transmissions available on some newer large and medium-sized tractors use electronic controls to automatically select gear and throttle setting depending on the drawbar load requirements and the travel speed selected by the operator. Transmissions marketed as "infinitely" or "continuously" variable generally have the ability to automatically operate at the most fuel efficient transmission setting for the selected speed and required load. New features such as this should be considered to improve overall fuel efficiency when deciding if an older tractor is nearing the end of its useful life in the farm operation.

Iowa State University
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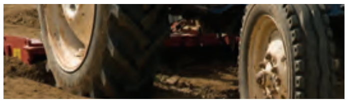
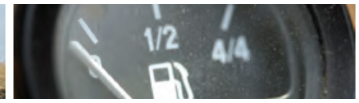
PM 2089M March 2011



Fuel savings and technique

Tractor operators with fixed-gear transmissions in either a powershift or standard manual transmission style can still easily take advantage of this fuel economy technique by selecting an appropriate gear for tractor operation in the field. Information from Nebraska/OECD (Organization of Economic Cooperation and Development) tractor tests show potential for fuel savings at reduced drawbar loads.

For example, in tractor tests a CaseIH Magnum 245 produces maximum drawbar power in 7th gear. If the tractor continues to use 7th gear when operating at a reduced load of 75% of maximum available drawbar power fuel consumption is 11.6 gal/hr at 2090 engine rpm. If the same load is pulled in 9th gear but with a throttle setting reduced to 1580 engine rpm (to maintain the same travel speed and drawbar power output) only 10.5 gal/hr is consumed – a 10% fuel savings. In a similar fashion, the tractor pulling at 50% of drawbar power uses 10.0 gal/hr when pulling in 7th gear at 2150 engine rpm but only7.9 gal/hr when pulling in 9th gear at the reduced engine speed of 1620 rpm, a 20% fuel savings at this reduced load.

Fuel savings examples from several tractors are shown in table 1. Tractor test research data suggests that fuel savings for many existing tractors can be significant. Tractors tested at the Nebraska Tractor Test Laboratory from1979 – 2002 had an average fuel savings of 13% at 75% drawbar load and fuel savings of 21% at 50% drawbar load (Grisso et al., 2004).

Table 1. Percent of fuel saved by switching to a higher gear when tractor is used at 75% or 50% of available power (from Nebraska/OECD tractor tests)

		% fuel saved by switching to higher gear	
Tractor model	Drive style[a]	75% load	50% load
CaseIH 245	Front-wheel assist	10	20
CaseIH 435	Front-wheel assist	11	14
Challenger MT 655	4WD	11	14
Deere 8220	Front-wheel assist	15	18
Deere 9330	4WD	9	11

For partial load applications, how high can the gear be shifted and engine speed subsequently reduced? The key is to not shift up so high or reduce the throttle so low as to overload or lug the engine down. A significant increase in black smoke (particulate matter in the exhaust) or the sound of the engine lugging down to lower speed when pull momentarily increases in harder spots are indicators to shift back down a gear and increase engine speed slightly to give the engine reserve torque capacity in difficult spots.

When to use

It's important to note that the "shift up, throttle down" technique is not suitable when using power-take-off (PTO) powered implements such as a baler or mower-conditioner. PTO shaft speed is directly related to engine speed. Because the PTO implement requires a standard shaft speed input (1000 or 540 rpm), tractor engine speed can't be reduced. Instead, engine speed is maintained at a level to produce standard PTO speed.

Use of the "shift up, throttle down" technique to save fuel is applicable any time available tractor drawbar power significantly exceeds the power required for implement operation. Common examples include use of a smaller field cultivator or disk for secondary tillage or planter operation, particularly if the implement size is small for the tractor and field conditions and a larger implement could be substituted. Another example is pull-behind sprayer operation if pump speed is not dependent on standard PTO speed.

Summary

- **Larger horsepower tractors are frequently required to do drawbar work at only 50 – 75% load or less.**
- **Shifting to a higher gear and reducing engine speed for partial drawbar loads can save 10 – 20% of fuel depending on tractor and load conditions.**
- **Avoid overloading or lugging the engine when engine speed is reduced.**
- **This technique is not suitable for PTO work when PTO shaft speed must be maintained by engine speed.**

Prepared by Mark Hanna, extension ag engineer; Stuart Birrell, professor, ag and biosystems engineering; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension.
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Energy fundamentals for farm lighting

Lighting plays an important role on the farm. In addition to enhancing security around the farm property, lighting also provides an acceptable production environment for livestock, a safe work environment for farm employees, and the ability to perform work effectively after dark. This publication gives basic information about a variety of farm lighting options. Refer to additional publications in the Farm Energy series for more information regarding indoor and outdoor lighting applications.

Terminology

The table included on page 2 of this publication provides a brief overview of energy efficiency, rated life, relative cost and other features for different types of lighting. To compare lighting options, it is also important to understand basic lighting terminology:

- **Lumens:** Quantity of light produced by a lamp is measured in "lumens" (lm). A 60 watt (W) incandescent bulb produces about 780 lumens.
- **Foot-candles:** The level of lighting at a working surface. Light meters commonly measure light levels in foot-candles. One foot-candle (fc) is defined as the amount of illumination from a candle falling on a surface at a distance of one foot. A bright sunny day might have a light level outdoors of 8000 fc while a brightly lit desktop may be about 100 fc.
- **Average Rated Life:** The average number of hours that it takes for half of a given bulb type to burn out. This is determined under ideal conditions in a laboratory and actual life may be shorter. Factors impacting actual bulb life include: ambient temperature, humidity, dust, power surges and the number of on/off cycles.
- **Efficiency:** Lighting efficiency is measured in light production per unit of energy used. Units are Lumens/W (lm/W).

In addition to light fixtures, many farm buildings have windows or skylights that utilize daylight to supplement interior lighting needs. Keeping these surfaces clean and free of debris is helpful to allow as much sunlight as possible to enter the building.

Incandescent phase-out

Currently, incandescent bulbs are utilized for a variety farm lighting applications but they are scheduled to be phased out in the near future. Incandescent bulbs utilize electrical resistance to produce light and most of their energy is actually given off in the form of heat rather than light, therefore they are the least efficient type of lighting. This inefficiency and short bulb life make them a costly source of lighting in spite of their low retail price. Now may be a good time to consider alternative lighting options before incandescent bulbs are no longer available to purchase. The scheduled phase-out among U.S. retailers is:

- **100W incandescent** – January 1, 2012
- **75W incandescent** – January 1, 2013
- **60W and 40W incandescent** – January 1, 2014

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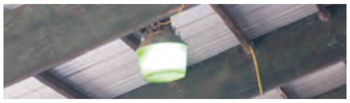
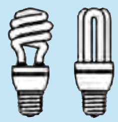
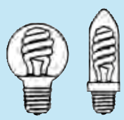
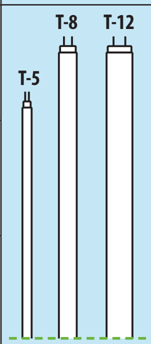
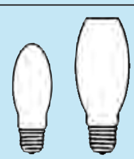
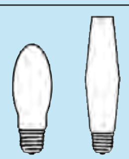
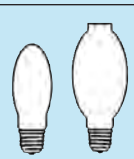
PM 2089N June 2011

Lamp	Example	Typical Lamp Size (W)	Efficiency Lumens/W	Average Rated Life (hrs)	Minimum Start Temp (F)	Ballast?	Relative Cost	Typical Application
Incandescent		25-200	10-35	1,000-4,000	Below 0	No	$	Indoor/outdoor
Compact Fluorescent		5-57	50-80	6,000-12,000	0	Yes	$$	Indoor/outdoor
Cold Cathode Compact Fluorescent		5-18	41-49	18,000-25,000	-10	Internal	$$$	Indoor/outdoor
LED		6-20	4-150	35,000-50,000	Below 0	N/A	$$$$$	Indoor/outdoor
T-5 Fluorescent		13-28	54-104	5,000-20,000	0	Yes	$$	Indoor/outdoor
T-8 Fluorescent		15-36	58-98	5,000-20,000	0	Yes	$$	Indoor
T-12 Fluorescent		14-60	42-98	7,500-30,000	50	Yes	$	Indoor
Metal Halide		35-1,000	60-80	7,500-10,000	Below 0	Yes	$$$$	Indoor high bays, outdoors
High Pressure Sodium		35-400	50-140	15,000-24,000	Below 0	Yes	$$$	Indoor/outdoor
Mercury Vapor		40-1,000	10-63	16,000-24,000	Below 0	Yes	$$$	Indoor high bays, outdoors

Prepared by Jay Harmon, professor, ag and biosystems engineering and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Fuel efficiency factors for tractor selection

When considering the addition of a new or used tractor for the farm equipment fleet, consider the operations for which it will be used. A larger tractor is sometimes selected for adequate weight (braking) or hydraulic power capacity required to lift or operate equipment. However, before acquiring a larger or heavier tractor, consider that at least seven percent of tractor power is commonly required to overcome rolling resistance created by the weight of the tractor. Tractor test data can be used to estimate fuel consumption and to aid tractor selection. To evaluate fuel efficiency, it is helpful to understand tractor test procedures, fuel efficiency measurements, and specific values found in tractor test reports.

Test procedures and fuel efficiency

Global manufacturers of tractors support testing through Organization for Economic Cooperation and Development (OECD) test procedures. The tractor test is generally conducted within the country of manufacture. U. S. –produced tractors are tested at the Nebraska Tractor Test Laboratory (NTTL) at the University of Nebraska. Test measurements are made of power and fuel use during power-take-off (PTO) and drawbar load tests as well as sound measurment and hydraulic power and lift capacity. Tests for tractors sold in the United States are available through NTTL either as a full report for the individual tractor or in a summary book with abbreviated test information for tractors currently sold in Nebraska.

PTO tests near the beginning of the report, followed by drawbar tests to measure fuel consumption at reduced loads and engine speeds, are useful to evaluate fuel consumption. PTO tests show PTO power available and fuel use at rated engine speed, standard PTO speed (1000 or 540 rpm), and if greater maximum power is available for at least one hour at a different engine speed. Fuel use and power output is then shown for several reduced (varying) PTO power loads.

Drawbar fuel consumption performance lists maximum drawbar power available along with tractor performance at 75 percent and 50 percent drawbar power loads using the same transmission gear used to develop maximum drawbar power. These values are followed by tractor performance at the same 75 percent and 50 percent power loads, but with the tractor operated in a higher gear selected by the manufacturer and at a reduced engine speed. These latter tests help show fuel economy at lighter loads using appropriate gear and throttle settings.

