ENERGY EFFICIENCY BEST PRACTICES GUIDE:

AGRICULTURE

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Agriculture Energy Efficiency Best Practices Guide

Brought to you by:

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Funding for this guidebook was provided by Focus on Energy. The goals of this program are to encourage energy efficiency, use of renewable energy, enhance the environment and ensure the future supply of energy for Wisconsin.

We wish to give a special thanks to Dewitz Photography for providing the majority of photos used throughout this guide.

Focus on Energy, Wisconsin utilities' statewide program for energy efficiency and renewable energy, helps eligible residents and businesses save energy and money while protecting the environment. Focus on Energy information, resources and financial incentives help to implement energy efficiency and renewable energy projects that otherwise would not be completed.

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WHAT'S INSIDE

Agriculture energy expenditures in Wisconsin amount to roughly $681.4 million each year. Farmers are constantly striving to eliminate unnecessary energy expenses, while still maintaining a safe and productive business. The purpose of the **Agricultural Energy Efficiency Best Practices Guide** is to provide Wisconsin's agriculture community with methods and tools to help reduce their energy use. The recommendations outlined in this guide are meant to aid in conservation efforts by encouraging the use of energy-saving farm equipment.

The goal of this document is to be a resource for farmers and service providers. It is organized to help readers understand farm energy use, evaluate potential equipment upgrades, and prioritize energy efficiency.

This guide focuses on cost-effective, energy efficient best practices that offer significant environmental and economic benefits. The three primary sectors represented in this guide are:

DAIRY AND LIVESTOCK

GREENHOUSES

CROP FARMS

The information in this guide is based on industry-specific research and Focus on Energy Program data.

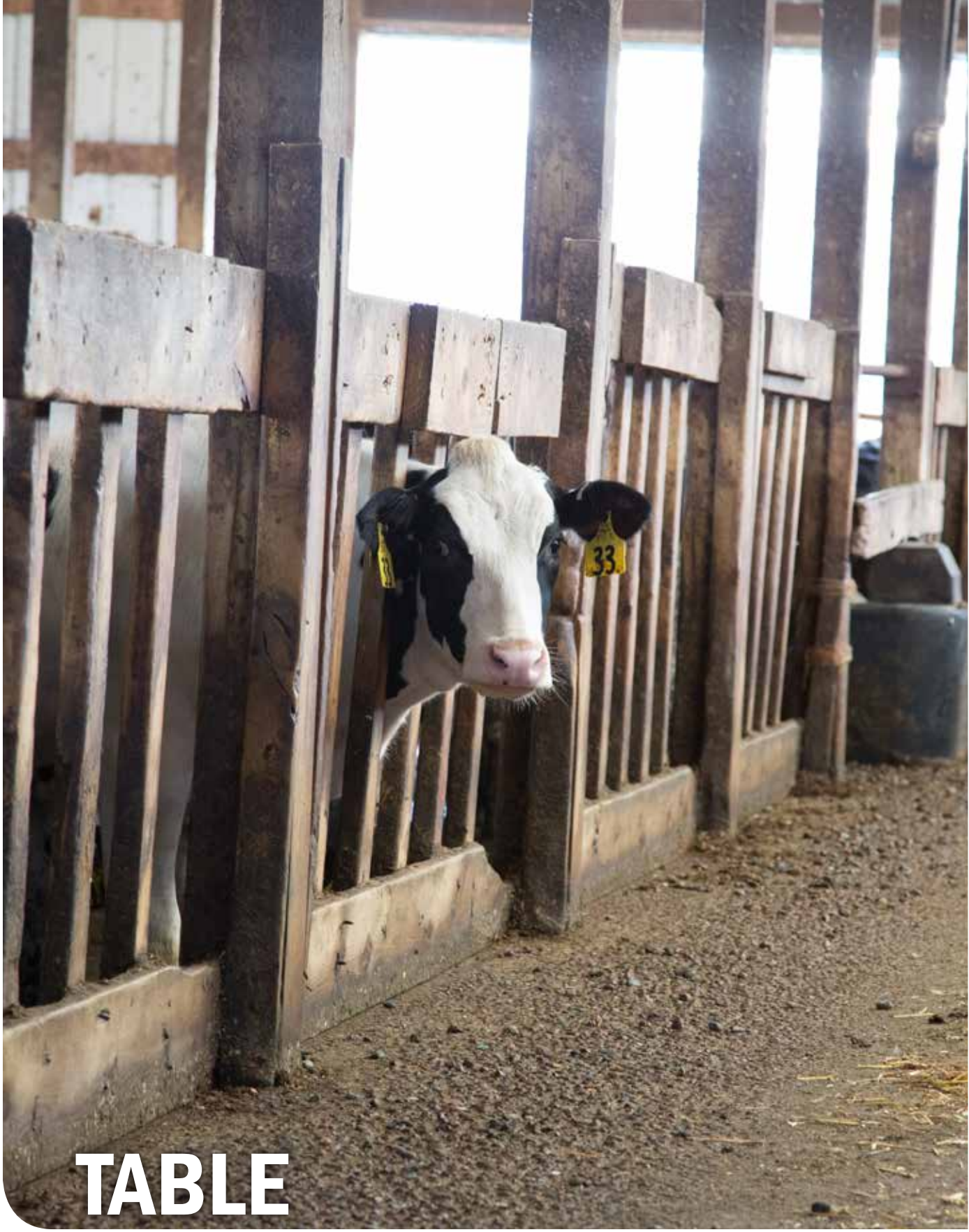


TABLE OF CONTENTS

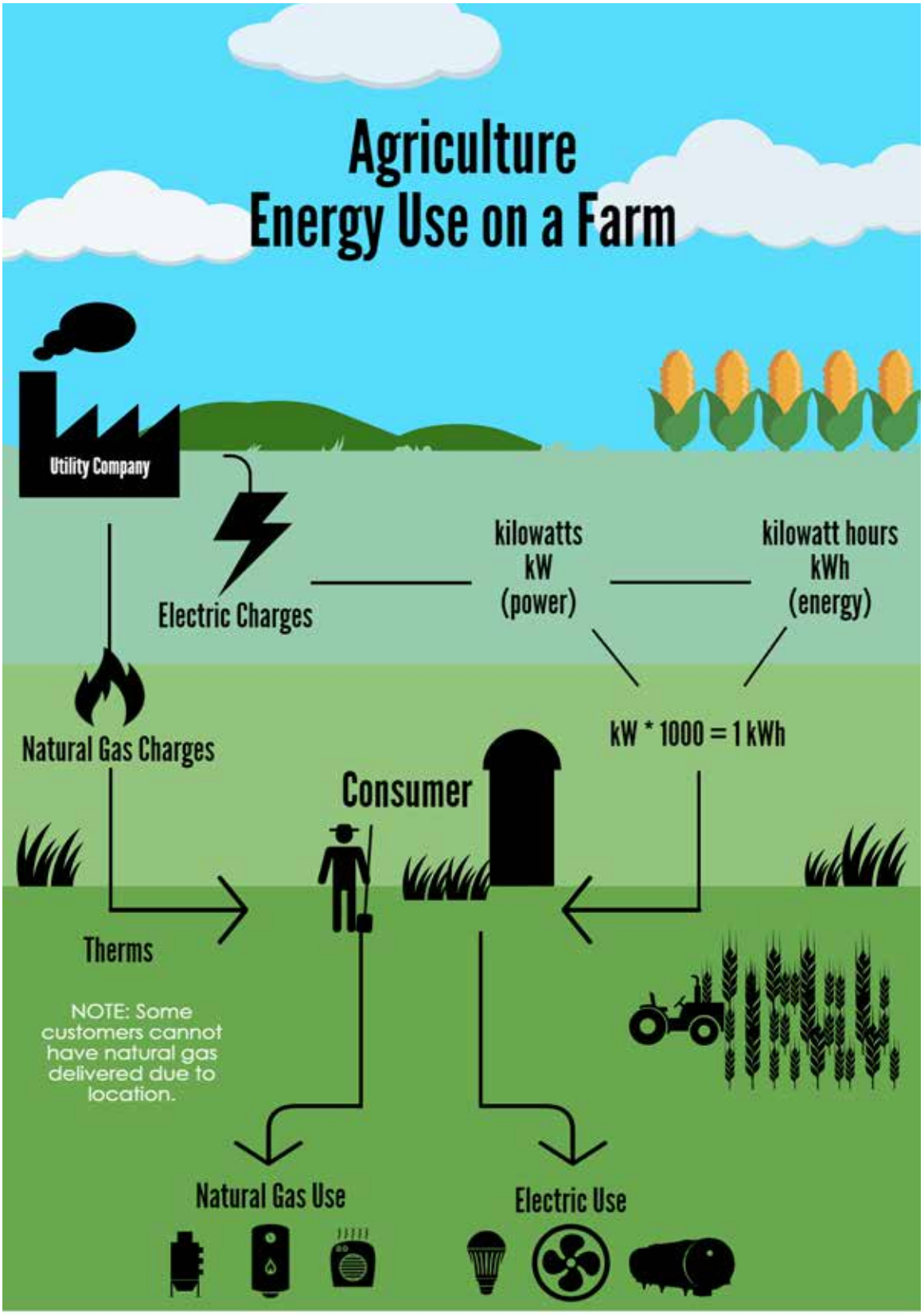
AGRICULTURE ENERGY EFFICIENCY BEST PRACTICES

INTRODUCTION

Wisconsin is nicknamed America's Dairyland for the large amounts of milk and cheese produced each year. Wisconsin also prides itself on high production yields of snap beans, cranberries, ginseng, mink pelts, whey, milking goats, corn for silage, and many other products. The production process for each of these agricultural entities, among many others, would not be possible without the use of energy.

Energy use in this industry is constantly affected by automation of machinery and advances in technology. In 2012, due to increases in demand, agricultural energy consumption increased by 7.8 percent, which was more than any other economic sector in Wisconsin. (Wisconsin Office of Energy Independence, 2013)

It's because of increases like these that farmers are striving to eliminate unnecessary costs wherever possible. Even though it's not feasible to completely eliminate energy expenses while keeping a modern, safe operation, there are many ways to decrease energy use. This can include anything from basic behavioral adjustments to new construction or major equipment upgrades. In the end, it's up to you to decide which modifications and improvements are best suited for your operation. This guidebook details energy efficiency best practices for agriculture producers and describes different ways to decrease energy expenses so you can make an independent, informed decision.



Please Note: Although there are many sources of power available to farms, this guidebook will focus solely on natural gas and electric use.

