Energy Best Practices Guide | November 2020

AGRICULTURE FACILITIES

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Agriculture Facilities Energy Best Practices Guidebook

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Introduction

Wisconsin is nicknamed America's Dairyland for the large amounts of milk and cheese produced each year within the state. Wisconsin also prides itself on high production of other products like snap beans, cranberries, ginseng, mink pelts and corn for silage. The production process for any agricultural entity would not be possible without energy.

In 2012, growing demand resulted in agricultural energy consumption increasing by 7.8% more than any other economic sector in Wisconsin (Wisconsin Office of Energy Independence, 2013). It's because of these increases farmers are striving to eliminate unnecessary costs wherever possible. While it's not feasible to completely eliminate energy expenses there are many ways to decrease energy use while keeping a modern, safe operation. This guidebook details energy efficiency best practices for agriculture producers to help you make an informed decision.

DAIRY AND LIVESTOCK

Lighting upgrades provide one of the quickest, most cost-effective energy improvements. Lighting technologies continue to advance, creating more options to find the right product for your lighting needs and budget. Below are considerations to advance, creating energy costs associated with your lighting systems.

Recommendations

Step 1 – Correct light levels

Work with a lighting professional who has experience designing lighting systems for agriculture facilities. The lighting professional will take light level measurements, commonly referred to as footcandle readings, at various locations throughout the facility and explore the most appropriate layouts to reach maximum energy efficiency.

Footcandle readings measure the light levels at the surface area where light is needed. Table 1 below details the recommended light levels for different areas found in livestock facilities.

Table 1: Dairy and livestock recommended lighting levels

TASK	RECOMMENDED FOOTCANDLES*
Egg packing and inspection	100
Exterior active areas	3-5
Exterior security	.5-1
Farm show/repair area	50
Free stall	15-20
General animal care area	20
General livestock housing	10
Holding area	10-20
Inside incubators	50
Loading and storage areas	20
Machine storage	10
Manual wash sink	100
Milking parlor	20
Milk room	20
Office area at desktop	50
Operator's pit (at udder)	50
Poultry barns	20
Restroom	20
Tie stall – Feed ally	-20
Tie stall – Center ally	20-50
Treatment or surgery area	100
Utility room	20

(Sanford, Energy-Efficient Agricultural Lighting, 2003)

Step 2 – Upgrade to energy-efficient fixtures

Prioritize lighting upgrades in areas with long runtime hours to maximize your savings. The most common energy-efficient lighting option today is LED. With the wide range of products on the market, knowing what key characteristics to consider helps to ensure you select the right product for your facility and application. When selecting an energy-efficient fixture, look beyond just wattage and consider other characteristics like light output (lumens), equipment life (hours), lumen maintenance factor, and lumens per watt (LPW). Try to maximize the values in each of these categories. It is recommended to seek help from a lighting professional if you are unsure of what product to select.

Rule of thumb:

The more lumens per watt, the more bang for your buck.

Table 2 details key lighting characteristics of common lighting options. 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.

Table 2: High efficiency lighting options

	LINEAR FLUORESCENTS	LIGHT EMITTING DIODES (LEDS)
Available wattages	32-54	1.2-200
Price per bulb	\$5-\$50	\$5-\$500
Average lamp life (hours)	20,000-36,000	60,000-100,000
Lumens per watt	60-110	80-110
Applications	Low-bay and high-bay use T5 and T8 most common Clean, protected environment	Interior and exterior lighting High bay uses Vapor-tight fixtures available
Benefits	Short payback Wide variety of applications Many options and lengths	Low maintenance Solid-state devices (durable) Immediate response No mercury
Drawbacks	Contain mercury Regular maintenance T12 is not an efficient size	High initial investment New options becoming more widely available

Step 3 – Utilize timers and motion sensors

Timers and motion sensors are excellent tools to use when it's not feasible to manually turn lights on and off. Options to consider include:

- Controls that gradually turn the light intensity up and down to simulate the sun (long-day lighting).
- Daylight sensing controls with a photocell to change the light intensity based on the natural light available.
- Motion-sensing controls to turn lights on and off based on occupancy. Consider these over entrances, in hallways and storage areas.

If a light doesn't need to be turned on, turn it off. This is the fastest and easiest way to decrease energy costs.