Fuel use (gal/hr) is listed in PTO tests, but also listed under fuel consumption in drawbar (and also in PTO) tests is 'Hp – hr/gal'. Hp – hr/gal is a measure of fuel efficiency with greater numbers indicating higher fuel efficiency.

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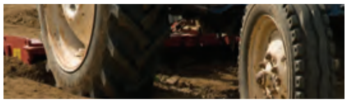
PM 2089O July 2011




Fuel efficiency values from a tractor test

Although it may seem difficult to believe at first, average tractor use for many row-crop tractors is near to 50% load. This occurs partly because of the need to match tillage and planting equipment to multiples of row spacing, but also because tractors are used for lighter loads at times such as spraying and mowing. Even heavily loaded tillage applications may use only 80 – 90% of power much of the time but allow for excess power in tough spots. With this type of tractor use, and assuming use of a reduced throttle setting and higher gear for reduced loads, the value of Hp – hr/gal at 50% pull and reduced engine speed (A, figure 1) is a good comparative indicator of fuel economy when comparing tractor tests. A greater number indicates better fuel economy.

If the tractor is to be used over a wide variety of load situations (from near full load to idling and routine chores), the average of fuel use (gal/hr) values in the varying PTO power tests (B, figure 1), multiplied by annual hours of operation, gives an estimate of annual fuel use. If a tractor is expected to be used predominantly at greater or lesser loading conditions, fuel use can be estimated by selecting an appropriate power within the varying PTO tests. For example, values from the tractor shown in figure 1 indicate that at about 60% power (120 hp) the tractor consumes 8.01 gal/hr. Just as in EPA automotive gas milage, exact fuel consumed depends on use and other factors such as maintenance, adjustment, ballasting, and the environment.

Nebraska OECD Tractor Test 1884-Summary 551
John Deere 8130 Diessel
16 Speed

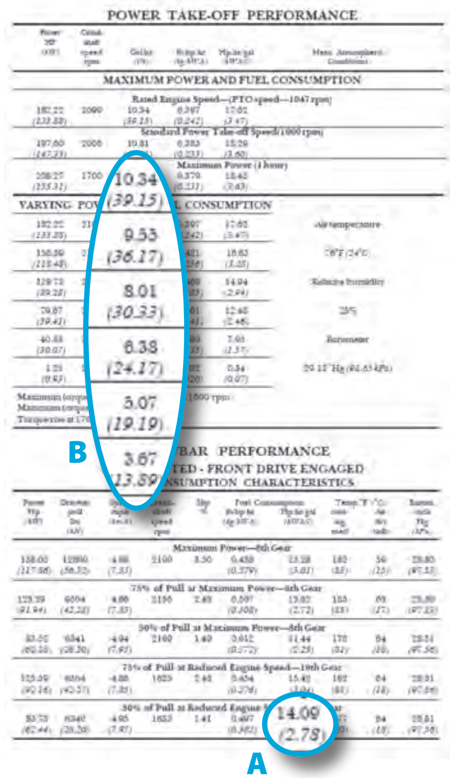


Figure 1. Sample first page of a tractor test report

New technology and other factors

Selecting a continuous or infinitely variable transmission to automatically match transmission gear and engine speed at reduced loads has significant potential for fuel savings (see PM 2089M). Adding auto-steering using a global positioning system (GPS) system can reduce swath overlap and result in less fuel and time spent in the field.

A percentage wheel slip indicator aids ballasting for fuel efficiency (PM 2089G). Easy-to-service air and fuel filters along with appropriate dashboard indicators for condition of air filtration and fuel pressure help maintain fuel efficiency (PM 2089L). In addition to fuel economy, other important factors such as dealer service proximity may also impact tractor selection.

For further information:

Nebraska Tractor Test Reports.
http://tractortestlab.unl.edu/

Grisso, R., D. Vaughan, J. Perumpral, G. Roberson, R. Pitman, and R. Hoy. Using tractor test data for selecting farm tractors. Virginia Cooperative Extension Publication 442-072.
http://pubs.ext.vt.edu/442/442-072/442-072.pdf

Prepared by Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Conserve heat energy in the farm shop

Proper insulation and a well-designed heating system are important for an energy efficient and comfortable farm shop. Most farm shops are used throughout the winter—some on a daily basis and others more sporadically. By maintaining a minimal temperature level, typically about 40 degrees Fahrenheit, supplies and equipment are protected from freezing. It also is easier to warm up the space to comfortable working temperature—typically 55–65°F.

Insulation and energy conservation

Good insulation is critical for energy efficiency, because a farm shop does not need as much ventilation as other facilities, such as livestock buildings, during winter heating. The minimum recommended insulation levels are R-Values of 15 to 20 in side walls, 30 in ceilings, and 10 for doors. A vapor barrier of 6-mil polyethylene should be installed between the inside wall or ceiling panels and the insulation to keep moisture out of the insulation.

Insulate the foundation with at least 2 inches of extruded polystyrene insulation (R 10 to R 12). This will keep the floor warmer and reduce heat loss through the floor. This perimeter insulation can be installed on the outside of the foundation wall to a depth of 4 feet or it can be installed underneath the floor for 4 feet around the outside edge. Maintain continuity of this foundation insulation up to the wall insulation to avoid having a cold spot with higher energy losses. Examples of these insulation methods are shown in figure 1.

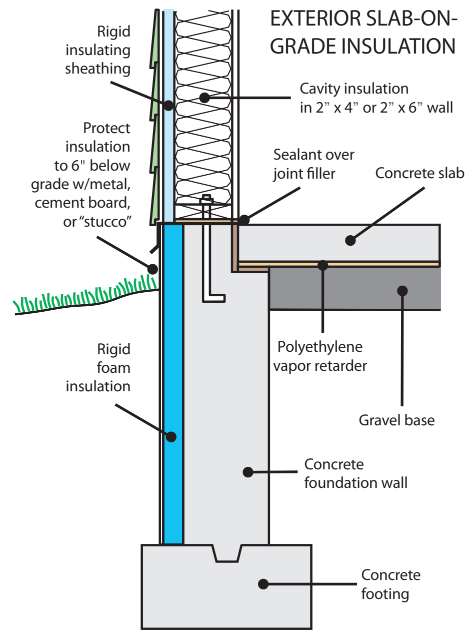
Install windows primarily on the south side to allow sun in during the winter and minimal solar gain in the summer. Windows in walls and overhead doors should contain double glazing.

Place large doors for bringing in equipment on the south or east side of the shop if possible to avoid wintertime prevailing winds from the north and west. Also, any snow and ice on door approaches will melt off more quickly on the south side of the shop.

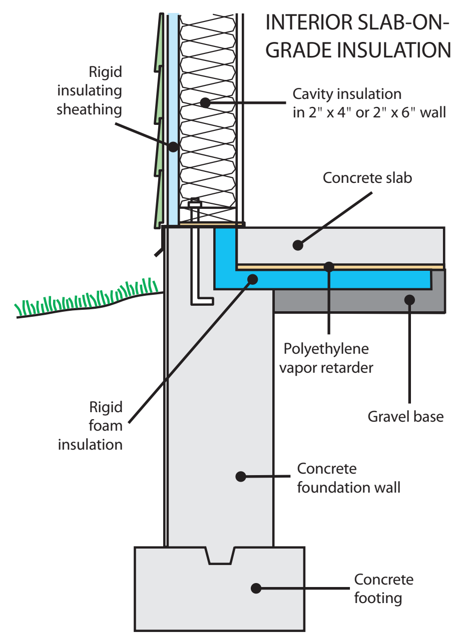
Heating systems

The size and type of heating system will depend on the size of the shop, how often the shop is used, and how often large doors will be opened and closed. Many types of heating systems are used in shops, including forced-air furnaces, infrared heaters, and in-floor heat. The most frequently used fuels are propane, wood, fuel oil, or waste oil.

Ceiling-mounted, forced-air space heaters work well, because the furnace blast helps keep hot air from stagnating near the ceiling. The furnace should be sized at approximately 50 BTU/hour per square foot of shop floor area. Use a minimum size of 70,000 BTUs per hour if the shop is fan-ventilated at the 1,000-cfm rate.



Foam boards are the most common form of exterior slab-on-grade insulation. The above grade portion must have UV and structural protection.



Interior slab-on-grade insulation can be horizontal. Interior placement avoids the need for protection, but may require cutting small pieces and more difficult details.

Figure 1 from Joseph E. King and Gene Meyer, *A Builder's Guide to Residential Foundation Insulation*, Kansas State University, Fall 1999.

IOWA STATE UNIVERSITY
Extension and Outreach

PM 2089P August 2011




Power-vented or condensing type heaters are much more efficient than natural draft heaters. A power-vented heater and a condensing type heater are approximately 13% more efficient and 25% more efficient, respectively, than a natural draft heater. Unvented liquid propane (LP) heaters, which are common in livestock buildings, are not recommended in farm shops because of the lack of ventilation and the danger of carbon monoxide poisoning.

Managing forced-air heaters for energy efficiency is somewhat difficult. Lowering the temperature when the shop is not in use will save energy; however, lowering the temperature too much will create an uncomfortable work environment due to the cold temperature of the concrete flooring. Maintaining the minimum temperature within 10°F of the desired working temperature is advised.

Infrared radiant heaters are more expensive than space heaters. However, radiant heating systems are very efficient at low shop temperatures, because the radiant heat warms the surfaces it strikes, providing comfortable equipment and surface temperatures.

Radiant heating systems can provide approximately the same comfort level as forced air heaters at a 10°F lower shop temperature. This reduces heat loss when large entry doors are opened. Radiant heat systems should be sized at 40 BTU/hour per square foot of shop floor area.

In-floor heating systems are popular for farm shops even though they are more expensive than most other heating systems. They are best suited to farm shops that are used frequently during winter. In-floor heat has the following advantages:
- Warm floors dry quickly and are comfortable to work on.
- Snow and ice melt quickly from vehicles.
- Heating is very uniform.
- The floor retains heat for long periods.

It also has some disadvantages:
- It is relatively high cost compared with other heating systems.
- The system can be damaged if the floor cracks badly.
- It is not well-suited for occasional use.
- By itself, it may not maintain 70°F room temperature during the coldest weather.

The best temperature for a heated shop floor is 75–85°F (warmer floors become uncomfortable). For a floor at 85°F and air temperature of 70°F, heat output is approximately 38 BTU/hour • ft2. If the air temperature cools to 60°F, the heat input to the shop will increase. It is recommended to design for 45 BTU/hour • ft2 and size the system slightly larger to account for system losses.