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BEST PRACTICES FOR DAIRY AND LIVESTOCK

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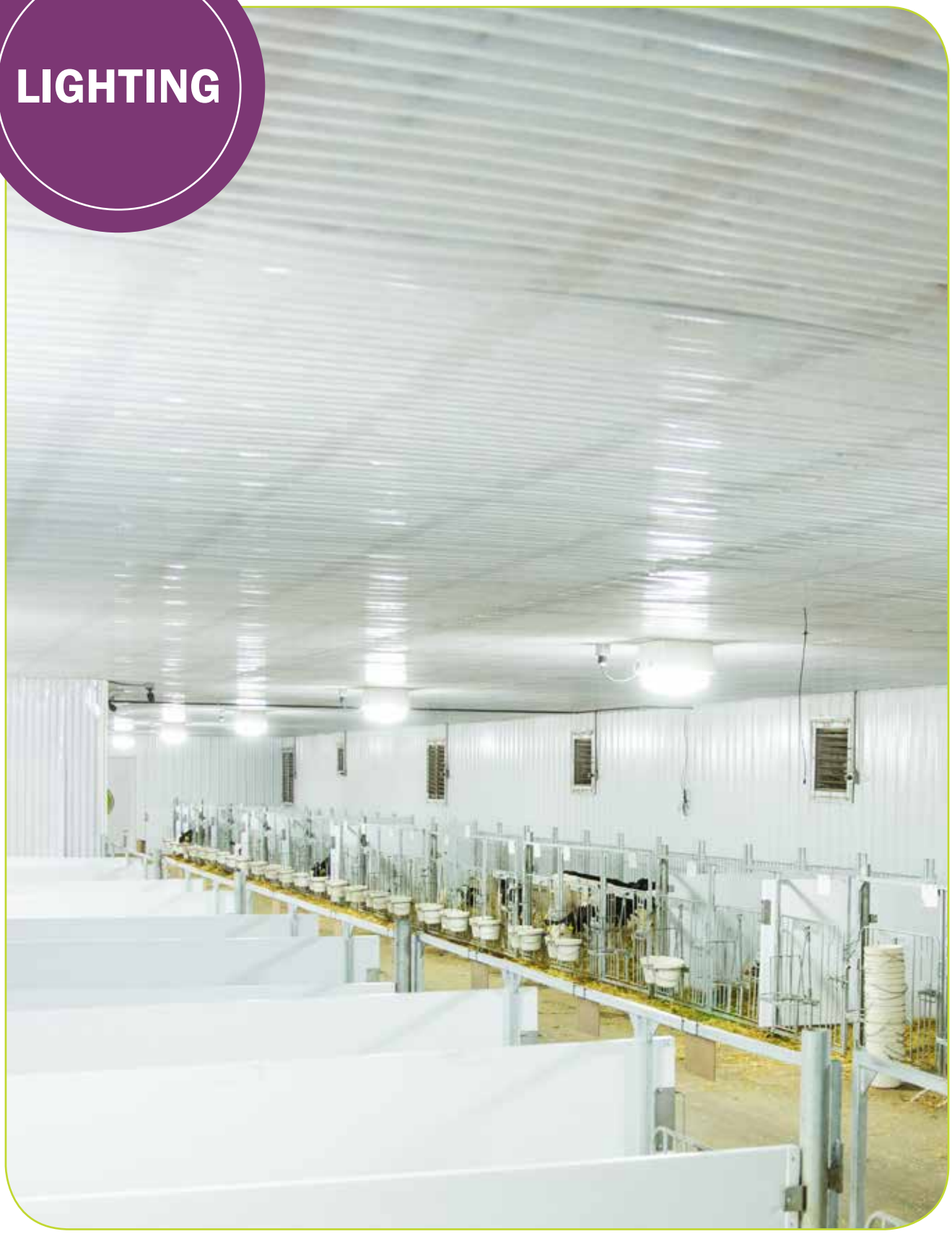
LIGHTING



Lighting upgrades provide one of the quickest, most cost-effective energy improvements on a farm. Rapid changes in lighting technology mean new products that provide brighter, longer-lasting light are becoming more affordable and available for a variety of applications. Upgrading to a well-designed lighting system can mean higher lighting levels while lowering energy costs.

BEST PRACTICES

TURN OFF LIGHTS WHEN NOT IN USE

This is the fastest and easiest way to decrease energy costs. If a light doesn't need to be turned on, turn it off. It costs nothing to modify behavior so this should always be the first step to energy efficiency.

PERFORM ROUTINE MAINTENANCE

A simple step to decrease energy costs is to perform the required maintenance on bulbs and fixtures. This will help extend the usable life and reduce the need to replace bulbs as frequently. Poorly maintained lighting systems cost far more in lost productivity than in the energy wasted. Basic maintenance steps include:

- Clean fixtures, bulbs and lenses by wiping off the dirt with a moist cloth. Repeat every six months to two years, depending on how much dust and debris is in the surrounding environment. Note: Never clean an incandescent bulb while it is turned on – the water's cooling effect will cause the bulb to shatter.
- Replace lenses if they appear yellow.
- Clean or repaint small rooms every year and large rooms every two to three years. Dirt that collects on these surfaces reduces the amount of light reflected.
- Lighting experts recommend replacing all bulbs in a lighting system at one time to save labor and avoid stressing any ballasts with dying bulbs. (Farrell, 2012)

ADJUST THE NUMBER OF LAMPS AND/OR FIXTURES

If a facility has more lamps and fixtures than necessary, de-lamp or completely remove excess lamps and fixtures when it is safe to do so. It is highly recommended to work with a lighting professional who has experience designing lighting systems for agriculture facilities. The lighting professional will take light level measurements at various locations throughout the facility and explore the most appropriate layouts to reach maximum energy efficiency.

Footcandles measure the light levels at the surface area where light is needed. This chart lists the recommended light levels for different areas found in livestock facilities.

Lighting Recommendations for Various Farm Areas

TASK	INTENSITY *(foot-candles)*
Free Stall	15-20
Tie Stall Barns	
Feed Alley	15-20
Center Alley	20-50
General Livestock Housing	10
Holding Area	10-20
Milking Parlor	20
Operator's Pit (at udder)	50
Milk Room	20
Manual Wash Sink	100
General Animal Care Area	20
Treatment or Surgery Area	100
Utility Room	20
Office Area at Desk Top	50
Machine Storage	10
Farm Shop/Repair Area	50
Exterior Security	.5-1
Exterior Active Areas	3-5
Poultry Barns	20
Egg Packing and Inspection	100
Inside Incubators	50
Loading and Storage Areas	20
Restroom	20

(Source: ASAE, 1993; NFEC, 1993; MWPS, 1992; Leech and Person, 1993)

UPGRADE TO ENERGY EFFICIENT FIXTURES

Lights that operate the most hours use the most electricity so upgrading those fixtures first will save the most money. There are many different lighting technologies available, such as CFLs and LEDs, and each has a direct impact on energy savings. Certain types of fixtures offer increased light output but have a short lifespan, whereas others have a lesser light output with a much longer lifespan. New lighting technologies are aiming to increase the lamp lifespan while maintaining the appropriate light output. Numbers to look for when selecting lights are the **lumen maintenance factor** and the number of **lumens per watt** (**LPW**). Lumen maintenance describes how much light is lost over the lifespan of a lamp. The less light output lost, the higher the lumen maintenance factor will be. Lumens per watt is the amount of light produced for each watt of electricity consumed.

General Rule of Thumb: The more lumens per watt, the more bang for your buck.

The table on the next page lists types of lights, their most common applications, and certain technical specifications.

HIGH EFFICIENCY LIGHTING OPTIONS			
	LINEAR FLUORESCENTS	**COMPACT FLUORESCENTS (CFLs)**	**LIGHT EMITTING DIODES (LEDS)**
AVAILABLE WATTAGES	32-54	5-57	1.2-200
PRICE PER BULB	$5-$50	$2-$20	$5-$500
AVERAGE LAMP LIFE (HOURS)	20,000-36,000	10,000	60,000-100,000
LUMENS PER WATT	60-110	50-80	80-110
APPLICATIONS	Low bay and high bay uses T5 and T8 most common Clean, protected environment	Over doorways Storage Rooms Personnel Areas	Interior and exterior lighting High bay uses Vapor-tight fixtures available
BENEFITS	Short payback Wide variety of applications Many options and lengths	Cost-effective Easy installation Easy maintenance	Low maintenance Solid-state devices (durable) Immediate response No mercury
DRAWBACKS	Contain mercury* Regular maintenance T12 is not an efficient size	Contain mercury* Not ideal for barn interior Some CFLs sensistive to cold temperatures	High initial investment New options becoming more widely available

**Always properly dispose of lighting materials. Certain lighting materials contain mercury and/or other harmful products that need to be recycled or disposed as hazardous waste in accordance with U.S. laws. Most major retailers offer free disposal services for these lighting products.*

UTILIZE TIMERS AND MOTION SENSORS

Timers and motion sensors are both great tools to use when manually turning lights on and off isn't feasible. Some options to consider for energy efficient lighting systems include:

- Controls that gradually turn light intensity up and down to simulate the sun.
- Daylight sensing controls that use a photocell to change the light intensity based on the natural light available.
- Motion-sensing controls that turn lights on to ensure personnel safety and turn off when the space is unoccupied. Consider these over entrances, in hallways and in storage areas.

IMPLEMENT HIGH EFFICIENCY LONG-DAY LIGHTING

Long-day lighting provides supplemental light by extending the short fall and winter days (September through April) to 16 to 18 hours of light in order to increase milk and livestock output. In poultry, manipulating the number of lighting hours per day can facilitate year-round egg production. In dairy cows, increasing light exposure through long-day lighting improves heifer growth and increases milk production. The idea of manipulating lighting times to increase production has been around since the 1970's and research has consistently revealed favorable results. In regards to dairy cows, studies show that supplementing lactating cows with 16 to 18 hours of continuous light can increase milk production 5 to 16 percent more than cows exposed to 13.5 hours or less of continuous light. (Shelford & Wright, 2013) In order for this technique to be effective, the light needs to remain sufficiently intense over the course of the photoperiod, then dark for 6-8 hours.

The average light intensity in a barn needs to be at least 15 foot-candles at the cows' eye level to simulate daylight. This can be achieved by installing sealed fluorescent or LED light fixtures over the manger. In most stall barns natural daylight is insufficient, therefore the manger lights also need to be on during the day. Timers and photo sensors should be installed to ensure consistent light and dark periods throughout the day.

High efficiency long-day lighting can be profitable and feasible for stall barns and freestall barns of all sizes. If farmers are able to take advantage of this lighting technique, it is a great opportunity to increase animal and milk production.

IMPLEMENT OTHER LIGHTING STRATEGIES

There are many other control strategies to consider when looking to decrease energy consumption. Work with a lighting professional to determine the best strategy for your facility. Some options for alternative lighting control strategies include:

- **Scheduling**: The use of operating schedules and time controls to turn lights on when needed and off when not needed.
- **Tuning**: Adjusting lighting levels appropriate to the existing occupancy, tasks, or conditions.
- **Lumen Maintenance**: Dimming the lights initially and then gradually increasing power to the lamps over time to compensate for the over-design of new lighting systems.
- **Demand Limiting**: Reducing electrical systems use during peak demand times in order to reduce demand charges.
- **Demand Response**: Reducing electrical use in response to a signal from the electric utility company when a building's peak demand draw gets too high.