Step 4 – Implement long-day lighting

Long-day lighting artificially extends the daylight hours on short fall and winter days (September through April) 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, it can improve heifer growth and increase milk production by as much as 16% (Shelford & Wright, 2013). The idea of manipulating lighting times to increase production has been around since the 1970s, and research has consistently revealed favorable results. For this technique to be effective, the light must remain sufficiently intense throughout the photoperiod, then dark for six to eight 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 LED light fixtures over the manger or feed alley in a free stall barn. Install timers and photo sensors to ensure consistent brightness and dark periods throughout the day.

Step 5 – Consider other lighting strategies

Some options for alternative lighting control strategies include:

- **Scheduling –** The use of operating schedules and time controls to turn lights on and off.
- **Tuning –** Adjusting lighting levels based on occupancy, tasks or conditions.
- **Lumen maintenance –** Dimming the lights initially and then gradually increasing power to the lamps overtime to compensate for over-design of new lighting systems.

Work with a lighting professional to determine the best plan for your facility (Council, 2009).

Step 6 – Perform routine maintenance

Routine maintenance can help extend equipment life and reduce the frequency of bulb replacement. Poorly maintained lighting systems cost far more in lost productivity than in wasted energy. Necessary maintenance steps include:

- Cleaning 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.
- Replacing lenses if they appear yellow.
- Cleaning or repainting small rooms every year and large rooms every two to three years. Dirt collecting on these surfaces reduces the amount of light reflected.
- Replacing all bulbs in a lighting system at once to save labor and avoid stressing any ballasts with dying bulbs.

Milk refrigeration equipment

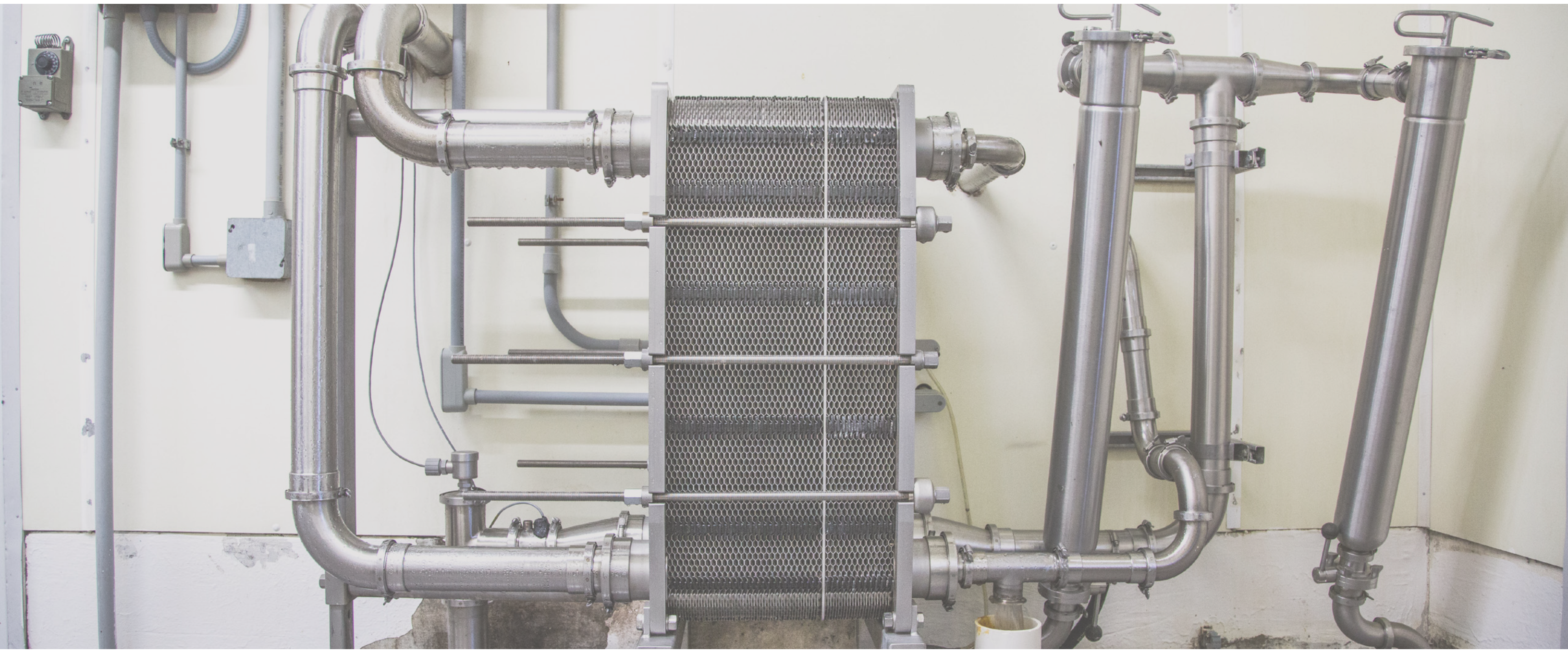
Milk cooling accounts for the most critical energy expenditure of a dairy farm. Two pieces of equipment in the milk cooling process having a considerable impact on energy use are the milk pre-cooler and the condensing unit. The purpose of a milk pre-cooler is to help cool milk faster and more efficiently with the goal to improve 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.