This heat output will keep a reasonably insulated shop at 55–60°F but does not have extra capacity for quick warm-up or reserve heat when large doors are opened in cold weather. Rather than depending entirely on an in-floor system, a smaller ceiling-level forced-air furnace can be used to provide a portion of the heating. This furnace should be hung to one side of the most frequently used large door. This will provide quicker temperature recovery following opening of the door in cold weather. If both an in-floor heat and a forced air system are used, provide a total of 50 BTU/hour per square foot of shop floor area between the two systems.

More information on designing floor heating systems is available in Extension Circular AE-1014, "Hot Water Floor and Space Heating," which is available from Extension Agricultural Engineering at North Dakota State University. A similar design bulletin is available from Canada Plan Service at http://www.cps.gov.on.ca/english/plans/E9000/9735/M-9735La.pdf.

Prepared by Greg Brenneman, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Dana Petersen, program coordinator, ISU Farm Energy; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Improving corn drying efficiency

In some years, energy bills for corn drying can rival costs for fuel used to plant and harvest the crop. Studying basic concepts of heated air and natural air drying—as well as understanding factors affecting in-field drying—helps to effectively control corn drying energy costs.

Basic drying principles

Corn is hygroscopic material: it allows moisture to enter and exit the kernels depending on surrounding conditions. The moisture content of corn kernels comes into equilibrium with the temperature and relative humidity of surrounding air.

In-field drying

After corn is physiologically mature, a black layer forms at the tip of the kernel, preventing further exchange of nutrients and water between the kernel and cob. After black layer formation, temperature and relative humidity of surrounding air are the main contributors to in-field drying. However, plant morphology also is important. A tight husk restricts air exchange with corn kernels and controls how much of the ear tip is left exposed.

Limited field-drying data suggest daily drying rates may average 1.0% in mid-September, 0.7% in late September, and 0.5% in early October. More importantly, there is wide variation among seasons due to weather conditions. Days early in the harvest season (e.g., the first week of October) with a strong, dry wind and air temperatures in the mid-70s°F can produce in-field drying of 1% per day. Conversely, corn moisture content in the field can remain unchanged for periods of two weeks or longer if weather is cold and wet. A plan for drying grain artificially is necessary during years with inadequate field drying conditions. In addition, evaluate stalk strength and standability before leaving corn to dry in the field late into the season.

Select earlier maturing hybrids rather than full maturity

Consider selecting an earlier maturing corn variety adapted for your location rather than full maturity. Figures 1 and 2 show moisture content and yield for corn hybrids identified as either full or early maturity by seed companies for several regions as tested by the Iowa Crop Improvement Association and Iowa State University. Early-season hybrids were drier at harvest and did not reduce yields.

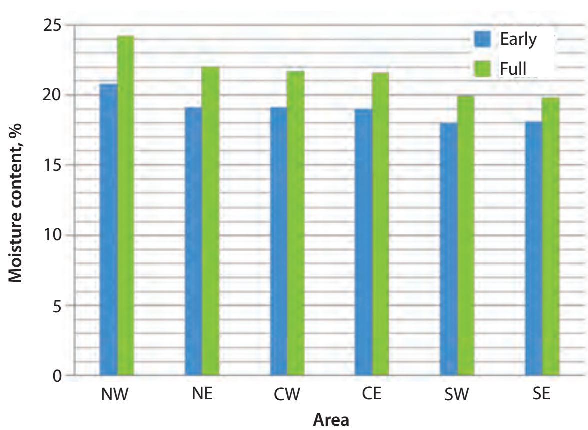

Figure 1. Corn moisture content at harvest of full- and early-season varieties (approximately 5 days earlier or more) in Iowa Crop Improvement Association and Iowa State University yield tests, 2009–2010. Early-season hybrids averaged 2.5% drier at harvest.

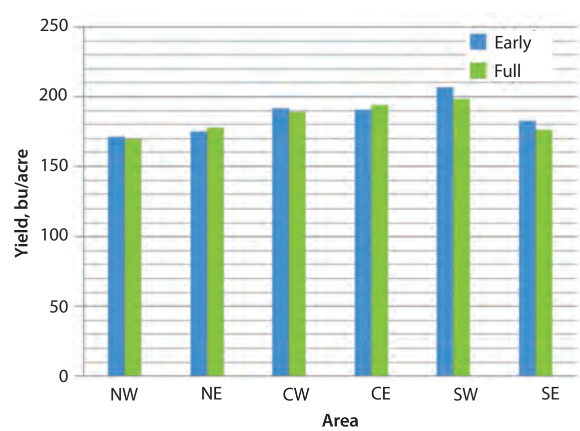

Figure 2. Corn yield averages of full- and early-season varieties (approximately 5 days earlier or more) in Iowa Crop Improvement Association and Iowa State University yield tests, 2009–2010.

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How artificial corn drying occurs

Corn kernel moisture content comes into equilibrium with surrounding air conditions during the drying process. Figure 3 shows this equilibrium relationship. For example, corn exposed to 40°F air at 45% relative humidity dries to 12% moisture content. In low-temperature drying systems, in which corn dries over a matter of days or weeks, moisture within the kernel has ample time to migrate to the kernel's surface and the whole kernel dries uniformly.

In high-temperature drying systems, kernels are exposed to high-temperature air with very low relative humidity over a matter of minutes. When air is heated to these high temperatures, relative humidity becomes quite low, resulting in some over-drying of corn — when hot air rushes past the kernel surfaces. Often outer parts of the kernel or whole kernels closer to the dryer's high-temperature air plenum are over-dried, while interior parts of the kernel or whole kernels closer to the airflow exit remain wetter than desired. After high-temperature airflow stops, heat retained in kernels and continued moisture migration allow additional drying to occur with unheated cooling air. During cooling operations or storage, wetter portions of the grain (either interior parts of kernels or whole, wetter kernels) approach equilibrium with drier portions of the grain. Understanding how kernels dry helps explain energy efficiency concepts described in high- and low-temperature drying publications in this farm energy series.

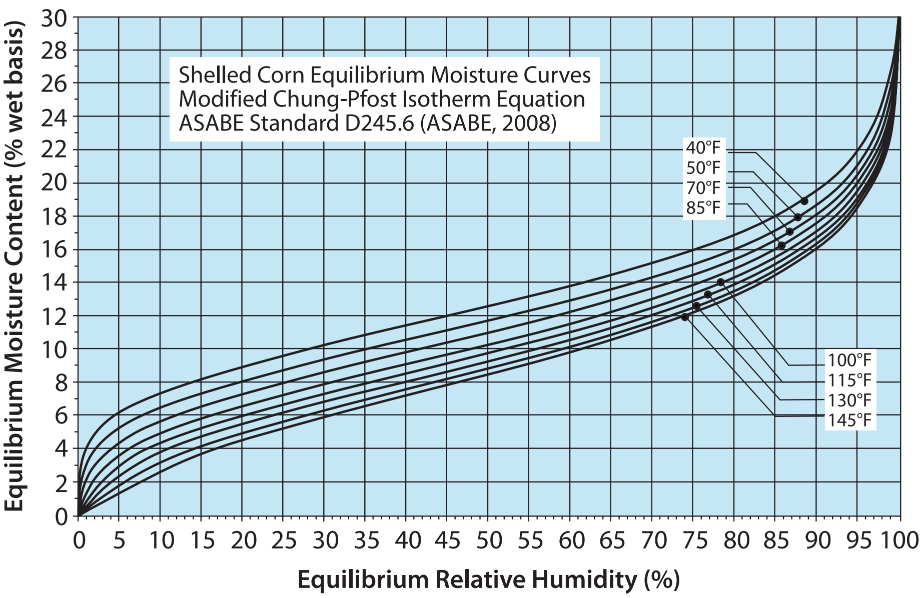
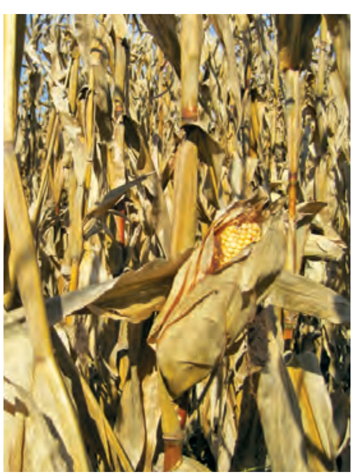


Figure 3. Equilibrium moisture content of shelled corn with air of various relative humidity and temperature.




Holding corn 'wet and cold'

Over-drying in the fall often leads to extra energy consumption. Corn quality generally can be maintained through Iowa's fall and winter weather if corn is dried to about 17% moisture content before storage. Temperatures below 40°F greatly slow mold growth in the grain. If corn will be fed locally to livestock before grain warms in the spring, avoid drying below 17% moisture content, as animals often prefer slightly wet grain.

To successfully hold grain wet and cold, use proper grain management practices, including cooling grain in storage as quickly as possible after harvest, checking grain condition weekly for moisture migration problems, and using fan cooling as necessary if any heating is detected (often at the top center of the storage bin). Because mold growth will increase as air and grain temperatures rise, grain held wet and cold through the winter must be fully dried before warmer spring and summer weather arrives for longer-term storage. Note that microbial degradation still slowly affects grain quality at 17% moisture content. Even though drying is completed before warm weather, periodically monitor grain, as a portion of its useful storage life will have been consumed.

Prepared by Shawn Shouse, extension ag engineer; Charles Hurburgh, professor, ag and biosystems engineering; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative, Iowa State University Extension and Outreach. Sponsored by the Iowa Energy Center.

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Indoor lighting for livestock, poultry, and farm shop facilities

Introduction

Indoor lighting for farm facilities is critical to safe and efficient production. Lighting systems should be designed to meet minimum lighting requirements in the most energy efficient and economical manner. This publication gives an overview of lighting types that are suited for livestock, poultry, and farm shop facilities.

Types of lighting

When selecting the proper lighting for an indoor application, consider not only energy efficiency, but also the initial cost of ballasts and fixtures and the rated life of bulbs. Keep in mind that dirty bulbs and fixtures can reduce light levels, and the environment within farm facilities (moisture, temperature, dust) generally shortens bulb life to less than its estimated "rated life."

Incandescent bulbs use electrical resistance to produce light. Most of their energy is given off as heat rather than light, therefore, they are the least efficient type of lighting. Although inexpensive to purchase, over time their inefficiency and short life make them a costly lighting source. These bulbs will be phased out of production during the next few years.