(Council, 2009)

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MILK REFRIGERATION EQUIPMENT

MILK REFRIGERATION EQUIPMENT

Milk cooling accounts for the largest energy expenditure of a dairy farm. There is significant opportunity to decrease these energy costs by upgrading existing equipment and installing new, more efficient equipment. Two pieces of equipment in the milk cooling process that have a big impact on energy use are the milk pre-cooler and the refrigeration compressor.

The purpose of a milk pre-cooler on a dairy farm is to help cool milk faster and more efficiently in an effort to increase milk quality and decrease cooling costs. A pre-cooler extracts heat from warm milk by running the milk against cold well water to quickly lower the milk temperature to within a few degrees of the well water temperature. This section will focus specifically on plate coolers which are a type of pre-cooler. There are other variations of pre-coolers available for milk cooling, such as a shell and tube heat exchanger, however other styles of pre-coolers are much less common and are less efficient in terms of heat transfer..

Dairy farms use refrigeration compressors to cool milk that is being stored in the bulk tank or being loaded into a milk tanker. For a long time, reciprocating compressors were used to cool milk to a desired temperature of approximately 38 degrees. However, over the past several years it has been recommended to install a scroll compressor. The scroll compressor has been found to be about 15 to 20 percent more efficient than a similar sized reciprocating compressor, and since milk cooling has the largest energy draw on a dairy farm, it pays to invest in efficient technology.

Consider investing in new milk refrigeration equipment when...

- Your refrigeration compressor runs excessively, or over an hour after a milking session is complete.
- Milk production is increasing and the current compressor is already operating at or near maximum cooling capacity.
- Your farm has increasing costs for milk cooling and water heating.
- Concerns of final milk quality arise due to the length of the cooling process.
- You want to take advantage of free cooling from groundwater.

(Massachusetts Farm Energy Program, 2012)

BEST PRACTICES

1 INVEST IN THE CORRECT SIZE PLATE COOLER

Since most dairy operations don't have time to allow the maximum amount of cooling to occur, using a plate cooler that is properly sized to the farm's milk output makes it possible to get milk cooled to within five degrees of the ground water temperature. Also, since milk is slightly acidic, it's best to invest in a stainless steel plate cooler to avoid rust and bacteria build up.

Another option to consider is the number of plates in a plate cooler. More plates in a plate cooler means more surface area available for heat transfer to take place. This helps to increase milk cooling potential, bringing it closer to the temperature of the incoming ground water.

2 IDENTIFY THE PLATE COOLER WATER TO MILK FLOW RATIO

The water to milk flow ratio directly impacts the amount of heat transferred out of the milk. Typically a 1:1 ratio is recommended. However, by increasing the water flow, heat transfer can be increased in order to gain additional degrees of milk cooling. The flow ratio can be controlled through the use of a variable frequency drive on the milk pump or a solenoid valve on the water pipe to account for variations in milk volume. The diameter and length of the water pipe are limiting factors for the system's maximum water flow. Use at least a one inch diameter pipe to allow for a sufficient amount of water flow when using a plate cooler.

Water Flow Rate *(gallons per minute)*

Pipe Diameter *(inches)*	Flow Rate *(GPM)*	
	50 ft Pipe	**100 ft Pipe**
0.5	9	6.1
0.75	27	18.6
1	55	39.2
1.25	100	71.1

Flow rates assume smooth copper or plastic pipes at 40 psi water pressure.

3 SELECT A SCROLL COMPRESSOR WITH A HIGH EER

It is recommended to select a scroll compressor with a high energy efficiency ratio (EER). EER measures the efficiency of a compressor based on certain evaporating and condensing temperatures. It will end up saving more money in the long run if you purchase a more efficient scroll compressor up front, instead of purchasing a less efficient, inexpensive version.

PERFORM PROPER MAINTENANCE

Like all milking equipment, regular maintenance is the key to ensuring a long, productive life for your scroll compressor and plate cooler. The main focus of plate cooler maintenance is keeping the unit clean and free from milk scale build-up which, when left untouched, can lead to bacteria growth. Scroll compressors are checked during a refrigeration tune-up. Many companies offer annual tune-up services to keep refrigeration systems running at peak performance. These tune-ups can uncover potential issues before they arise, and can increase the operating efficiency of the compressor. A tune-up should include:

- Clean and inspect condenser coils
- Clean and inspect evaporator coils
- Clean drain pan
- Clean and inspect fans
- Clean or replace screens, grills, filters and drier cores
- Inspect and adjust heat reclaim operation
- Tighten all line voltage connections
- Inspect or replace relays and capacitors as needed
- Add or remove refrigerant charge

PRODUCT DETAILS

PLATE COOLERS

There is not a one size fits all option for plate cooler technology. High milk yields will require a large capacity plate cooler to achieve the right amount of cooling. The payback period for purchasing and installing a plate cooler will depend on the amount of milk produced and the up-front purchase price of the plate cooler. A properly sized plate cooler could potentially achieve a simple payback in as little as two to three years. However, it's important to work closely with a reputable equipment dealer when looking to install a plate cooler to ensure it is sized appropriately for your farm's needs.

The use of a plate cooler is a great option for most dairy farms. A dairy farm has to have milk cooled to an acceptable temperature in a short period of time to prevent bacteria growth during storage and transportation. A dairy farm also has a high demand for warm water that can be used for animal watering and cleaning certain equipment. A plate cooler achieves both of these needs simultaneously.

SCROLL COMPRESSORS

Scroll compressors are more efficient than reciprocating compressors due to their design. Scroll compressors use two scrolls to compress the gas by having one scroll oscillate around the other fixed scroll. This differs from typical piston compressors, which are found in reciprocating compressors. In addition to being more efficient, scroll compressors also have less moving parts which require less maintenance, lessen the noise level, and help build a reputation for sustainability.

It is recommended that reciprocating compressors be replaced with scroll compressors upon failure and that scroll compressors be requested for new construction. Scroll compressors generally cost $300 to $500 more than a reciprocating compressor. However, if the condensing unit has been well maintained, you can save money by only replacing the compressors instead of replacing the whole condensing unit. (Sanford, 2012)

REFRIGERATION HEAT RECOVERY UNITS

The installation of a Refrigeration Heat Recovery (RHR) unit provides one of the fastest paybacks on a dairy farm. You capture the heat from the refrigeration system to preheat well water up to 140 degrees, while also improving the efficiency of your refrigeration system.

Major advantages to installing a RHR unit include:

- Greatly reduced energy costs associated with heating water.
- Capture waste heat from the refrigeration system and transfer that heat to water.
- Use the hot water for cleaning and sanitizing milking equipment.

BEST PRACTICES

SELECT AN APPROPRIATE SIZE STORAGE TANK

The RHR unit storage tank should be large enough to supply enough hot water required for one milking. Farms that need additional hot water can connect an insulated storage tank to the RHR storage tank, so water can move between the two as it is heated and used. An easy way to find the appropriate tank size is to take:

$$\text{Tank Size} = \frac{\text{Average Daily Hot Water Usage}}{\text{\# of Milkings Per Day}}$$

(GDS Associates, Inc., 2012)

ENSURE PROPER INSTALLATION

The RHR unit should be located as close to the compressor as possible in order to minimize heat losses. The storage tanks need to be kept warm during the cold winter months, but you should not install a heating element. Instead, storage tanks should contain at least two inches of appropriate insulation to protect against the cold winter air.

DECIDE WHETHER A RHR OR PRE-COOLER IS THE BETTER OPTION, OR BOTH

According to the USDA, it is not economical to use both a pre-cooler and RHR unit with dairy herds of less than 100 cows. A RHR unit will provide smaller dairies with greater energy efficiency and cost savings compared to a pre-cooler. Dairies with more than 100 milking cows are usually able to benefit from using both technologies without increasing overall energy use.

PERFORM PREVENTATIVE MAINTENANCE

Preventative maintenance on a RHR unit is similar to that of a water heater in that the main goal is to reduce sediment buildup in the storage tank. A common solution is to install a valve on the RHR unit drain and use the lukewarm water from the bottom of the tank for daily chores that don't require hot water. This practice will result in regularly drawing water from the bottom where sediment buildup occurs. (Ohm, 2013)

VARIABLE FREQUENCY DRIVES

VARIABLE FREQUENCY DRIVES

Variable frequency drives (VFDs) regulate the speed and rotational force of an electric motor. The speed of the motor is changed by controlling the power that is fed into the machine, which results in energy savings. The two most common pieces of equipment on a dairy farm that will see significant cost benefits as well as energy savings from the installation of a VFD are the vacuum pump and milk transfer pump.

There is other equipment that may benefit from the installation of a VFD, however, energy savings associated with the installation of a VFD depends greatly on the specific application and will vary from farm to farm. The applications where significant energy savings may be saved include:

- Vacuum pumps
- Milk transfer pumps
- Second-use water systems
- Ventilation fans
- HVLS fans
- Sand-manure separation systems

BEST PRACTICES

SELECT THE CORRECT SIZE VFD

Farmers should ensure the VFD is sized properly for the application. If a unit is either oversized or undersized, it will neither perform well, nor yield the expected energy savings.

ENSURE CORRECT INSTALLATION IN AN APPROPRIATE LOCATION

A VFD is extremely sensitive to its surrounding conditions so it should be contained in an approved enclosure that protects it from dusty and damp conditions. VFDs can also be damaged by lightning strikes so they should be installed with proper grounding. Keeping the VFD in a clean environment that is heated in the winter will help to prolong its useful life. You should also locate the VFD as close to the application as possible. Electromagnetic emissions are greatly reduced when placed within ten feet of the application.

ADJUST THE SETTINGS AND CONTROLS

Always make sure the minimum speed setting of the VFD is matched to the system's needs. Operating a VFD below the manufacturer's recommended minimum speed may reduce the lifespan of the equipment.

REQUEST QUOTES FROM MULTIPLE VENDORS FOR NEW VFDS

Installation costs and methodologies will vary between vendors, so you should always acquire bids or estimates from multiple vendors. This will help you select the product and vendor best suited for your needs.

VENTILATION

Dairy and livestock operations utilize fans to promote proper ventilation in order to control the air quality and air temperature. It's important to keep animal well-being in mind when selecting and installing fans. Animals in these facilities are susceptible to airborne diseases so the air quality needs to be closely regulated. Typically these farms will have a specially designed ventilation system that is monitored and controlled by the operator to ensure air quality and temperature accuracy.