Dairy farms use condensing units to cool milk being stored in the bulk tank or being loaded into a milk tanker. These condensing units contain compressors able to handle the required temperature changes. For a long time, reciprocating compressors were used to cool milk to the desired temperature of approximately 38 degrees. However, over the past several years, it has been recommended to install a scroll compressor. The scroll compressor is about 15 to 20% more efficient than a similar-sized reciprocating compressor. Since milk cooling has the most significant energy draw on a dairy farm, it pays to invest inefficient technology.

Consider investing in new milk refrigeration equipment when:

- Your condensing unit runs excessively, or over an hour after a milking session is complete.
- Milk production is increasing, and the current condensing unit is already operating at or near maximum cooling capacity.
- Your farm has increased 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)



Product details

Plate coolers

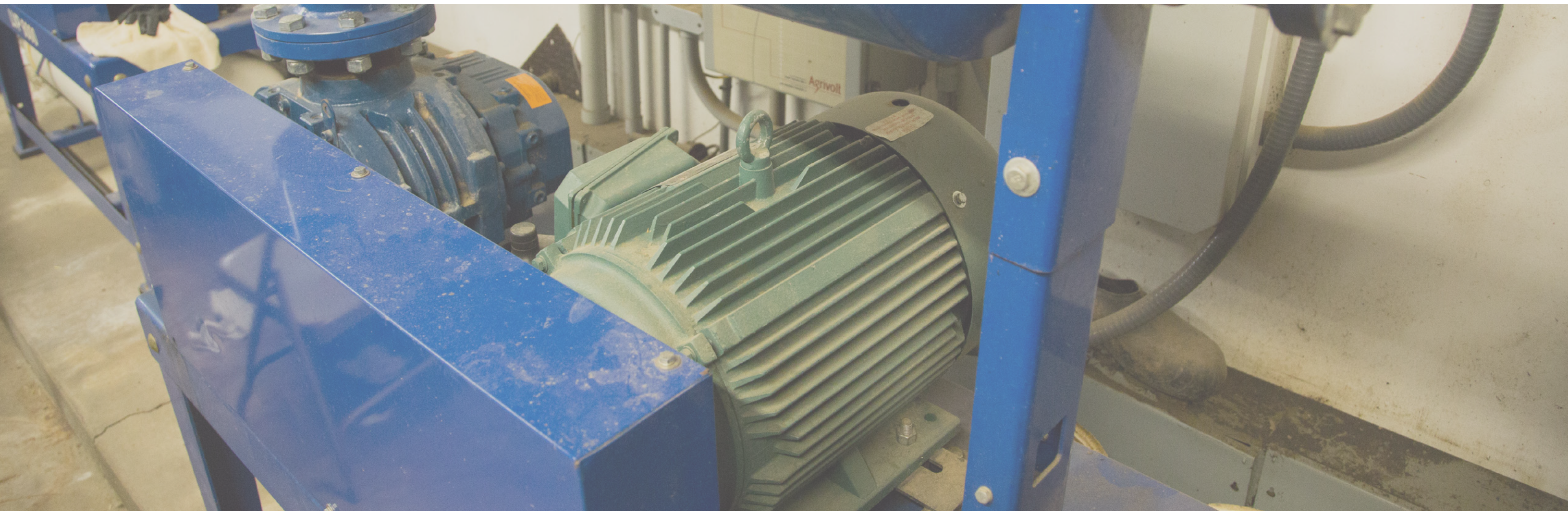
There is not a one-size-fits-all option for plate cooler technology. High milk yields will require a large capacity plate cooler to achieve the right amount of cooling. The payback period for purchasing and installing a plate cooler will depend on the amount of milk produced and the up-front purchase price of the plate cooler. A properly sized plate cooler could achieve a simple payback in as little as two to three years. However, it's essential 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 to prevent bacteria growth during storage and transportation. A dairy farm has a high demand for warm water that can be used for animal watering and cleaning specific 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. It differs from typical piston compressors found in reciprocating compressors. In addition to being more efficient, scroll compressors also have less moving parts requiring less maintenance, lessen the noise level and help build a reputation for sustainability.