Compact fluorescent lights (CFL) can be direct replacements for incandescent bulbs because they require no wiring changes. They typically use 75% less energy than incandescent bulbs and last approximately 10 times longer. CFLs normally will not operate below 0°F and require about 1 minute to reach full light output. CFLs installed in livestock and poultry facilities should be rated for damp environments; however, bulb life may be shortened by placing them in globes or enclosures, due to increased temperatures. CFLs are best suited for facilities where lights stay on for extended periods, since frequent on/off cycles shorten their life.

Cold cathode fluorescent lights (CCFL) typically last two to three times longer than other CFLs, start at lower temperatures, are compatible with many types of dimmers, and can be turned on and off frequently without significantly shortening bulb life. They are more expensive and slightly less energy efficient than CFLs.

Light emitting diodes (LED) use semiconductor diodes, electronic devices that permit current flow in only one direction, to produce light. They are up to five times more efficient than incandescent lighting and long-lasting, with ratings up to 100,000 hours. LEDs emit directional lighting rather than the 360-degree illumination provided by other bulbs. They currently have limited application in livestock and poultry housing, due to their susceptibility to moisture, heat, and dust. However, new LED products are being developed and some have been tested successfully in broiler housing.

Tube fluorescent bulbs are available in three diameters. T5 and T8 bulbs are 0.6 inch and 1 inch in diameter, respectively. The most commonly used is the T12 bulb (1.5 inches in diameter); however, its manufacture is being phased out because it is the least efficient tube fluorescent bulb. T8 systems are four times more efficient than incandescent lights and 30% more efficient than T12 tubes. They are best suited for applications where they are mounted less than 12 feet above the floor.

In livestock and poultry housing, standard output tube fluorescent bulbs should be mounted with electromagnetic ballasts in waterproof, gasketed fixtures. T5 bulbs are shorter and more efficient than T8 bulbs. Both T8 and T5 bulbs tend to retain the original light output longer than T12 bulbs. However, T5 bulbs are not recommended for use in vapor-tight fixtures and should be limited to clean-dry environments. High output versions of tube bulbs will start as low as -20°F, but are less efficient than standard output bulbs.

High intensity discharge (HID) lamps include metal halide and high pressure sodium vapor lamps. These typically are easy to install and maintain and are well suited for high bay applications (ceilings higher than 12 feet). However, they require a few minutes to warm up before they reach full light output, so they are not ideal for short-cycle lighting. They should be replaced when light output begins to fade appreciably or when they continually shut off and restrike while power is still on.

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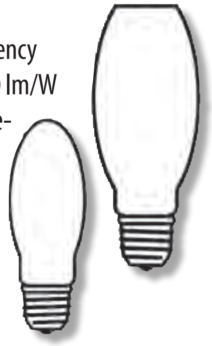
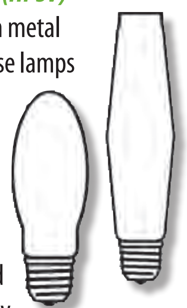
Metal halide (MH)



bulbs generally have efficiency ratings between 60 and 80 lm/W and are available in a pulse-start or standard version. Pulse-start bulbs typically are more efficient and can have 50% more lamp life than the standard version. MH are not instant-on lights, requiring 1 to 3 minutes to reach full light output. They must also cool down 5 minutes before re-starting.

High pressure sodium vapor (HPSV)



lighting is more efficient than metal halide lighting. However, these lamps emit a yellow-orange light that may not be desirable for livestock facilities where true color observation is critical to monitoring animal health. They work well at cold temperatures and are typically used outdoors.

Minimum Illumination Levels

Table 1 shows recommended minimum lighting levels for various farm facilities. You cannot simply order light bulbs to provide a given number of foot-candles. To design a lighting system or select bulbs to provide the recommended illumination level, you must know the area to be covered, the lumen rating of the bulb, and the coefficient of utilization (CU). The CU accounts for the amount of light that actually reaches and reflects from the work surface or floor. A good guideline is to use 0.5 for CU. Example 1 shows how to calculate the required lumens per bulb for an existing system. Example 2 shows how to calculate the number of bulbs required in a new system.

Example 1 (existing system): A swine nursery currently uses incandescent lights. There is one light fixture for every 10' x 10' pen. What size compact fluorescent light (CFL) is needed to provide 5 fc (lumens/square foot)?

$$\frac{\text{Desired illumination (fc) x area per bulb (sf)}}{\text{CU}} = \text{lumens/bulb}$$

$$\frac{\text{5 fc x (10' x 10')}}{0.5} = \text{1,000 lumens/bulb}$$

A 1,000 lumen CFL would provide 5 fc when it is first installed. Over time it will produce less light, and accumulated dirt also will reduce the effective output.

Example 2 (new system): A new calf housing barn is being constructed and it is decided to use 24 Watt T8 fluorescent light bulbs with an output of 1,400 lumens to achieve a light level of 10 fc. How many double fixtures will be needed if the barn is 40' x 100'?

$$\frac{\text{Desired illumination (fc) x total area (sf)}}{\text{lumens/bulb x CU}} = \text{no. of bulbs}$$

$$\frac{\text{10 fc x (40'x100')}}{\text{1,400 lumens/bulb x 0.5}} = \text{57 bulbs or 29 double fixtures}$$

This could be calculated using various bulb choices to come up with the optimal selection. The fixtures would be spaced evenly to provide full light coverage.

Table 1. Recommended minimum lighting levels for various facilities and applications.[1]

Usage	Minimum Light Level (fc)[2]
Swine	
Breeding/Gilts	15
Gestation	5
Farrowing	10
Nursery	5
Grower - Finisher	5
Poultry	
Broilers (0 - 2.5 weeks)	1 - 3
Broilers (2.5 to market)	0.5 - 2
Layers (0 to 6 weeks)	1 - 3
Layers (6 to mature)	0.5 - 1
Turkeys (0 - 8 weeks, hens)	3 - 5
Turkeys (grow out hens)	3 - 5
Turkeys (0 - 8 weeks, toms)	3 - 5
Turkeys (grow out toms)	1 - 3
Cattle	
Lactating dairy (freestall barn)	20 - 30
Dry cows	5 - 10
Milking parlor	20
Holding area	3
Cow udder	40 - 50
Calf housing and veal	10 - 20
General Use	
Office	50
Office task lighting	75 - 100
Machinery storage	3
Shop machinery repair	50
Shop rough benchwork	50
Shop detailed benchwork	100

[1] Adapted from "Agricultural Wiring Handbook". 15th Edition, 2009. Rural Electricity Resource Council and "Wiring Handbook for Rural Facilities". 3rd Edition, 2006. Midwest Plan Service.

[2] In lumens/square foot; photoperiod for livestock and poultry can influence production efficiency.




Cost Comparison

A cost comparison of lighting systems should include initial cost, operational cost, and bulb life. Bulb life is difficult to fully assess due to the shortened life that most bulbs will experience as a result of exposure to moisture, dust, and heat in livestock and poultry buildings. The example below shows a simple cost comparison. As a conservative estimate, the rated life was reduced by 50%. In addition there may be expenses associated with bulb disposal or recycling. Only incandescent bulbs should be discarded without recycling.

Example: A livestock facility currently is equipped with 100 W incandescent bulbs. Lights are used 8 hours per day, every day (2,920 hrs/yr). Compare the costs of replacing these bulbs with 23 W CFLs that produce roughly the same light output.

Type of Lamp	CFL	Incandescent
Input Wattage	23 W	100 W
Lumen Output	1,600 lm	1,580 lm
Efficiency	69.5 lm/W	15.8 lm/W
Hours	2,920 hrs/yr	2,920 hrs/yr
Energy Use	67.2 kWh	292 kWh
Utility Cost	$0.10/kWh	$0.10/kWh
Energy Cost/yr	$6.72	$29.20
Rated Lamp Life	12,000 hrs	1,500 hrs
Assumed Life[1]	6,000 hrs	750 hrs
Bulbs/yr[2]	0.49 bulbs/yr	3.9 bulbs/yr
Cost per bulb	$3.19	$0.45
Bulb cost/yr	$1.56	$1.75
Annual Operating Cost[3]	$8.28/fixture/yr	$30.95/fixture/yr
Savings	$22.67/fixture/yr	
Payback[4]	0.14 yrs or 1.7 mo	

[1] Actual life varies from rated life based on exposure to dust, heat and moisture; 50% is a conservative estimate.
[2] Bulbs/yr = hours/yr ÷ assumed life
[3] Annual operating cost = energy cost/yr + bulb cost/yr
[4] Payback = cost per bulb ÷ savings

Summary

Several lighting types are suitable for providing efficient lighting to indoor agricultural applications. The impact of dust and humidity on some lighting types make them less practical; they will have a shorter life in livestock and poultry housing than when used in cleaner facilities such as shops or offices. Lamps should provide adequate lighting to meet basic needs of the activities within the facility in a safe manner. When examining the cost, include up-front cost as well as operational costs. Appropriate disposal measures should be considered.

Prepared by Jay Harmon, professor, ag and biosystems engineering and Dana Petersen, program coordinator, Farm Energy Conservation and Efficiency Initiative; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Estimating payback for energy efficiency

Many farmers and agribusiness owners who are investing in new or re-furbished equipment want to know how quickly the returns from reduced energy costs will help the investment reach its break-even point. If only energy costs are considered, equipment with longer payback periods may not be economical until it nears the end of its useful life. When equipment must be replaced, consider a more complete cost analysis including initial investment, energy usage, equipment life, and maintenance costs. Saving money today by purchasing equipment with lower initial cost (and higher energy demands) puts the buyer at risk when energy prices rise in the future. This can potentially negate the savings associated with a low purchase price.

Simple payback

The payback period is typically calculated as "simple" payback: divide the initial cost of the energy-saving investment by the projected annual energy cost savings. For example, if new equipment costs $4,800 and the projected annual energy savings at current energy prices is $1,600, after three years (= $4,800/$1,600) the initial cost of the purchase has been repaid through energy savings. If annual maintenance costs increased, they would be subtracted from energy savings.

Examples

Specific examples of potential energy savings and equipment costs are provided in several other Farm Energy fact sheets from the PM 2089 series. Short summary examples are given here to illustrate the concept.

Pick-up truck

The existing farm truck has an estimated fuel efficiency of 15 mpg, but a late-model truck gets an estimated 25 mpg and is available for $15,000 plus trade-in. Assuming 18,000 annual mileage, the newer truck would consume 720 gallons (= 18,000/25) of fuel versus 1,200 gallons (= 18,000/15) for the existing truck. At fuel prices of $3.00 per gallon, the extra 480 gallons of fuel conserved equals $1,440 annually. The simple payback period is 10.4 years (= $15,000/$1,440). However, at increased fuel costs of $4.00 per gallon, the simple payback is 7.8 years (=$15,000/$1920). Both trucks also will incur annual maintenance costs, but these costs are lower for the newer truck and it will also have a higher salvage value than its predecessor.