Proper ventilation in livestock facilities is important for several reasons:

- Circulate oxygen
- Remove moisture and odors
- Control temperatures
- Dilute airborne contaminants
- Dispel disease carrying organisms

BEST PRACTICES

UTILIZE NATURAL VENTILATION WHENEVER POSSIBLE

Always utilize natural ventilation whenever possible. This will dramatically reduce energy costs and eliminate man hours spent updating and maintaining equipment. However, there should be a backup plan to be used during inclement weather or other instances where natural ventilation isn't possible.

OPT FOR VARIABLE SPEED FANS AND MOTORS

Variable speed fans and motors allow you to regulate the amount of air flow and ventilation in your operation through the use of sensors. This will help reduce energy costs by managing the speed of the fans based on the outside air temperature and naturally occurring ventilation.

USE PROPERLY SIZED FANS

Using properly sized, energy efficient fans is important to lower monthly energy costs. Using less efficient fans because the initial investment is less will end up costing more money in the long run, and the less expensive fans may not be as durable. Since you will most likely be installing multiple fans, there is potential to save hundreds or thousands of dollars in electric charges.

CONSULT A PROFESSIONAL

Consult a professional who is experienced in designing ventilation systems for agriculture facilities. That person will help to identify needs and will be knowledgeable about which fan types and sizes are appropriate. They will also help with the design and layout for the fans to make your facility as energy efficient as possible.

PERFORM ROUTINE MAINTENANCE

Like all pieces of equipment, fans need regular maintenance in order to continue to perform at peak standards. Fans need to be kept clean and properly lubricated to ensure maximum performance and minimal energy use. Additional maintenance of fans should include:

- Wiping down fan blades, housing, and shutters
- Removing dust and debris from wires and outlets to avoid corrosion
- Cleaning air inlets and removing debris caught in screens
- Lubricating fan shutters using graphite
- Tightening loose belts

(Janni, 2014)

TYPES OF FANS

CIRCULATION fans are used to regulate airflow and temperature. They come in a variety of sizes, ranging from 12 inches in diameter to 72 inches in diameter. As the diameter of circulation fans increase, so does their efficiency. Circulation fans work best in freestall barns that have two, four or six rows and they are most often located in 30 to 40 foot intervals over the feed alley and the freestall area. Circulation fans are tested by independent companies to rate their efficiency. This testing rates how certain characteristics affect airflow such as guards, blade design, motor location, and speed. The results are publicly available and should be consulted when determining which fan is best for your farm.

EXHAUST fans are used to promote ventilation. As with circulation fans, when exhaust fan diameter increases, fan efficiency also increases. To achieve cross ventilation, fans are installed on one wall to pull air from one side of the barn to the other. Another design option for exhaust fans is tunnel ventilation. To achieve tunnel ventilation, fans are installed on one end of the barn and move air across to the rest of the barn. With both of these designs, the fans are usually thermostatically controlled to turn on different banks of fans when the temperature hits a certain degree. Exhaust fans should be installed away from prevailing winds whenever possible.

HIGH-VOLUME, LOW-SPEED (HVLS) fans are able to quietly move large amounts of air over a large area. This time of fan is gaining in popularity as more energy efficient options become available in the marketplace. They are available in a range of sizes, starting around four feet and ranging to over 24 feet in diameter. Depending on the facility and owner preference, these fans are oftentimes preferred over other types of fans. As a general rule, three row freestall barns should run two rows of fans that are placed directly over the freestalls, and four row freestall barns should install the fans directly over the feed alley. There isn't a general rule for six row freestall barns, because the layouts can vary greatly.

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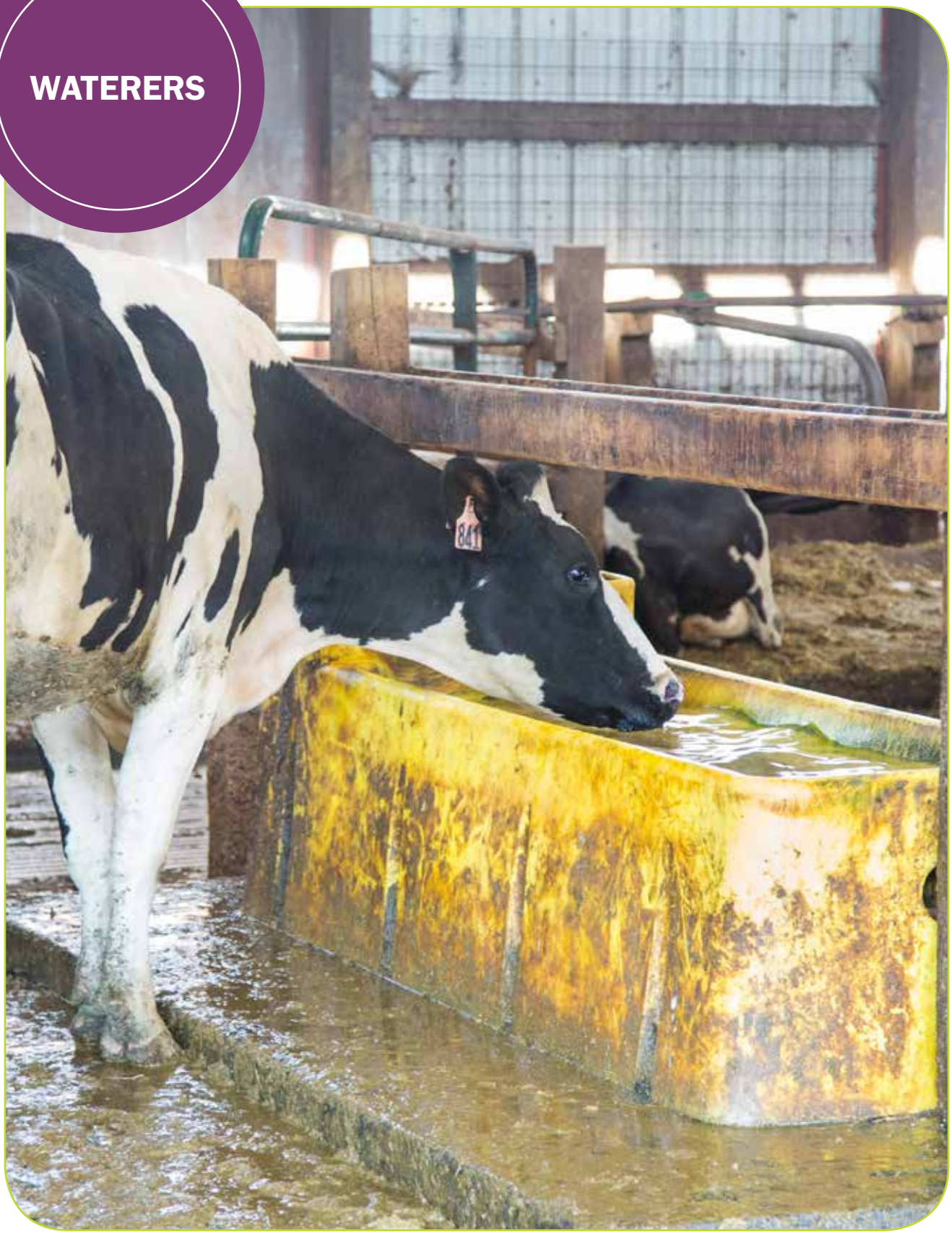
WATERERS



Livestock waterers are vital pieces of equipment used on a daily basis to maintain animal health and well-being. Waterers provide a reliable supply of drinking water to animals throughout all seasons of the year. Older versions can be extremely inefficient causing you to pay hundreds of dollars extra per month during the cold winter months. New waterers have increased insulation to reduce heat loss, therefore reducing or eliminating the need for energy to keep the water from freezing. Consider replacing your current waterer with a new energy efficient version to cut your water heating energy costs from 20 to 80 percent, depending on which design you choose.

BEST PRACTICES

SELECT AN APPROPRIATELY SIZED WATERER

Energy efficiency can only be achieved if the waterer matches the size of the herd it serves. If the herd is too small, the waterer will have to use more energy during the winter to keep the water from freezing. If the herd is too large, the waterer won't be able to keep up with the water needs of the herd.

INSTALL A WATERER BUILT FOR COLD CLIMATES

Make sure you install a waterer that is built to withstand the cold Wisconsin climate. Energy efficient waterers will have several inches of insulation built into them to keep the heat in the waterer, thus preventing the water from freezing during the winter. Some may even run a small heater to prevent freezing, however these are not as efficient as energy free waterers.

CONSIDER A WATERER WITH LIDS OR COVERS

Lids or covers on a waterer help form a protective barrier between the water and the outside air. They help to keep heat inside and cold air and debris outside. Waterers with lids or covers that have been installed in equine and bovine facilities have all seen positive results with animals adjusting to the new waterers right away.

ENSURE APPROPRIATE LOCATION AND INSTALLATION

Locating the livestock waterer in or near a building, somewhere sheltered from the wind, will drastically reduce the amount of energy required to keep the water from freezing. Insulation is also a key factor. It is recommended that at least two inches of appropriate insulation be used to keep the heat inside the waterer.

PERFORM CONTINUAL TEMPERATURE REGULATION

If a heating element is necessary, it is best to use a thermostatically controlled heater and set it to remain just above freezing, between 32 degrees and 34 degrees. The thermostat should be checked regularly to ensure proper calibration. Some waterers with heating elements keep the water temperature too warm, which results in excess energy use and increased operating costs. (GDS Associates, Inc., 2012)

TYPES OF WATERERS

ENERGY-FREE waterers use geo-thermal energy to keep the tank water from freezing. They are installed with a dry well or riser pipe surrounding the water supply pipe. The dugout, which holds the water, is well insulated and the circulation of fresh water through the pipe and water tank keeps the water from freezing. (Clarke & House, 2010) This is why it is important to match the waterer(s) to the size of the herd in order to ensure sufficient water circulation through the pipes and water tank. In very cold climates, these waterers need to be checked regularly to make sure the water or pipes have not frozen.

LOW ENERGY, ELECTRICALLY HEATED waterers are a great alternative when energy-free waterers aren't an option. Heated waterers rely on electricity to heat the pipe and water in the tank. If the waterer uses a removable heater, it should not be left in place during the warmer months as they are more prone to sediment and bacteria build up and will need to be thoroughly cleaned on a regular basis. The operator also needs to make sure that all wires are covered and grounded so as to avoid electric shock to livestock or humans.

ENERGY EFFICIENCY CHECKLIST

Use this checklist as a guide for energy efficiency upgrades. To help you get started on what best practices to consider, review this list to decide what options are applicable to your farm.

❍ COMMIT TO ENERGY EFFICIENT LIGHTING PRACTICES

- Turn off lights when not in use.
- Perform routine maintenance.
- Adjust the number of lamps and/or fixtures.
- Upgrade to energy efficient fixtures.
- Utilize timers and motion sensors.
- Implement energy efficient long-day lighting or other lighting strategies.