Replace reciprocating compressors with scroll compressors upon failure, and request scroll compressors for new construction. Scroll compressors generally cost $300 to $500 more than a reciprocating compressor. However, a well-maintained condensing unit can save money by replacing the compressors instead of replacing the whole condensing unit (Sanford, 2012).



Recommendations

Step 1 – Invest in the correct size plate cooler

Using a plate cooler appropriately sized to the farm's milk output makes it possible to cool milk within five degrees of the groundwater temperature in a more timely manner. 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 mean 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 groundwater.

Step 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. By increasing the water flow, heat transfer can be increased to gain additional degrees of milk cooling. Control the flow ratio using 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.

Table 3: Water flow rate (gallons per minute)

PIPE DIAMETER (GALLONS PER MINUTE)	**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

Step 3 – Select a scroll compressor with a high EER

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.

Step 4 – Perform routine maintenance

Regular maintenance is the key to ensuring a long, productive life for your scroll compressor and plate cooler. Plate coolers are generally maintenance-free, but over time, milk scale builds up which can lead to bacteria growth. If milk temperature drops lower than expected, clean the water portion of your plate cooler. Many companies offer annual tune-up services to keep scroll compressors and other elements of your refrigeration system running at peak performance. These tune-ups can uncover potential issues before they arise and can increase the condensing unit's operating efficiency. A tune-up should include:

- Cleaning and inspecting condenser coils
- Cleaning and inspecting evaporator coils
- Cleaning drain pan
- Cleaning and inspecting fans
- Cleaning or replacing screens, grills, filters and drier cores
- Inspecting and adjusting heat reclaim operation
- Tightening all line voltage connections
- Inspecting or replacing relays and capacitors as needed
- Adding or removing refrigerant charge

The installation of a refrigeration heat recovery (RHR) unit provides one of the fastest paybacks on a dairy farm. This unit captures 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 an RHR unit include:

- Greatly reducing energy costs associated with heating water.
- Capturing waste heat from the refrigeration system and transferring this heat to water.
- Using the hot water for cleaning and sanitizing milking equipment.

Recommendations

Step 1 – Select an appropriate size storage tank

The RHR unit storage tank should be large enough to supply enough hot water required for one milking, but not too large that it is expending unnecessary energy. Farms needing 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)

Step 2 – Ensure proper installation

Minimize heat losses by aligning the RHR unit as close to the compressor as possible. Instead of installing a heating element, the tank should have at least two inches of insulation to keep the tank warm during cold winter months.

Step 3 – Decide between an RHR or pre-cooler

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. An 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.

Step 4 – Perform routine maintenance

Routine maintenance on an RHR unit is similar to a water heater with the main goal of reducing sediment buildup in the storage tank. A standard 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 not requiring hot water. This practice will result in regularly drawing water from the bottom where sediment buildup occurs (Ohm, 2013).

Variable frequency drives (VFDs) regulate the speed and rotational force of an electric motor. VFDs allow the motor to run more efficiently by matching the speed to the application. The motor's speed is changed by controlling the power fed into the machine, which results in energy savings. The two most common pieces of equipment benefiting from a VFD are a vacuum pump and milk transfer pump. Other equipment may benefit from the installation of a VFD, however, energy savings associated with the installation depends on the application. Other applications with significant energy savings include:

- Second-use water systems
- Ventilation fans
- HVLS fans
- Sand-manure separation systems

Recommendations

Step 1 – Select the correct size VFD

Ensure the VFD is appropriately sized for the application. A unit not properly sized will not perform or yield the expected energy savings.