10 hp electric motor

A 10 hp electric motor is being used 10 hours per week to grind feed. A new replacement motor is estimated to save one kWh of energy during each hour of operation, saving 10 kWh each week or 520 kWh annually. Assuming electricity costs $0.10 per kWh, the annual cost savings is $52. If replacement cost for a 10 hp motor is $1,000 on average, the simple payback is 19.2 years (= $1,000/$52). Therefore, if economics are the only factor considered, replacement would most likely be delayed until the end of the motor's useful life.

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Lighting

Initial cost to replace bulbs in a livestock facility is $400, but projected annual electrical energy savings is $2,000. The simple payback period is 0.2 years (= $400/$2,000) with a savings of $1,600 in year one and $2,000 in year two. Estimated bulb life for the project is two years, so return on investment is $3,600 over two years. Extra labor costs may be incurred to make the switch to new lightbulbs or fixtures, but consider if the energy savings from the upgraded, energy efficient lighting will cover labor and installation costs.

Useful life

Determining the useful life of farm equipment is a combination of how long the equipment remains functional with reasonable repair costs and the availability of replacement equipment that is more energy efficient or more technologically advanced. A component with limited annual hours, such as an infrequently used motor, is unlikely to be replaced solely to conserve energy, due to its replacement cost and limited use.

Comparing energy projects with different useful lifetimes

When comparing energy-savings investments it is important to note the relative payback period versus annual energy savings and estimated useful life. In Table 1, the initial cost and annual savings for projects A and B result in the same simple payback of three years. However, equipment for project B has a useful life of eight years. Equipment for project A lasts only four years. Even though both projects have the same simple payback, project B has a greater economic advantage over project A since the equipment in B continues to generate additional savings over a longer time.

Project C, with a similar life span as project B (eight years), requires an initial cost of $1,200 and generates energy savings of $800. Simple payback for C, at 1.5 years, is twice as fast as project B. However, the greater annual energy savings of project B results in more total money saved after five years and possibly longer, if the equipment remains useful. These examples show the limitations of using simple payback to compare projects where the useful lives or annual projected energy savings of the equipment are considerably different.

Table 1. Comparisons of projects with different useful lives and annual energy savings.

	Project		
	A	B	C
Initial cost	$4,800	$4,800	$1,200
Annual savings	1,600	1,600	800
Simple payback	3 yr	3 yr	1.5 yr
Useful equipment life	4 yr	8 yr	8 yr
Cost (-) or savings (+) at the end of year:			
1	-3,200	-3,200	-400
2	-1,600	-1,600	400
3	0	0	1,200
4	1,600	1,600	2,000
5	-1,600	3,200	2,800
6	0	4,800	3,600
7	1,600	6,400	4,400
8	3,200	8,000	5,200

Time-value of money

Because of gradually increasing inflation, future dollars aren't worth quite as much as present dollars spent on equipment. Thus, if energy prices did not increase, calculating the time (e.g., number of years) for payback by simply dividing additional cost by annual savings would understate the actual payback period. If it's assumed that energy prices generally rise at about the same rate as overall inflation, a simple direct payback calculation is valid. If energy prices increase faster than inflation, then the simple direct payback calculation overstates time required to reach a breakeven point and actual payback occurs a bit more quickly.

Summary

When examining return on investment, consider the total cost of energy, useful life, availability of newer technology, etc. Replacing a well-functioning piece of equipment that is seldom used is nearly impossible to justify when considering only energy savings. Replacement of well-functioning, high-usage equipment is more practical, but all costs should be considered. Just because something is more energy efficient does not mean that replacement is a wise investment.

Prepared by Mark Hanna, extension ag engineer; Jay Harmon, professor, ag and biosystems engineering; and Dana Petersen, program coordinator, ISU Farm Energy; Iowa State University Extension. Sponsored by the Iowa Energy Center.

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Managing swine ventilation controller settings to save energy

Ventilation is by far the largest source of heating energy loss in swine facilities. To maintain air quality, it is essential to provide proper minimum ventilation, but it is also important to avoid expelling excessive energy from the building. Most buildings use electronic controllers that activate fans, heaters, and cooling systems and are designed to interlock the equipment operation to avoid conflicts that waste energy. For instance, if fans and heaters are controlled separately, there can be occurrences when heaters are cycling at the same time the ventilation rate has increased, thereby wasting a great deal of heating fuel. Modern controllers prevent heater operation and ventilation above the minimum rate from occurring at the same time, but improper settings can still contribute significantly to excessive energy consumption.

Terminology

Before addressing how controllers work, it is important to define common terminology. Actual terminology varies among companies that manufacturer controllers.

Setpoint (SP) is a basic temperature setting within the controller that is adjusted as animals grow and their thermal needs change. SP is sometimes called desired room temperature (DRT). When the room temperature is above the SP, ventilation increases to facilitate cooling. Likewise, for room temperatures below the SP, the heater may begin to cycle. Setpoint is not the average temperature, but establishes the line between heating and cooling. During periods of heating, such as during winter when pigs are small, the room temperature will remain a little below the SP. During periods of cooling, room temperature will be above the SP.

Heaters normally have two parameters, both set in the controller. Many controllers use a heater "on" and "off" temperature, while others use a ***differential***, the number of degrees between when the heater comes on and when it goes off, and an ***offset***, the number of degrees below the SP at which point the heater turns off. For example, if the SP was set to 68°F, the differential set to 1°F and the offset set to 1.5°F, the heater would start when the room temperature drops to 65.5°F (SP minus the sum of the differential and offset). The heater would then run until the room temperature reaches 66.5°F as shown in Figure 1.

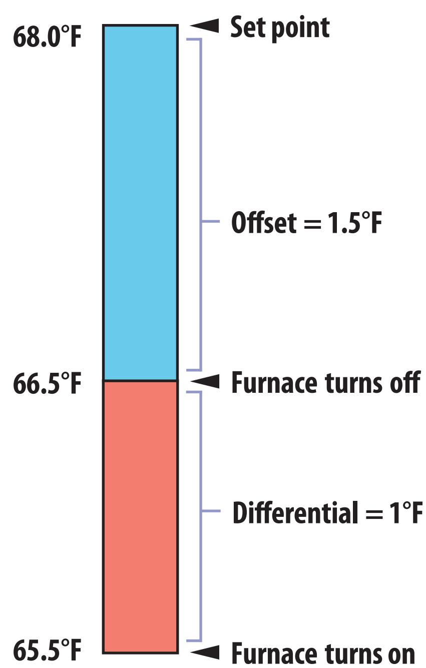

Figure 1. Differential and offset.

Variable speed fans are used for most swine ventilation systems to provide minimum ventilation. Two settings are required for basic fan control. ***Minimum speed*** is a setting in the controller that represents the minimum ventilation rate. The value displayed by the controller may or may not correspond to the percentage of full speed air flow or motor RPM. Most variable speed fans move 50% of their rated airflow at approximately 65% of their full speed rpm. The minimum ventilation fans operate at the minimum speed any time the temperature is below the SP. Above the SP, the minimum ventilation fans gradually increase speed as the temperature rises. The number of degrees it takes the fan to reach 100% is called the ***bandwidth*** or ***range***.

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Potential problems

High energy consumption can be associated with improper heater settings. When the building temperature drops to the heater "on" temperature, the heater ignites and provides heat until the controller senses the heater "off" temperature. Because air is a fluid, it takes some time for the heat to circulate throughout the building, especially if heaters are oversized. This causes the temperature to continue to rise even after the heater has shut down. This is why the heater "off" temperature is set 1.5 to 2°F below the SP. When the heater shuts off at a temperature too near the SP, the room temperature may exceed the SP, which will cause the minimum ventilation fans to increase their speed. This effectively means that the heater has used fuel to heat the room and then the fans are exhausting that heated air to cool the room, because the temperature has crossed into the range of cooling temperatures. This can cause a tremendous waste of energy. Figure 2 shows an example of such an occurrence.

The left side of the graph shows the furnace run time when it was set to come on 2°F below SP and turn off at 1°F below. The right side shows the furnace stopped running when the off temperature was changed from 1°F below to 1.5°F below SP. This resulted in a savings of 3.75 gallons of fuel per furnace per day. In this case, a small increase in the temperature difference between the SP and when the heater turns off prevented the cycling and reduced fuel usage significantly.

If the furnace size is relatively large compared to room or facility size, as observed by the furnace not running for long even in extreme cold conditions, the off temperature must be set lower relative to the SP to avoid the problem of exhausting heated air when the room temperature continues to rise as the rapidly heated air disperses throughout the building.

A similar situation can occur if sensors are improperly located. Sensors should be located where they are representative of the mixed air in the building. They should not be impacted by sprinklers, cold air from inlets, or hot air from heaters. Proper controller settings can have a big impact on energy usage. Even a slight change may dramatically improve energy efficiency and yield immediate savings.

No endorsement of products or firms is intended, nor is criticism implied of those not mentioned.