❍ INSTALL EFFICIENT MILK REFRIGERATION EQUIPMENT

- Invest in the correct size plate cooler.
- Identify the water to milk flow ratio of the plate cooler.
- Select a scroll compressor with a high EER.
- Perform proper maintenance.

❍ INVEST IN A REFRIGERATION HEAT RECOVERY TANK

- Select an appropriate size storage tank.
- Ensure proper installation.
- Decide whether RHR or Pre-Cooler is better option, or both.
- Perform preventative maintenance.

❍ INSTALL VARIABLE FREQUENCY DRIVES

- Select the correct size.
- Ensure correct installation in an appropriate location.
- Adjust settings and controls.
- Request quotes from multiple vendors for new VFDs.

❍ USE EFFICIENT VENTILATION EQUIPMENT

- Utilize natural ventilation whenever possible.
- Opt for variable speed fans and motors.
- Use properly sized fans.
- Consult a professional.
- Perform routine maintenance.

❍ INVEST IN ENERGY EFFICIENT WATERERS

- Select an appropriately sized waterer.
- Install a waterer built for cold climates.
- Consider a waterer with lids or covers.
- Ensure appropriate location and installation.
- Perform continual temperature regulation.

BEST PRACTICES FOR GREENHOUSES

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LIGHTING

Greenhouses provide natural and supplemental light to plants in order to boost plant growth and extend the growing season. The amount of light energy that is provided to leaf surfaces directly affects plant growth. Providing the correct wavelength and light intensity is essential to meet the photosynthesis needs of each plant. In order to keep production costs low, it is important to consider energy efficient lighting in greenhouses.

BEST PRACTICES

UPGRADE TO LED LIGHTS

Light emitting diode (LED) lights offer an economic solution to reduce production costs by up to 70 percent when compared to traditional lights. LED technology has the capability to alter the light spectrum so the lights provide the appropriate wavelengths to optimize plant growth and appearance without increasing operating costs.

Aside from saving energy by providing low wattage options, LEDs also have the ability to be customized for particular crops. For example, some studies have shown that LED grow lights can reduce the production costs of tomatoes by 25 percent compared to traditional high-intensity discharge lighting. (Devesh, 2012)

It is important to work with a qualified greenhouse lighting expert when looking to install LED lighting as this technology is continually evolving. The expert will help you identify LED fixtures that meet crop specific needs while aiming to reduce overall energy costs.

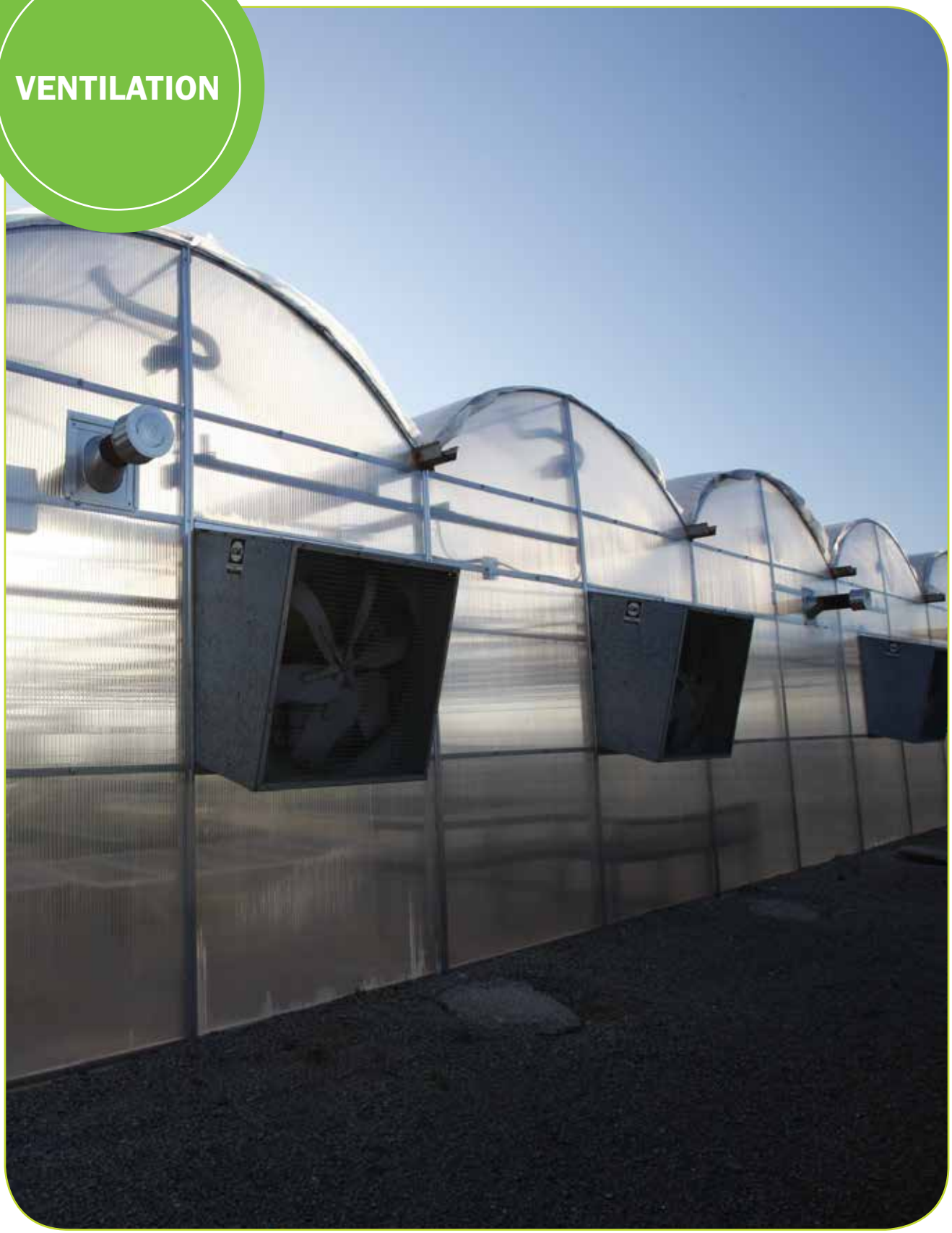
INSTALL LIGHTING CONTROLS

Consider achieving additional energy saving opportunities by installing dimming controls that adjust light levels when there is natural light available. Timers that automatically turn lights on or off depending on the amount of natural light available can add additional energy savings. This energy saving measure offers a quick payback and can help to optimize production.

PERFORM ROUTINE MAINTENANCE

LEDs are low maintenance due to the longevity and sturdiness of the fixtures. These lights have also shown a reduction in heat stress due to low amounts of radiant heat. This results in reduced maintenance requirements.

VENTILATION



A key to successful greenhouse operation is proper ventilation. Ventilation in a greenhouse is essential to keep temperature, moisture levels, and air pollutants in check. The main goal is to continuously swap inside air with fresh outside air in order to maintain a desired level of indoor air quality. Greenhouse ventilation is a year-round requirement; however the rate of ventilation will vary depending on the season. The ventilation process and equipment implemented in a greenhouse will have a direct impact on annual energy costs.

BEST PRACTICES

UTILIZE NATURAL VENTILATION

PROS	CONS
✓ No energy use	× No consistency in air exchanges
✓ Little or no need for fans	× May not always have sufficient airflow
✓ Less affected by electrical grid outages	× Additional cooling required at times

(Massachusetts, 2012)

SELECT FANS TO ACHIEVE DESIRED AIRFLOW

Fans should be sized to achieve the recommended one air exchange per minute during the summer months. A fan with various speed settings, or the use of multiple fans, can be utilized to achieve this required airflow. Using a VFD on a fan is a smart addition in order to automatically adjust air speeds and conserve energy when maximum airflow is not needed.

General Rule of Thumb: The larger the fan diameter, the more efficient the fan will be. It's almost always more efficient to run a few large fans than many small fans to achieve the same airflow rate.

LOCATE FANS APPROPRIATELY

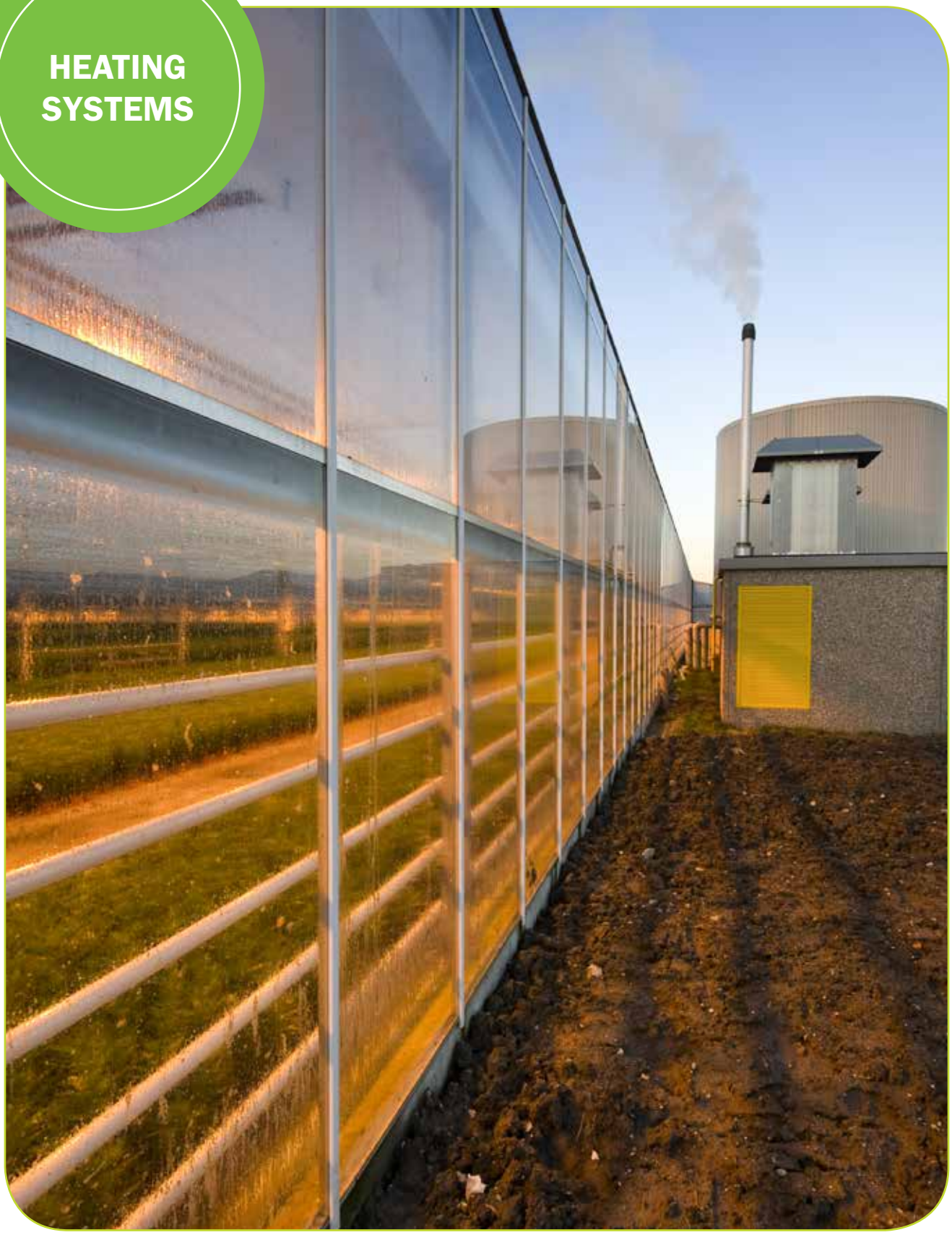
Fans are most effective if their total air draw is less than 150 feet. In most cases fans should be located at one end of a greenhouse with inlet louvers positioned at the other end so a nice steady breeze travels the length of the greenhouse. In the case of an extra-long greenhouse, additional fans can be placed in the middle of the greenhouse to provide enough extra air support to maintain proper airflow. It is recommended to invest in fans that have been certified efficient by an accredited fan testing company.