Step 2 – Ensure correct installation

A VFD is extremely sensitive to its surrounding conditions. Contain the electronic device in an approved enclosure to protect it from dusty and damp conditions. Lightning strikes can also damage VFDs, making it important to install with proper grounding. Keeping the VFD in a clean environment heated in the winter will help prolong its useful life. It is advised to locate the VFD as close to the application as possible, ideally within 10 feet, to reduce electromagnetic emissions.

Step 3 – Adjust settings and controls

Match the minimum speed setting of the VFD to the system’s needs. Check and fix air leaks on milk lines to avoid VFDs running at higher RPMs. Operating a VFD below the manufacturer’s recommended minimum speed may reduce the lifespan of the equipment. Optimize the pipeline for CFM loss. CFM loss in a vacuum system will result in VFDs running at higher RPMs resulting in wasted energy.

Dairy and livestock operations utilize fans to promote proper ventilation as well as control air quality and air temperature. Because animals in these facilities are susceptible to airborne diseases, air quality needs to be tightly regulated. Typically farms will have a specially designed ventilation system monitored and controlled by the operator to ensure air quality and temperature accuracy.

Proper ventilation in livestock facilities is essential for several reasons:

- Circulating oxygen
- Removing moisture and odors
- Controlling temperatures
- Diluting airborne contaminants
- Dispelling disease carrying organisms

Types of fans

Circulation fans

Circulation fans come in a variety of sizes, ranging from 12 inches in diameter to 72 inches in diameter. As the width of circulation fans increase, so does their efficiency. Circulation fans operate best in free stall barns with two, four or six rows and position in 30 to 40-foot intervals over the feed alley and the free stall area. Circulation fans are tested by independent companies to rate their efficiency. This testing rates how specific characteristics affect airflows 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.

Expected savings: $30 to $108 per year with an estimated 16 year useful life

Exhaust fans

As with circulation fans, when exhaust fan diameter increases, fan efficiency also increases. Achieve cross-ventilation by installing fans on one wall to pull air from one side of the barn to the other. Another design option for exhaust fans is tunnel ventilation. Attain tunnel ventilation when 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. Install exhaust fans away from prevailing winds whenever possible.

Expected savings: $159 to $347 per year with an estimated 16 year useful life

High-volume, low-speed (HVLS) fans

This type 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 ideal over other types of fans.

Expected savings: $98 per year with an estimated 15 year useful life

Recommendations

Step 1 – Utilize natural ventilation

Natural ventilation can dramatically reduce energy costs and eliminate working hours spent updating and maintaining equipment. There should be a backup plan for inclement weather or other instances where natural ventilation isn't possible.

Step 2 – Opt for variable speed fans and motors

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

Step 3 – Use properly sized fans

Adequately sized, energy-efficient fans are vital to lowering 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. Because it's likely multiple fans would be replaced, there is potential to save hundreds or thousands of dollars in electric charges.

Step 4 – Consult a professional

Consult an experienced professional in designing ventilation systems for agriculture facilities. This person will help identify needs and recognize 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.

Step 5 – Perform routine maintenance

Like all pieces of equipment, fans need regular maintenance 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 fan maintenance should include:

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

Waterers provide a reliable supply of drinking water to animals throughout all seasons of the year. Older versions can be extremely inefficient, costing hundreds of dollars extra per month during the cold winter months. New waterers have increased insulation to reduce heat loss, 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 by 20 to 80%.

Types of waterers

Energy-free waterers

Geothermal energy keeps the tank water from freezing by installing a dry well or riser pipe surrounding the water supply pipe. The dugout, which holds the water, is well insulated, and the circulation of freshwater through the pipe and water tank keeps the water from freezing (Clarke & House, 2010). It is crucial to match the waterer(s) to the herd's size to ensure sufficient water circulation through the pipes and water tank. In freezing climates, check these waterers regularly to make sure the water or pipes have not frozen.

Low energy, electrically heated waterers

This is 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 regularly. The operator also needs to ensure all wires are covered and grounded to avoid electric shock to livestock or humans.