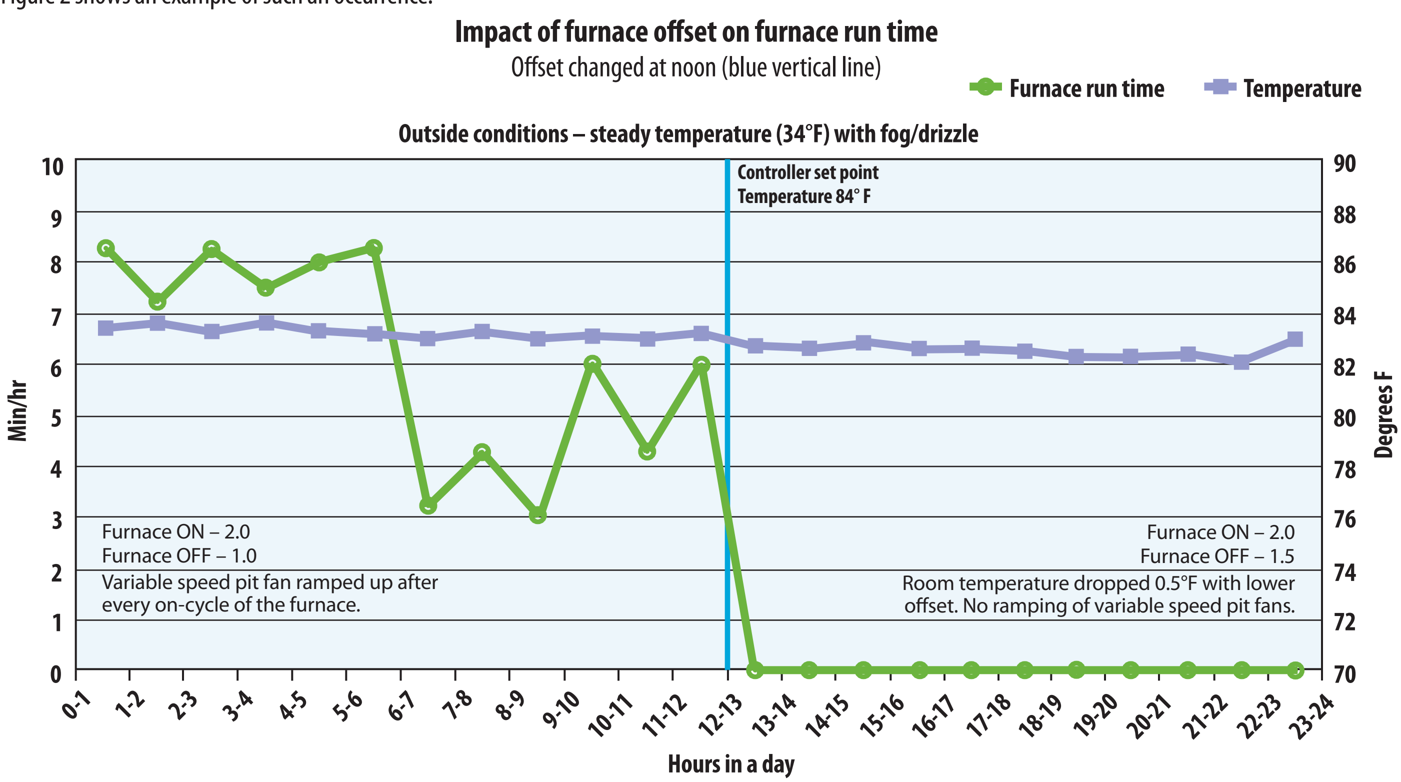

Figure 2. Impact of furnace offset on furnace run time. *Courtesy of Brumm Swine Consultancy.*

Prepared by Jay Harmon, professor, ag and biosystems engineering; Mike Brumm, professor emeritus in animal science at University of Nebraska-Lincoln and Brumm Swine Consultancy; and Dana Petersen, program coordinator, ISU Farm Energy Initiative; Iowa State University Extension and Outreach. Sponsored by the Iowa Energy Center.

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Energy considerations for low-temperature grain drying

Energy efficiency of low-temperature drying

Harvested corn often requires artificial drying to lower moisture content (m.c.) for safe storage into the following spring and summer. Although much artificial drying in Iowa is done with high-temperature LP or natural gas dryers, some corn is dried with natural-air or low-temperature systems.

Low-temperature systems take advantage of the natural drying potential in warm autumn air. Drying in the bin occurs as corn kernels come into moisture equilibrium with outside air blowing past. Air temperature and relative humidity fluctuate in autumn, but corn in Iowa will typically dry to 12 – 13% m.c. if adequate airflow and time are available to remove the moisture (PM 2089Q).

Low-temperature grain drying can be an energy efficient strategy for grain stored in shorter bins (e.g., 18 ft or less of grain depth). Due to airflow requirements, low-temperature drying is not well-suited to larger bin sizes. For example, consider a 40,000 bushel bin. At a diameter of 42 ft, the corn is 36 ft deep. To provide 1 to 1.25 cubic feet per minute (cfm) airflow per bushel (bu) for drying, more than 180 hp of fan capacity would be required to force the air up through 36 ft of grain. Compare this to two 42-ft diameter bins each filled 18 ft deep and requiring 28 hp of fan capacity each (56 hp total), or three 36-ft diameter bins filled 16 feet deep and requiring only 14 hp of fan capacity each (42 hp total). Each system stores 40,000 bu, but as grain depth increases with bin size, increasing horsepower and airflow requirements make low-temperature drying more inefficient and impractical.

If the farm operation can store grain in smaller bins, it can gain energy efficiency by using the drying potential of natural air for low-temperature drying. Assuming on-farm bin storage is already needed and a full perforated drying floor is used, low-temperature drying could be accomplished with a larger fan and additional electricity, without the need for gas, heaters or extra drying equipment. An advantage of low-temperature drying is that corn needs to be moved only once into the bin that will provide drying and storage, so there is no waiting for the dryer to catch up with the harvest rate.

Energy costs vary with cost per electrical kilowatt-hour (kWh) or gallon of LP and also efficiency of the systems, but energy used for low-temperature drying is generally about two-thirds that of conventional high-temperature systems, because much of the drying potential is contained in natural air. LP consumption for high-temperature drying ranges from 0.010 to 0.025 gal per bushel per point (average 0.018 gal) plus 0.01 kWh per bushel per point for fans. Natural air drying uses only electricity for fans ranging from 0.30 to 0.40 kWh per bushel per point (average 0.33 kWh).

Low-temperature or natural-air drying

Low-temperature drying spans weeks of time (sometimes requiring completion in the spring); therefore, management techniques are different from high-temperature systems and should be fully understood before implementation. This energy efficiency fact sheet provides a brief introduction to low-temperature drying.

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PM 2089U May 2012

In low-temperature drying, a layer of corn about 1 – 2 ft deep (the drying zone) dries as the kernels come into equilibrium moisture content with the air blowing past them (Figure 1). The drying zone moves slowly upward through the bin: previously dried corn is below the drying zone and wet corn (yet to be dried) is above it.

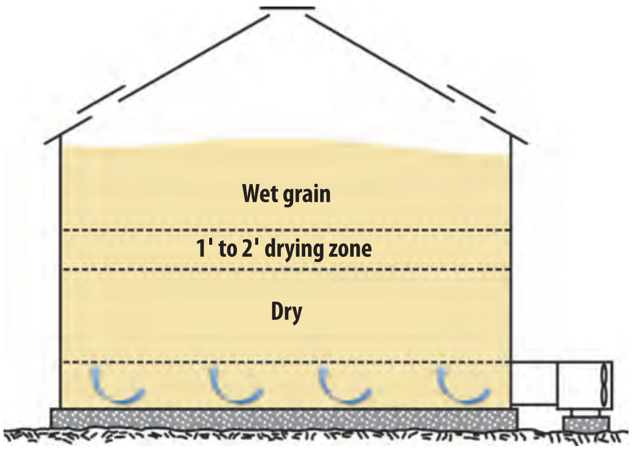

Figure 1. Low-temperature grain drying

Wet grain in the top of the bin is the last to dry and has a limited allowable storage time before it starts to degrade with mold or other biological activity. Adequate airflow is needed to push the drying front to the top of the grain mass and to complete drying before top grain spoils. Slower drying in a cold, wet autumn may delay finishing the top grain drying until spring. A greater risk of spoilage occurs, however, if unseasonably warm air temperatures during the autumn prematurely shorten the allowable storage life of wet corn in the top of the bin. Table 1 shows that greater airflow per bushel allows corn to dry successfully starting at slightly higher m.c., however greater fan horsepower (Table 2) is required to increase airflow through a given mass of grain (more cfm/bu) resulting in lower energy efficiency.

Table 1. Maximum corn moisture content for successful natural-air drying in Iowa

	Corn harvested on or after		
	Sept. 15	Oct. 1	Oct. 15
Airflow, cfm/bu	**Maximum corn moisture content, %**		
1.0	20	20	21
1.25	20	20.5	21.5
1.5	20.5	21	22.5

Table 2. Approximate fan power requirements (hp per 1000 bu) for natural-air drying[a]

Airflow, cfm/bu	Corn depth, ft			
	14	16	18	20
1.0	0.5	0.7	1.0	1.3
1.25	0.9	1.3	1.7	2.2
1.5	1.4	2.0	2.7	3.5

Most importantly, corn harvested above 21% m.c. is typically not suitable for low-temperature drying with commonly used airflow rates and normal Iowa weather. An alternative high-temperature drying strategy is required with wetter corn. Table 1 shows maximum corn m.c. that can be successfully dried in Iowa using natural-air based on drying start date, and airflow rate (cfm/bu.) Note lower allowable starting corn m.c. when grain is harvested earlier in the fall and air temperatures are warmer, which results in more microbiological activity (Table 1). Another strategy for starting harvest with wetter corn is partially filling bins early in the season, which allows greater airflow per bushel. After this corn has dried, the bin can be fully filled later when temperatures are more suitable for full bin airflow rates.

Summary

Low-temperature or natural-air grain drying can be an energy efficient option. Management techniques are different from high-temperature drying and should be fully understood. An alternate plan for high-temperature drying is necessary in years when corn must be harvested above 21% m.c. Successful low-temperature drying requires high fan horsepower for adequate airflow when grain depth is greater than 18 ft, which can limit application of this drying method for farms with large storage bins.

References

[a]Wilcke, W., and R. V. Morey. 2009. *Natural-air corn drying in the upper Midwest.* (WW-6577-GO) University of Minnesota Extension bulletin.

VanFossen, L. 1985. *Low-temperature drying systems in Iowa.* (PM1016) Iowa State University Extension bulletin.

Prepared by Shawn Shouse, extension ag engineer; Mark Hanna, extension ag engineer; and Dana Petersen, program coordinator, ISU Farm Energy Initiative; Iowa State University Extension and Outreach. Sponsored by the Iowa Energy Center.

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Conserving energy by using localized heating in swine housing

Providing a thermally comfortable environment for pigs while conserving energy can be a complex problem. For instance, farrowing rooms have animals with very different thermal needs in close proximity. Newborn pigs are most comfortable at a temperature of 86-95°F, however sows would experience significant heat stress at that temperature and prefer temperatures closer to 60-70°F.

To address this, a microclimate is created for the piglets using some type of radiant heater, either an electric heat lamp or a propane brooder, or floor heating, such as an electric heat mat. The heater creates a warm surface so that the piglets can remain in a room with a cool air temperature, best suited for the sow, but still feel comfortable. Piglets can then freely choose the environment that is most suitable for them by either staying close to the heat source or moving away from it.

Heat mats

One common tool to provide a microclimate is a heat mat. Mats have electrical resistance coils which create a warm and comfortable surface for piglets. Mats are generally provided in the creep area of the farrowing crate with one double-mat being used for two adjacent crates. Mats generally have lower wattage (60 –100 W per crate) than heat lamps, and are potentially more energy efficient.