INSTALL CONTINUOUS LOUVERS

Continuous louvers are recommended over fixed louvers due to greater operator control of temperature and pressure changes inside the greenhouse. These louvers should be controlled by a pressure sensor to automatically control opening and closing in order to maintain a constant pressure differential across the length of the greenhouse.

Louvers should be positioned approximately three feet from the bottom of the floor to ensure the main air flow stream is flowing directly through the greenhouse canopy. This will help to maximize the evaporative cooling effect on the plants. (Massachusetts, 2012)

HEATING SYSTEMS



Commercial greenhouses in Wisconsin typically require supplemental heat in order to meet growing schedules and assure the quality of plants. Some greenhouses incorporate central heating systems and others install smaller units placed throughout the facility. Each facility is different and it's up to you to decide which type of heating system is right for your greenhouse.

BEST PRACTICES

SELECT THE APPROPRIATE TYPE OF HEATING SYSTEM

Centralized systems generate heat in one location and utilize a distribution system to disperse it throughout the entire building. The heat is distributed using plumbing and pipes for water or steam, and air ducts for hot air. Heat is then applied under the plants for propagation and germination. Additional heat may be required to maintain air temperatures after the sun goes down. Since the installation and maintenance costs can be quite high, centralized heating systems are usually more feasible for large-scale operations.

Localized heating systems are used to heat certain areas of a greenhouse, not the entire building. Hot air units called unit heaters are most often used in this type of heating system and they are only placed where they are needed. These units run on either propane or natural gas. Since these units are purchased on an as-needed basis, this type of heating system is feasible for operations of all sizes.

Bottom heating systems offer the greatest opportunity for reduction in energy costs. By moving heating pipes and air distribution systems from overhead to either under bench, on floor, or in floor, you can save 20 to 25 percent in heating costs and have the added bonus of faster plant growth. One study reported a seven percent increase in tomato production, largely due to a 7degrees increase in root median temperature. (Sanford, 2011)

VERIFY THE HEATER'S EFFICIENCY RATING

Efficiency ratings show how much of the fuel burned is actually converted to heat. **Thermal efficiency** is a rating of the individual unit while operating. **Seasonal efficiency** takes into consideration the entire system as it operates throughout the entire heating season. (Sanford, 2011)

PERFORM ROUTINE MAINTENANCE

Peforming routine maintenance of heating systems is important to maintaining their energy efficiency. Many companies offer annual furnance checkups, but it is also recommended to perform additional maintenance that a checkup may not cover.

Annual furnace checkup includes:

- Change fuel filters
- Clean nozzles
- Check valves and controls
- Check and align belts
- Lubricate bearings
- Test combustion efficiency
- Remove soot from inside the firebox

Other recommended maintenance tips:

- Clean thermostats regularly and calibrate them annually.
- Replace deteriorating unit heaters.
- Make sure gas burner flame burns as blue as possible, yellow indicates insufficient air.
- Insulate heating pipes and air ducts in headhouses and boiler rooms.

EXPLORE ALTERNATIVE HEATING SYSTEMS

Several solar heating systems are worth considering in order to reduce utility costs. One way to passively collect the sun's warmth is to incorporate a series of water-filled plastic containers that collect heat during the day and expel the heat as it cools in the evening. Masonry or rocks can also act as thermal mass energy sources to store the heat from the day and dispense it at night. However, passive solar options are not likely to provide sufficient heat for the whole greenhouse during the winter months so more reliable sources will most likely be necessary.

Another option is an active solar or subterranean system that captures hot air from the peak of the greenhouse during the day and directs it to ducts below the soil that run through a series of rocks. The rocks absorb heat from the sun during the day, turning them into heaters at night. They will then radiate the absorbed warmth to the soil above once temperatures drop. (University of Minnesota Extension, 2013)

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HEAT LOSS SOLUTIONS

Heating is one of the largest expenses for a greenhouse. As heat escapes through uninsulated walls or bare windows, the load on your heating system increases. A few low-cost products will help you maintain plant-friendly temperatures, regardless of outside conditions, to minimize heat loss and improve energy efficiency.

BEST PRACTICES

CONSIDER INFRARED (IR), ANTI-CONDENSATION TREATED FILMS

Many greenhouses use a double-layer of polyethylene to minimize heat loss. This helps to retain heat but is far from the most efficient solution. Opting for a combination IR/anti-condensation treated film will reduce space heating energy use by 10 to 20 percent and eliminate condensation problems. The treated film should be installed on the inside of the greenhouse with a standard film installed on the outside. The installation costs are low – typically an extra $.02 per square foot, or approximately $80 for a 30 by 96 feet greenhouse. The payback on this treated film is short, usually only four to six months, or one heating season.

INSULATE GREENHOUSE SIDE WALLS

If you utilize a bench system, insulating side walls, end walls and perimeter with one or two inches of foam insulation board can greatly reduce energy use. The insulation board should be dug in 12 to 24 inches deep and can rise to plant height. The foam should have a protective cover to prevent UV deterioration and reduce fire hazards. Spray-on foam is a good alternative but it also needs to be protected. Foam placed inside the greenhouse should be topped with a reflective coating to reflect direct solar radiation back to the drop canopy.

Energy savings can be substantial. Two inches of foam insulation around the knee wall of a 28 by 100 feet greenhouse will save over 550 therms of natural gas ($400+) annually.

INSTALL NIGHT CURTAINS

A movable insulated curtain is a great way to minimize nighttime heat loss. There are several types of curtain materials:

- **Porous** curtains cut heat loss by 20 to 30 percent allow water to drain through and can be used for shade in the summer.
- **Non-porous** aluminized materials provide up to 70 percent more shade in the summer and heat retention in the winter. However this material holds water which can cause the curtain system to fail from the additional water weight.
- **Semi-porous** aluminized materials do the best job of cutting energy costs. They reduce heat loss by 65 percent, provide summer shade, and efficiently drain condensation.

CLIMATE CONTROLS

Control systems and external solutions can help to optimize the efficiency of any greenhouse. These options can be implemented by themselves or combined with other energy efficiency upgrades to decrease utility costs.

BEST PRACTICES

INSTALL A THERMOSTAT

Thermostats are essential in maintaining an accurate temperature throughout the greenhouse. If you purchase a new thermostat or controller, make sure to select an electronic model with one degree differentials. Also consider a low-cost solid state controller with multiple control options to ensure optimum efficiency. Thermostats should be cleaned regularly and calibrated annually to ensure accuracy. A dirty thermostat will not read temperature correctly.

Be sure to install the thermostat near the center of the greenhouse or utilize several sensors placed throughout the greenhouse to get an average internal air temperature.

SET A NEUTRAL ZONE

It is highly recommended to set a neutral zone between heating and ventilation equipment to avoid unnecessary consecutive runtime. If the desired greenhouse temperature is 67 degrees, adjust your thermostat set points to 64 and 71 degrees to ensure the heating and ventilation equipment don't run simultaneously.

PLANT TREES

An exterior strategy to assist in climate control is to plant trees on the west or southwest side of the greenhouse. Plants prefer morning sunlight to afternoon so deciduous trees planted on the western side create shade across the greenhouse as the day moves along acting as natural air conditioning. This means that fans will not need to operate at full capacity during the warmer months. As leaves fall during the cooler months, the sun's low angle will naturally warm the greenhouse to save on heating costs.

VARIABLE FREQUENCY DRIVES

VARIABLE FREQUENCY DRIVES

Variable Frequency Drives (VFDs) installed on well pumps are a great way to decrease greenhouse energy costs. In addition to decreased energy costs, greenhouses that install a VFD on their well pump can expect to see improved process control and an extended usable life of the pump. VFDs can reduce a pump's energy use by as much as 50 percent. The VFD will pay for itself over time through the savings from reduced energy use. Normally the payback will range from a few months to less than three years, making it a feasible investment for greenhouses.

BEST PRACTICES

SELECT THE CORRECT SIZE

Farmers should ensure the VFD is sized properly for the application. If a unit is either oversized or undersized, it will neither perform well nor yield the expected energy savings.

ENSURE CORRECT INSTALLATION IN AN APPROPRIATE LOCATION

A VFD is extremely sensitive to its surrounding conditions. The electronic device should be contained in an approved enclosure that protects it from dusty and damp conditions. VFDs can also be damaged by lightning strikes so they should be installed with proper grounding. Keeping the VFD in a clean environment that is heated in the winter will help to prolong its useful life. You should also locate the VFD as close to the well pump as possible. Electromagnetic emissions can be reduced when placed within ten feet of the pump.

VERIFY SETTINGS AND CONTROLS

Always make sure the minimum speed setting of the VFD is matched to the system's needs. Operating a VFD below the manufacturer's recommended minimum speed may reduce the lifespan of the equipment.

REQUEST QUOTES FROM MULTIPLE VENDORS FOR NEW VFDS

Installation costs and methodologies will vary between vendors so you should always acquire multiple bids or estimates to ensure the vendor is able to provide you a high-quality product at an affordable price.

ENERGY EFFICIENCY CHECKLIST

Use this checklist as a guide for energy efficiency upgrades. To help you get started on what best practices to consider, review this list to decide what options are applicable to your farm.

❍ UPGRADE EXISTING LIGHTS

- Upgrade to LED lights.
- Install lighting controls.
- Perform routine maintenance.

❍ USE EFFICIENT VENTILATION EQUIPMENT

- Utilize natural ventilation.
- Select fans to achieve desired airflow.
- Locate fans appropriately.
- Install continuous louvers.