Recommendations

Step 1 – 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 herd's water needs.

Step 2 – Install a waterer built for cold climates

Install a waterer built to withstand the cold Wisconsin climate. Energy-efficient waterers will have several inches of insulation built into them to keep the waterer's heat, thus preventing the water from freezing during the winter. Others utilize buried heat tubes to avoid freezing. Some may even run a small heater; however, these are not as efficient as energy-free waterers.

Step 3 – 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 installed in equine and bovine facilities have all seen positive results with animals quickly adjusting to the new waterers.

Step 4 – Ensure appropriate installation location

Locating the livestock waterer 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. Keep the heat inside the waterer by using at least two inches of appropriate insulation.

Step 5 – 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. Check the thermostat regularly to ensure proper calibration. Waterers with heating elements keep the water temperature too warm, resulting in excess energy use and increased operating costs (GDS Associates, Inc., 2012).

Energy efficiency checklist

Lighting systems

- ❑ Correct light levels
- ❑ Upgrade to energy-efficient fixtures
- ❑ Utilize timers and motion sensors
- ❑ Implement long-day lighting
- ❑ Consider other lighting strategies
- ❑ Perform routine maintenance

Milk refrigeration equipment

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

Refrigeration heat recovery units

- ❑ Select an appropriate size storage tank
- ❑ Ensure proper installation
- ❑ Decide between an RHR or pre-cooler
- ❑ Perform routine maintenance

Variable frequency drives

- ❑ Select the correct size VFD
- ❑ Ensure correct installation
- ❑ Adjust settings and controls

Ventilation systems

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

Waterers

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

GREENHOUSES

Greenhouses provide natural and supplemental light to plants to boost growth and extend the growing season. The amount of light supplied to leaf surfaces directly affects plant growth. Providing the correct wavelength and intensity is essential to meet the photosynthesis needs of each plant. You can keep production costs low by considering energy-efficient lighting in greenhouses.

Recommendations

Step 1 – Upgrade to LED lights

Light emitting diode (LED) lights offer an economical solution to reduce production costs by up to 70%. LEDs can alter the light spectrum to provide the appropriate wavelengths to optimize plant growth and appearance without increasing operating costs. This technology is more efficient and has the potential to be designed with a vast array of light output levels, optical distributions and controls, which were not possible with older lighting technologies (T. Pocock, 2015).

Aside from the wattage savings, LEDs can be customized for particular crops. For example, some studies have shown LED grow lights can reduce the production costs of tomatoes by 25% compared to traditional high-intensity discharge lighting (Devesh, 2012). If non-stacked indoor farms converted 96% of the HID and linear fluorescent lighting fixtures to LED, it would result in over 41% energy savings (Energy Savings Potential of SSI in Horticultural Applications, 2017).

It is essential 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 meeting crop-specific needs while aiming to reduce overall energy costs.

Step 2 – Install lighting controls

Consider achieving additional energy savings by installing dimming controls to adjust light levels when there is natural light available. Timers 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.

Step 3 – Perform routine maintenance

LEDs are low maintenance due to the longevity and sturdiness of the fixtures. These lights have reduced heat stress to plants because of the moderate amounts of radiant heat given off the fixtures. For this reason, LEDs can be mounted closer to plants. Ensure the fixture's longevity, including efficacy, by performing frequent cleanings to remove dirt or film buildup.

Ventilation in a greenhouse is essential to keeping temperature, moisture levels, and air pollutants in check. The main goal is to continuously swap inside air with fresh outside air to maintain desired 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.

Recommendations

Step 1 – Utilize natural ventilation

Natural ventilation removes heat by creating a pressure difference between the wind and temperature using a series of roof and sidewall vents drawing cooler air into the greenhouse. Table 4 below compares the pros and cons of natural ventilation.

Table 4: Natural ventilation comparison

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)

Step 2 – Use properly sized fans

Size fans to achieve the recommended 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. A VFD on a fan can automatically adjust air speeds and conserve energy when maximum airflow is not needed. Compare fan ratings from BESS Labs to ensure efficiency.

Rule of thumb:

The larger the fan diameter, the more efficient the fan will be. It's almost always more economical to run a few large fans than many small fans to achieve the same airflow rate. Fans should have a greater CFM/watt at 0.1 static pressure.