Figure 1 shows thermographs (surface temperature distribution) for three different mats. The top mat illustrates red and yellow "hot spots" from the heating elements. These hot spots will drive the piglets off the mat, thus greatly reducing the effectiveness of the heat source. The green areas of the middle mat are also excessively hot, but the bottom mat is more evenly heated and therefore better suited to accommodate an entire litter of pigs.

Heat mats can be controlled much like heat lamps, with reduced heat output as pigs grow larger and their thermal needs decrease. With an increased litter size, a larger mat size of 1 x 5 ft (vs. 1 x 4 ft) per crate should be considered to ensure adequate heated space for the litter before 3-5 days of age.

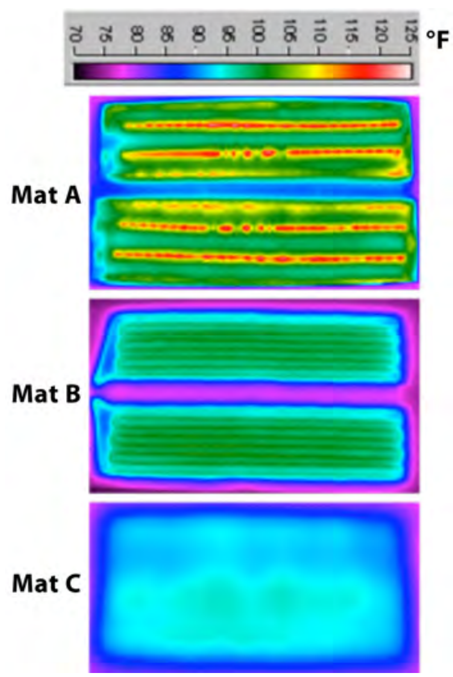

Figure 1. Thermograph photos of three different heat mats.

Heat lamps

Heat lamps are often used to provide a microclimate for piglets in farrowing barns. A study at Iowa State University comparing 175 W and 250 W heat lamps found that the smaller wattage lamps saved approximately 360 kWh per crate ($36 at $0.10/ kWh) in one year. The study also found that pigs gain weight slightly faster with the smaller lamp, had 45% lower lamp breakage rate and there was a 19% lower mortality rate as compared to the 250 W lamps.

Management of the environment below the lamp is important to piglet comfort. Floor temperature below the lamp should be 95-100°F for newborn pigs . If the area beneath the lamp is too hot, piglets will move away from it. Because piglets would then spend more time in close proximity to the sow, they tend to be injured or laid on more frequently. This reinforces why proper lamp adjustment is important.

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Piglets need less localized supplemental heat and their temperature preference decreases as they grow. Another ISU study examined constant 175 W lamps versus variable output lamps. When less heat is needed, reducing lamp output saves energy and still provides the proper environment. In the research trial, 175 W lamps were operated by reducing lamp output approximately 2% per day . This reduced electrical power use by 20% compared to constant output lamps. These energy savings cannot be achieved by simply using a rheostat. Rheostats "chop" the output voltage and give off the unused power as heat, but the input voltage or power remains the same. Instead, a controller such as a triac or a device which varies the electrical frequency is required.

The fine-tuning of the lamp output can be accomplished by observing the piglets. The figure below shows how the seven-day-old piglets on the left seem too warm directly under the 250 W lamp and congregate to the sides while the pigs on the right appear comfortable under the 175 W lamp. Observing pig behavior is the best way to evaluate proper settings.

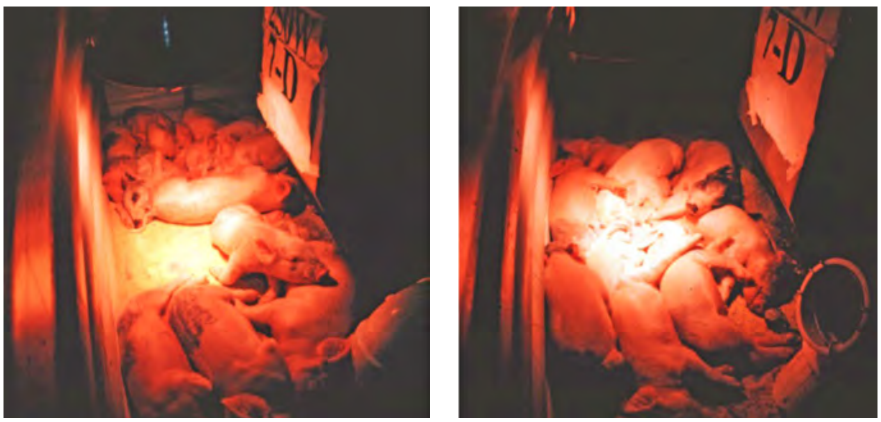

Figure 2. Posture of seven-day-old piglets underneath two different wattage lamps, 250 W on left and 175 W on right.

Propane gas brooders

Propane gas brooders are also an option in farrowing houses. Most often found in wean-to-finish buildings, they save energy by keeping the room temperature low, normally in the 70 to 75°F range, while still providing a warmer microclimate to piglets. These brooders work by using propane to create a hot surface which radiates heat to pigs much like heat lamps do. Most of these systems have control valves which allow the output to be adjusted by changing the line pressure.

Excessive energy use with gas brooders can be caused by its size and ventilation settings. When sizing brooders, keep in mind that they are rated by the maximum output in BTU/hr. Oversized brooders may operate at a very low level which may not be as efficient as at high level of operation. The lowest level may also not be as low as needed. When adjusting ventilation settings, the objective of using brooders is to keep the room temperature lower to save energy. However, if the room temperature rises due to pig activity or weather conditions, the ventilation rate may increase to maintain a cooler temperature, thereby causing the brooders to operate longer. One way to avoid this is to program the ventilation rate to increase at a temperature which is higher than the setpoint, but set the space heaters in the room to start at a temperature just below the desired room temperature.

For instance, if the target temperature for young pigs is 86°F, then with brooders the desired room temperature is 72°F. If the controller setpoint was programmed to be 72°F, then ventilation will increase above 72°F. Increasing ventilation to maintain 72°F when we actually desire a temperature of 86° for the pigs is not prudent. A better approach would be to make the setpoint for increasing ventilation rate to be 86°F, but have the room space heater come on at 71°F and off at 72°F. The room temperature may rise above 72°F, perhaps creeping up to 76° or even 80°F at times, but the changes will be gradual and will conserve energy while still providing a good environment for the pigs.

SPECIAL NOTE:

Propane brooders require regular cleaning of filters to provide efficient operation. Clogged filters will cause the production of carbon monoxide.

Summary

There are benefits to proper usage of heat mats, heat lamps, and gas brooders for efficient production as well as for energy efficiency. Small adjustments and management decisions have an impact on both of these. Before purchasing heat lamps, heat mats or variable output controllers, check with your electrical provider for rebate opportunities.

Prepared by Jay Harmon, professor, ag and biosystems engineering; Hongwei Xin, professor, ag and biosystems engineering; and Dana Petersen, program coordinator, ISU Farm Energy Initiative; Iowa State University Extension and Outreach. Sponsored by the Iowa Energy Center.

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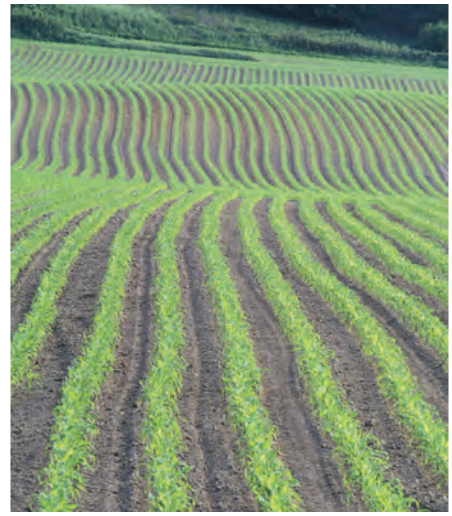
Energy consumption for row crop production



Each year, Iowa farmers plant approximately 24 million of Iowa's 31 million acres of farmland to corn and soybeans. Energy prices vary over time, but Iowa agriculture spends nearly one billion dollars annually on direct energy purchases. Due to the fact that so many Iowa farmers raise corn and soybeans, a basic understanding of energy used in row-crop corn and soybean production is helpful for managing farm energy expenses.

Annual energy consumption for corn and soybean production is in three major areas: field operations, artificial drying (typically corn only), and fertilizer/pesticides (agricultural chemicals). Agricultural chemicals are not a direct energy purchase by farmers. However, the thermal and chemical processes used in their manufacture can be significant and are often considered in farm energy budgets.

Energy is also used in other production steps which are less significant to farm budgets. Some vary with location, for example:

- Energy used for transportation from the farm to the final destination can be significant depending upon shipping distances. However, much of this energy cost is borne by off-farm grain marketers.
- Transportation energy costs for hauling from the field to farmstead bin or to the local market vary with distance.

Additionally, energy required to manufacture machinery and other larger capital equipment such as grain bins can be significant at the time, but can be paid off over several years. Solar photosynthetic (renewable) energy required to grow and dry crop, also significant, is not considered a direct cost to the farmer.

Field operations

Diesel fuel used for field operations varies with management practices. A range of 4 to 6 gallons per acre is common, particularly if one primary and one or more secondary tillage operations are used (Figure 1). Seeds must be planted, grain harvested, and weeds controlled (typically with spraying). Fuel used for these operations is typically 2 to 2.5 gallons per acre, which represents fuel consumption for a no-till system. The energy required for tilling soil can be an additional 2 gallons of fuel per acre or more.

The amount of fuel required for tillage depends on both the type and number of tillage operations (PM 709 *Fuel Required for Field Operations*). Primary tillage refers to initial tillage on untilled soil. One single primary tillage operation that covers the entire soil surface, such as chisel plowing, usually requires at least one gallon of fuel per acre when tilling at a depth of 6 to 8 inches. Fuel consumption may be two gallons per acre or more depending on tillage depth and/or the number of different soil manipulations that occur (e.g., subsoiling and disking with a combination disk-ripper). Individual secondary tillage operations often require 0.6 to 0.7 gallons of fuel per acre. However, fuel consumption may be greater for large 'combination' implements with several operations (e.g. discs, sweeps, harrow, etc.).

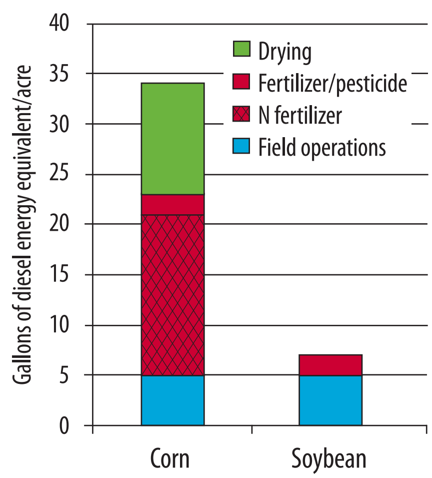


Figure 1. Relative energy requirements (gallons of equivalent diesel fuel energy) per acre for corn and soybean production. (Assumptions: 125 lb of commercial N fertilizer applied per acre on corn; 5 percentage points of moisture removed from 175 bu corn; full-width tillage operations for both crops).