❍ IMPLEMENT EFFICIENT HEATING SYSTEMS

- Select the appropriate type of heating system.
- Verify the heater's efficiency rating.
- Perform routine maintenance.
- Explore alternative heating systems.

❍ CONSIDER ADDITIONAL HEAT LOSS SOLUTIONS

- Consider infared (IR), anti-condensation treated films.
- Insulate greenhouse side walls.
- Install night curtains.

❍ INVEST IN QUALITY CLIMATE CONTROLS

- Install a thermostat.
- Set a neutral zone.
- Plant trees.

❍ INSTALL VARIABLE FREQUENCY DRIVES ON WELL PUMP

- Select the correct size.
- Ensure correct installation in an appropriate location.
- Verify settings and controls.
- Request quotes from multiple vendors for new VFDS.

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BEST PRACTICES FOR CROP FARMS

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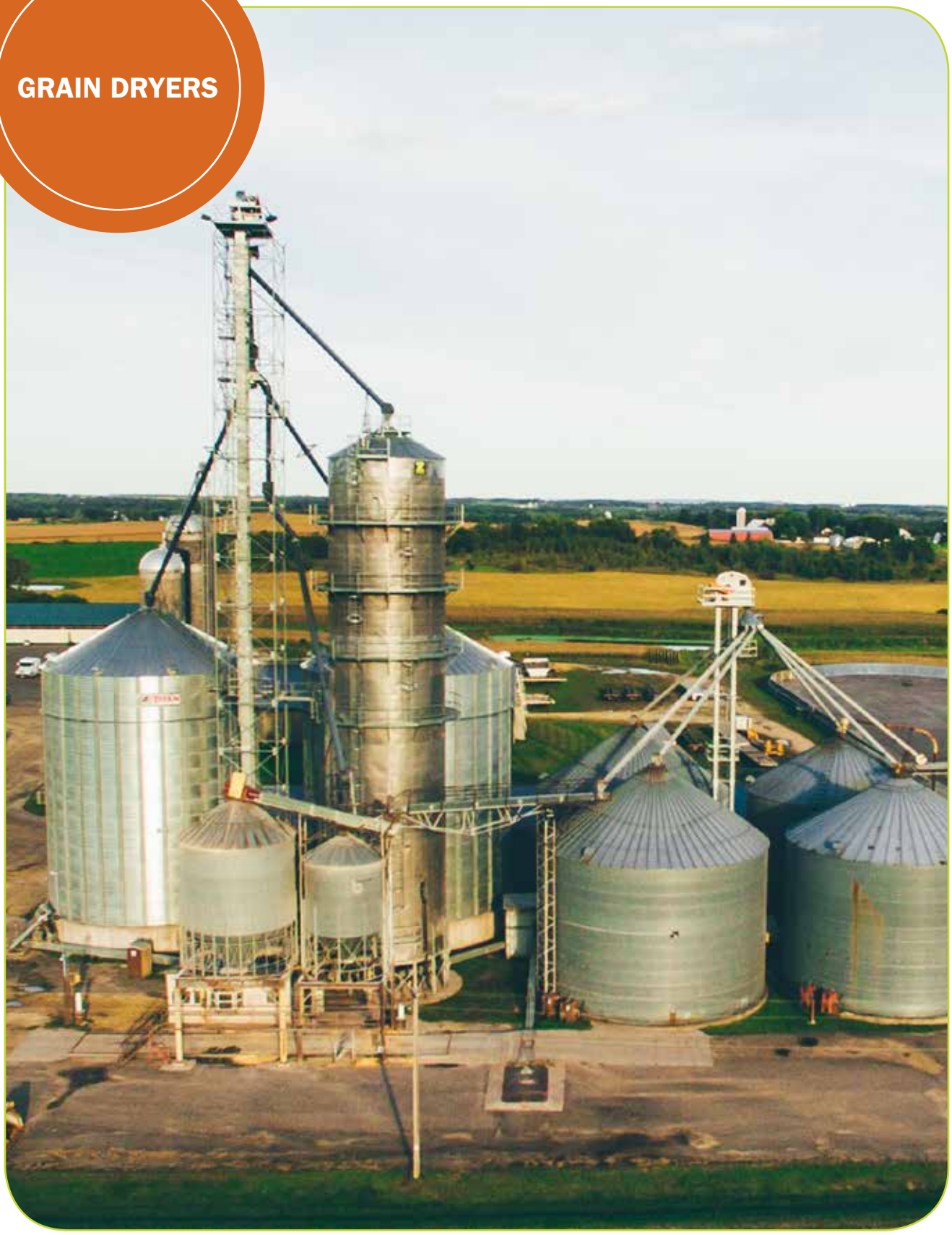
GRAIN DRYERS



A large component of energy consumption on a crop farm is energy used to dry harvested crops. Grain typically has a moisture content of 20 to 30 percent during the harvest period. Drying the grain is necessary to reduce moisture to acceptable levels before selling the grain to the open market. Prior to long-term storage, grain drying is necessary to prevent spoilage. While most crops require some level of drying, corn is typically the most energy intensive because it has a higher moisture content upon harvesting compared to crops such as soybeans or wheat. Several drying techniques can be implemented to reduce the amount of energy needed to dry the grain, therefore lowering the associated utility costs.

- **Ambient Air Drying** - This technique uses the natural drying potential of air to replace the fuel energy and takes place over a long period of time. Tests have shown this process to use one-quarter to one-half less energy than a typical cross-flow high-temperature dryer. This process is best for crops coming out of the field at less than 22 percent moisture content.
- **High Temperature Drying** - High Temperature drying is the most common form of drying used in Wisconsin. There are several models of high temperature grain dryers; generally the most efficient type is a Continuous Flow In-Bin dryer. Continuous in-bin dryers work on a much smaller cross section of the bin and are able to remove the most moisture from the grain using the least amount of energy. There are other forms of continuous flow dryers as well which generally have higher drying capacities but are not as efficient. (USDA, 2015).
- **Combination Drying** - This technique uses high temperatures to dry grain to approximately 20 percent moisture content and then finishes with ambient air or low-temperature drying. This practice can reduce energy use up to 60 percent when compared to high temperature drying alone and has been shown to improve grain quality. (Madison Gas & Electric, 2015)

BEST PRACTICES

DELAY HARVESTING

Delay harvesting of grain as long as possible to allow natural drying in the field. This will reduce the energy needed to dry the grain once it is in the grain dryer.

CLEAN THE GRAIN

Prior to drying, use a grain cleaner to remove any fine particles permitting greater airflow across the grain and speed up drying time. It will also create less mess in the dryer and cooling bins once the grain is dry.

INSTALL MOISTURE SENSORS

Use moisture sensors along with an automatic monitoring system to verify moisture levels and avoid over drying and excess energy use. Moisture sensors should be calibrated annually to ensure the readings remain accurate.

BEST PRACTICES 4 CROP FARMS

PERFORM REGULAR MAINTENANCE

Keep fans and air vents clear of dust and debris to allow for more efficient airflow and reduced stress on the fans. Regular maintenance on the fans should include lubrication of motor bearings, checking belt quality and alignment, and tightening loose components – all of which can reduce fan efficiency when left unchecked.

For high temperature dryers, verify combustion characteristics and ensure that full combustion is occurring. If it is not, the burner needs a tune-up to correct the problem and return to its normal operating efficiency.

BEST PRACTICES 5 CROP FARMS

UPGRADE THE DRYER AND INSTALL A COOLING BIN

If an existing grain dryer is 20 to 30 years old, consider replacing it with a newer, more efficient model. You can save additional energy through in-bin cooling or dryeration techniques. These methods of cooling help to reduce energy use, increase dryer capacity and achieve higher quality kernels.

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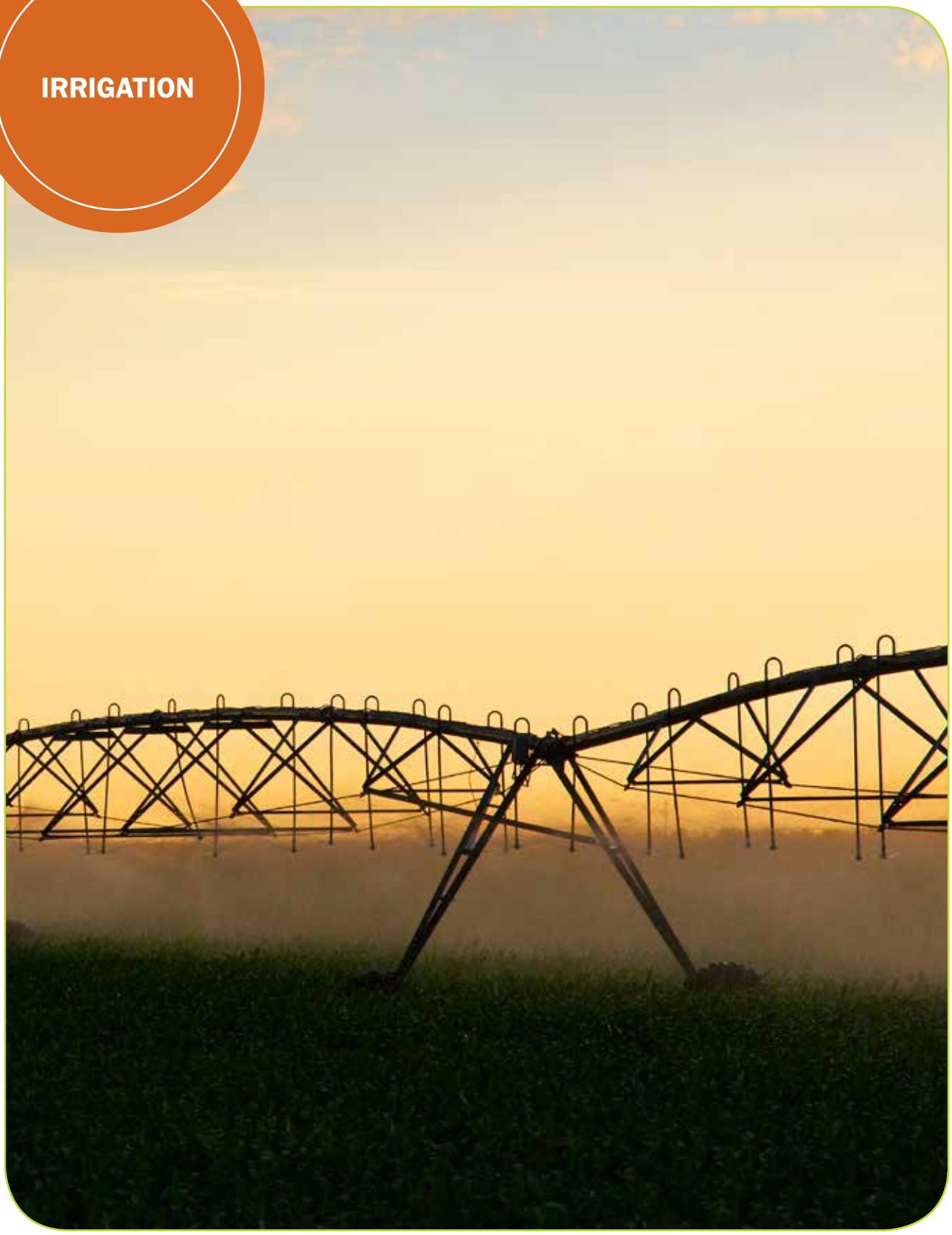
IRRIGATION