Drying

Soybeans typically dry to a moisture content of about 12% in the field prior to harvest and don't usually need to be dried. Corn, on the other hand, may need to be dried if it does not dry adequately in the field. The need for drying depends on the planting date, the weather during the growing season and harvest, and the adapted maturity level for the growing location.

If corn needs to be dried in the fall, the amount of moisture to be removed can vary widely, sometimes by as much as 10 percentage points or more. To remove 5 percentage points of moisture content from an acre of corn yielding 175 bu, a conventional high-temperature dryer uses about 16 gal of LP and 18 kWh of electricity. Fan use for electricity in a natural-air dryer used to remove the same amount of moisture would require about 280 kWh of electricity (about ⅔ of the energy used by the high- temperature dryer). Actual energy consumed by a grain dryer to remove a specific amount of moisture depends on several factors including grain depth, drying times, and heat recovery.

Fertilizers and pesticides

Even though they are not considered a 'direct' energy purchase for the farm, fossil fuels are used in the manufacture and transportation of fertilizers and pesticides. The cost of the energy to produce these inputs is incorporated into their purchase price each year. When considering the three primary fertilizer inputs—nitrogen, phosphorous, and potassium—the energy needed to create nitrogen fertilizer is by far the greatest.

Energy required to manufacture nitrogen (N) fertilizer is approximately 13 – 18 times greater[1] than phosphate or potassium on a pound-for-pound basis. When anhydrous ammonia, a more energy efficient nitrogen source, is applied to soil, it is equivalent to 15 gallons of diesel per acre at an application rate of 125 lb/N acre. This application rate is typically used in a corn-after-soybean rotation. Similarly, an anhydrous ammonia application rate of 175 lb N/acre is equivalent to 21 gallons of diesel per acre. This application rate is typically used for corn-after-corn.

The energy used to manufacture pesticides varies depending on the product. In general, an equivalent of one gallon of diesel energy is used to produce approximately one pound of active ingredient. Using this value, two pints of glyphosate with one pound of active ingredient applied per acre would be equivalent to approximately one gallon of diesel fuel energy per acre.

Due to the fact that adjusting the nitrogen application rate by ten pounds per acre equates to more energy consumption than the amount commonly used for phosphorous, potassium or pesticide, most fertilizer and pesticide energy consumption is attributed to nitrogen fertilization for corn. Nitrogen is not usually applied for soybean production, and only about one to two gallons per acre (diesel fuel equivalent energy) would be used for phosphorous, potassium and pesticides combined.

Summary

Diesel fuel required for field operations is a consistent energy input for both corn and soybeans. Fuel consumption can be reduced by minimizing the number and aggressiveness of tillage operations[2] along with consistent tractor maintenance and operation. For corn production, energy required for commercial nitrogen fertilizer is greater than field operations. Much of this energy is consumed as natural gas during the manufacturing of fertilizer. If corn needs to be dried significantly in the fall, the amount of energy consumed by drying can be greater than that used in field operations. However, this energy is consumed as electricity and liquid propane (LP) or natural gas.

References

[1]Sawyer, John E., and M. Hanna. 2010. *Energy conservation in corn nitrogen fertilization.* (PM 2089i). Iowa State University Extension publication.

[2]Hanna, M. and J. Harmon. 2010. *Limiting field operations.* (PM 2089d). Iowa State University Extension publication.

Prepared by Mark Hanna, extension ag engineer; John E. Sawyer, extension soil fertility specialist and professor of agronomy; and Dana Petersen, program coordinator, ISU Farm Energy Initiative; Iowa State University Extension and Outreach. Sponsored by the Iowa Energy Center.

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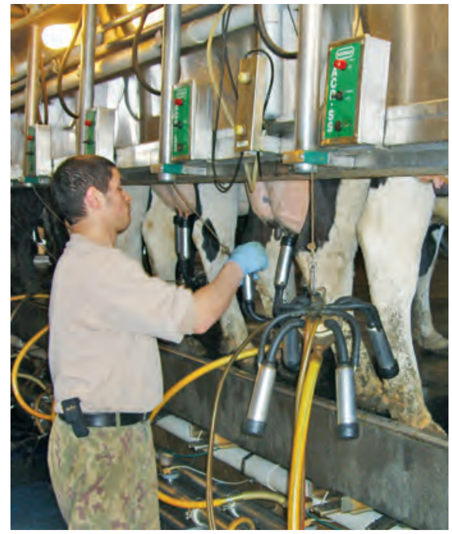
Energy efficiency for dairy milking equipment



Dairy farms typically require more energy for day-to-day operations than other farmsteads, especially daily kWh of electricity for milking the herd and for cooling and storing the milk. Scroll compressors, milk precoolers, and variable frequency drives can improve energy efficiency during the daily milking routine.

Equipment maintenance and planning

Milk prices have been especially volatile during the past decade. Maintaining existing milking equipment to operate at peak performance is an effective way to conserve energy on the dairy farm. If equipment is worn due to poor maintenance or age, this often leads to air leaks and inadequate sanitation, and excessive energy use may occur.

Before critical parts of the milking system reach the end of their useful life, take time to review energy efficient replacements. Consider new technologies that not only meet the needs of your dairy operation but also improve its energy efficiency.

Producers are encouraged to work closely with equipment suppliers and local utility service providers to evaluate their specific needs. This may include a site assessment or an energy audit when possible to determine eligibility for energy rebate programs. Some equipment upgrades will quickly pay back the initial cost by reducing energy consumption. Carefully consider the most energy efficient equipment to meet existing—and future—needs of the farm.

Energy needs for the milking routine

In general, the results of dairy farm energy assessments show that operations with large herd sizes typically have greater energy needs and greater energy savings potential than smaller dairies. However, like all farms, the specific energy demands of each dairy are unique. In particular, the configuration of the milking system impacts energy consumption: how many milking units are in the parlor and the level of vacuum needed to operate and clean them.

Three key areas for improving energy efficiency during the daily milking routine are milk cooling, water heating, and vacuum pumps. When combined, these three factors account for approximately half of the energy consumption on Midwestern dairy farms.

Compressors

Scroll compressors can provide energy savings for dairies of all sizes. Compared to conventional reciprocating compressors, scroll compressors typically use 15-20 percent less energy. Their design compresses refrigerant using two intermeshing scrolls. One scroll is fixed while the second oscillates around the first, providing continuous compression without the need for mechanical valves. This action is similar to rolling up a tube of toothpaste. If an existing compressor fails or needs to be replaced, consider installing a scroll compressor.

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Refrigeration and heat exchange

Milk refrigeration consumes a lot of energy. Milk precooling and refrigeration heat recovery (RHR) are proven to reduce energy and have been gaining popularity among dairy producers for decades. However, one may suit your needs more than the other.

A refrigeration heat recovery (RHR) unit can recover 20-60 percent of the energy that is removed from the milk as heat during the cooling process. However, RHR units and milk precoolers may interact and compete with one another, so an energy assessment should be done to determine if one or both units would be optimal for your dairy facilities.

The most common style of heat exchanger is the plate heat exchanger, also called a plate cooler or milk plate precooler. Plate heat exchangers contain a series of ribbed plates placed side by side. Two separate circuits are created between the plates using rubber gaskets. Milk flows along its designated circuit in direct contact with every other plate. At the same time, cold well water absorbs heat from the milk as it flows through the other circuit on the opposite side of the plate.

Older facilities may have "shell and tube" heat exchangers, sometimes called concentric tube heat exchangers. Compared to plate heat exchangers, which can be expanded or customized with additional plates, this older style is typically difficult to modify as the dairy grows.

Warm water from the heat exchanger can be used for washing or to supply drinking water for the dairy herd. For more details, see "Energy Conservation on the Farm: Well Water Precoolers" (A3784-3) by Scott Sanford.

Variable frequency drive

The motors on milking vacuum pumps are sized for wash cycles that require high vacuum capacity. However, less vacuum—and lower horsepower—is needed for milking versus washing. A variable frequency drive (VFD) can significantly reduce energy use without compromising the vacuum system.

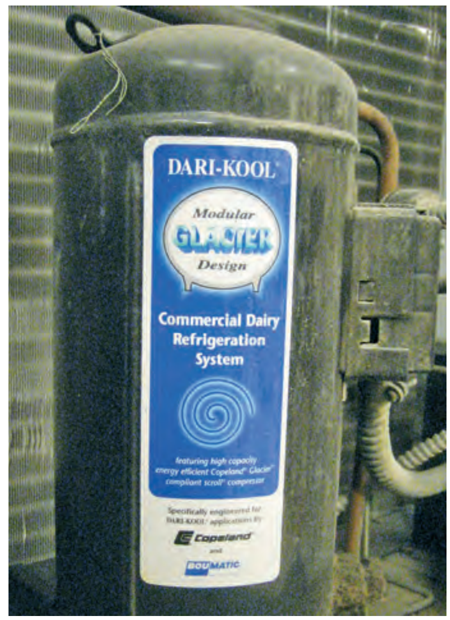
The VFD regulates the speed of the vacuum pump motor to match its load requirement at any given time. It measures changes in pressure with a sensor in the vacuum line and adjusts the speed of the pump motor to maintain vacuum pressure. With the VFD, the vacuum pump motor requires less horsepower and less energy during each milking.

Without a VFD, a conventional vacuum system runs the pump at a high speed for the entire milking. Air is bled into the system through a regulator to maintain vacuum pressure. Depending on the specifications of the milking system, installing a VFD can reduce vacuum pump energy consumption by 30-80 percent with typical savings of 50-65 percent.

Rotary lobe (blower) vacuum pumps are best paired with a VFD, but the technology can also be installed with a rotary vane pump. Carefully review the requirements of your equipment to ensure proper sizing. If the speed of the vacuum pump motor drops below its minimum recommended speed, the VFD may reduce the useful life of the vacuum pump.


Summary

A dairy can manage its energy costs by maintaining existing milking and cooling equipment for optimal performance. When expanding facilities or replacing equipment, review options such as scroll compressors, refrigeration heat recovery, precoolers, and variable frequency drives with your equipment supplier or utility provider. Also consider an on-farm energy assessment to gather specific information about the energy needs of your operation.



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