Irrigation can account for a large portion of a farm's total energy consumption. Since most of the crop farmers in Wisconsin use center pivot irrigation, one of the biggest energy saving opportunities for pivot irrigation systems is to reduce system pressure which allows for a reduced application time. For example, if a pumping system with current pivot pressure of 80 psi installed a low pressure sprinkler package to decrease the pivot pressure to 30 psi, there would be an estimated 35 percent reduction in energy costs. (Madison Gas and Electric, 2015)

BEST PRACTICES

ENSURE PROPER SPACING OF LOW PRESSURE NOZZLES

In order to optimize energy savings while providing adequate irrigation to crops, it is important to ensure that low pressure nozzles are spaced close enough together to cover the same amount of area. Typically, little water savings is associated with the installation of a low pressure system however energy can be saved with proper nozzle spacing. The instantaneous rate of application increases because the same amount of water is applied over a smaller area for a shorter amount of time. (UW-Extension, 2012)

REDUCE THE SIZE OF THE WELL PUMP

Since the capacity of the well pump will increase when the system pressure decreases, the pump can either be modified to operate at a lower head pressure or a smaller, premium efficient well pump should be installed. The combination of a low pressure sprinkler package and a horsepower reduction on the well pump could provide energy cost savings up to 40 percent.

INSTALL A VFD ON THE IRRIGATION PUMP

Another opportunity for energy savings is the installation of a Variable Frequency Drive (VFD) on the irrigation pumps. The VFD allows the pump to speed up or slow down to provide uniform application of water and maintain the correct pressures throughout the irrigation system(s). Typically a VFD will be most beneficial for systems that have end guns or swing arms, precision application packages, or one pump supplying water to multiple irrigation systems. The VFD controller connected to a pressure transducer monitors the total system pressure and maintains precise irrigation.

PERFORM PREVENTATIVE MAINTENANCE ON PUMPS AND MOTORS

Conduct uniformity and pump/well testing on the irrigation systems every two to three years to improve water utilization and uncover potential maintenance concerns that could arise. The increased efficiency and preventative maintenance will save energy and expenses in the long run.

CONSIDER IRRIGATION SCHEDULING

Irrigation scheduling may be another option to consider when trying to optimize crop production in a cost-effective manner. Using a computer-based system along with moisture sensors, farmers can track and better forecast moisture needs for the crops. The scheduling system can decrease energy costs, water use, fertilizers, and labor costs by scheduling the irrigation system to run only when it is necessary.

VENTILATION

Maintaining a quality product after harvest is important for crop farms. Using fans to control the proper temperature and humidity while pushing air through a crop is common for these operations. Selecting an energy efficient fan is important to decrease energy costs while maintaining a high quality product.

General Rule of Thumb: As the fan diameter increases, the fan energy efficiency also increases.

BEST PRACTICES

MAINTAIN AIRFLOW REQUIREMENTS

Fan airflow is measured by cubic feet per minute (cfm). Each crop unit has its own recommended airflow rate to achieve proper drying. The selected ventilation methods should be able to achieve the required airflow for your crops while remaining energy efficient. The table below outlines different types of crops and the associated airflow recommendations.

TYPE OF CROP	RECOMMENDED AIRFLOW
Hay drying	150 to 500 cfm/ton
Forced-air produce cooling	1 to 10 cfm/lb.
Potato ventilation (per hundredweight)	0.5 to 1.5 cfm/cwt
Natural-air drying of grains and oilseeds	0.75 to 1.5 cfm/bushel
Aeration of stored dry grains and oilseeds	0.05 to 0.5 cfm/bushel

Source: Wilcke, William F. "Selecting Fans and Determining Airflow for Crop Drying, Cooling, and Storage." (2013): n. pag. : Crops : University of Minnesota Extension. Web. 10 Sept. 2015.

OPT FOR VARIABLE SPEED FANS AND MOTORS

Variable speed fans and motors allow you to regulate the amount of air flow and ventilation in your operation through the use of sensors. This will help reduce energy costs by managing the speed of the fans based on moisture levels and air temperature.

SELECT THE APPROPRIATE TYPE OF FAN

Four main types of fans to promote ventilation in crop farms are: **tube-axial** and **vane-axial**, **centrifugal**, and **in-line centrifugal**.

- **Tube-axial** and **vane-axial** fans are the most common fan types used for aeration and grain drying. They are fairly efficient and relatively inexpensive, however they create a lot of noise.
- **Centrifugal** fans are mainly used on crop farms for drying and storage. Although they are more expensive than other fan types, they operate quieter and are the most energy efficient. The motor is usually located outside the airstream so you can install a special housing around the motor if you want to capture the radiated heat.
- **In-line centrifugal** fans fall in between the axial and centrifugal fans in terms of efficiency and price. These fans are not as common as the other types of fans listed above.
(Madison Gas and Electric, 2015)

PERFORM ROUTINE MAINTENANCE

Like all pieces of equipment, fans need regular maintenance in order to continue to perform at peak standards. Fans need to be kept clean and properly lubricated to ensure maximum performance and minimal energy use. Proper maintenance of fans should include:

- Wiping down fan blades, housing, and shutters
- Removing dust and debris from wires and outlets to avoid corrosion
- Cleaning air inlets and removing debris caught in screens
- Lubricating fan shutters using graphite
- Tightening loose belts

(Janni, 2014)

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LIGHTING

Please refer to the ***Dairy and Livestock Lighting*** section on page 13 of this guidebook for information regarding energy efficient lighting for agricultural facilities.

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REFRIGERATION

Many of the goods harvested on crop farms require cooling after harvest. Removal of field heat is important to maintain produce quality and ensure a long edible life. Fruit and vegetable farm refrigeration systems see intense operation during the warm summer months, typically when electrical costs reach their peak. Improving the energy efficiency of refrigeration systems can lead to significant savings on utility bills.

BEST PRACTICES

PRACTICE PRODUCE PRECOOLING

Before transferring produce into refrigerated areas, spray or submerge the produce in cold water. This will jumpstart the cooling process, therefore reducing the amount of energy needed from the refrigeration systems.

IMPROVE INSULATION TO REDUCE INFILTRATION

The cold refrigeration storage areas should be well insulated to prevent unnecessary heat loss which leads to increased energy bills. Installing adequate insulation will reduce infiltration of warm air through doors, cracks and other openings.

INSTALL ENERGY EFFICIENT EQUIPMENT

Many options are available for efficient refrigeration equipment. Farmers should utilize energy efficient compressors, heat exchangers, refrigerants and other pieces of equipment whenever possible.

PERFORM REGULAR MAINTENANCE

Regular maintenance of the refrigeration areas and equipment will ensure energy costs do not increase over time. The refrigeration areas should be kept clean to avoid dust and debris build up which can retain heat. The owner should also inspect insulation and all door and window seals for cracks or holes where heat loss may occur. Equipment should be kept free of debris and rust. Many vendors offer annual refrigeration tune-up services to inspect equipment for damage or leakage.

ENGINE BLOCK HEATER TIMERS

ENGINE BLOCK HEATER TIMERS

Crop harvesting equipment is often a forgotten area with potential energy savings. Engine block heaters are commonly used in cold climates to warm engines prior to start-up. Since diesel engines can take a long time to warm up, engine bock heater timers are a great way to save energy with a small initial investment. Many operators leave the heater turned on overnight, or whenever the tractor is not in use. Using a timer eliminates the need to monitor when the heater is plugged in, as it will automatically turn on at the pre-selected time. The engine will be warm in only one or two hours.

COST OF OPERATING

If you run a 1000-watt engine heater for ten hours per day from November to March, you will pay $105 per year in electrical costs. If you installed a timer on that same heater and programmed it to only run for two hours before it is normally used, you will only pay $21 per year in electric costs, saving more than $80 per year.

Timers can cost anywhere from $20 to $60 depending on the size, and you can expect to see a payback of less than one heating season. Be sure to invest in timers that are outdoor or weatherproof rated. Also be sure to install the timers on properly grounded electrical circuits.

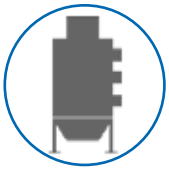
The table below shows annual operation costs for engine block heaters of different wattages, along with annual savings if a timer is used.

WATTAGE HEATER	COST TO OPERATE		ANNUAL SAVINGS
	10 HRS / DAY	2 HRS / DAY	
400	$42.00	$8.40	$33.60
600	$63.00	$12.60	$50.40
750	$78.75	$15.75	$63.00
1000	$105.00	$21.00	$84.00
1250	$131.25	$26.25	$105.00
1500	$157.50	$31.50	$126.00

(Values were calculated assuming a cost of $.1050/kWh)

ENERGY EFFICIENCY CHECKLIST

Use this checklist as a guide for energy efficiency upgrades. To help you get started on what best practices to consider, review this list to decide what options are applicable to your farm.



❍ PRACTICE ENERGY EFFICIENT GRAIN DRYING TECHNIQUES

- Delay harvesting.
- Clean the grain.
- Install moisture sensors.
- Perform regular maintenance.
- Upgrade the dryer and install a cooling bin.

❍ INVEST IN ENERGY EFFICIENT IRRIGATION PRACTICES

- Ensure proper spacing of low pressure nozzles.
- Reduce the size of the well pump.
- Install a VFD on the irrigation pump.
- Perform preventative maintenance on pumps and motors.
- Consider irrigation scheduling.

❍ USE EFFICIENT VENTILATION EQUIPMENT

- Maintain airflow requirements.
- Opt for variable speed fans and motors.
- Select the appropriate type of fan.
- Perform routine maintenance.

❍ COMMIT TO ENERGY EFFICIENT LIGHTING PRACTICES

- Turn off lights when not in use.
- Perform routine maintenance.
- Adjust the number of lamps and/or fixtures.
- Upgrade to energy efficient fixtures.
- Utilize timers and motion sensors.
- Implement long-day lighting or other lighting strategies.

❍ PRACTICE ENERGY EFFICIENT REFRIGERATION

- Practice produce precooling.
- Improve insulation to reduce infiltration.
- Install energy efficient equipment.
- Perform regular maintenance.

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