Step 3 – Locate fans appropriately

Fans are most effective if their total air draw is less than 150 feet. In most cases, align fans at one end of a greenhouse with inlet louvers positioned at the other end, so a gentle, steady breeze travels the greenhouse's length. 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. Invest in fans certified efficient by an accredited fan testing company.

Step 4 – Install continuous louvers

Utilize continuous louvers over fixed louvers for 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, helping 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 primary air flow stream is flowing directly through the greenhouse canopy. Lubricate louvers to reduce air infiltration. This will help to maximize the evaporative cooling effect on the plants (Massachusetts, 2012).

Step 5 – Perform annual maintenance

Maintaining current ventilation systems provide a cost-effective and straightforward way to improve fan performance in a greenhouse. Growers performing annual service maintenance on fans will save on energy costs while adding extra years of service. Annual maintenance should include:

- Cleaning ventilation system
- Checking fans and motors
- Testing belt tension
- Cleaning and calibrating thermostats
- Optimizing controls

Commercial greenhouses in Wisconsin typically require supplemental heat 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.

Recommendations

Step 1 – Select the appropriate type of heating system

Centralized systems

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

Localized heating systems heat specific areas of a greenhouse, not the entire building. Hot air units called unit heaters in this type of heating system 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

Bottom heating systems offer the most significant opportunity for a reduction in energy costs. By moving heating pipes and air distribution systems from overhead to either under a bench, on the floor, or in-floor, you can save 20 to 25% in heating costs and have faster plant growth. One study reported a 7% increase in tomato production, primarily due to a 7-degree rise in median root temperature (Sanford, 2011).

Step 2 – Verify the heater's efficiency rating

Efficiency ratings show how much of the fuel burned is converted to heat. Thermal efficiency is a rating of the individual unit while operating. Seasonal efficiency takes into consideration the entire system as it runs throughout the whole heating season. High efficiency condensing unit heaters have an additional heat exchanger extracting more heat from the exhaust air which increases efficiency by about 10% (Sanford, 2011).

Step 3 – Explore alternative heating systems

Several solar heating systems are worth considering 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 likely be necessary.

Another option is an active solar or subterranean system that captures hot air from the greenhouse's peak during the day and directs it to ducts below the soil that runs 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).

Step 4 – Perform routine maintenance

Performing routine maintenance of heating systems is important to maintain energy efficiency. Many companies offer annual checkups and additional maintenance support a checkup may not cover.

Annual heating system checkup includes:

- Changing fuel filters
- Cleaning nozzles
- Checking valves and controls
- Checking and aligning belts
- Lubricating bearings
- Testing combustion efficiency
- Removing soot from inside the firebox

Other recommended maintenance tips:

- Cleaning thermostats regularly and calibrating them annually
- Replacing deteriorating unit heaters
- Ensuring gas burner flame burns as blue as possible, yellow indicates insufficient air
- Insulating heating pipes and air ducts in headhouses and boiler rooms

Heating is one of the most substantial 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 external conditions, to minimize heat loss and improve energy efficiency.

Recommendations

Step 1 – Consider infrared (IR), anti-condensation treated films

Many greenhouses use a double-layer of polyethylene to minimize heat loss. It helps to retain heat but is far from the most efficient solution. Opting for a combination of IR/anti-condensation treated film will reduce space heating energy use by 10 to 20% and eliminate condensation problems. Install treated film inside the greenhouse with a standard film installed on the outside. The installation costs are low – typically an extra $0.02 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. Reduce heat loss even more by installing two layers of polyethylene inflated with a slight air space between the layers and an inner layer having an IR inhibitor.

Step 2 – 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 significantly 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 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.

Step 3 – Install night curtains

A movable insulated curtain is a great way to minimize nighttime heat loss. Optimize energy savings by closing curtains at sunset and retracting at sunrise. There are several types of curtain materials:

- **Porous** curtains cut heat loss by 20 to 30% allow water to drain through and can be used for shade in the summer.
- **Non-porous** aluminized materials provide up to 70% 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%, provide summer shade, and efficiently drain condensation.

Step 4 – Reduce infiltration

Tightening up a greenhouse and sealing the gaps can reduce heating bills by 5 to 10%. Avoid infiltration and heat loss during the winter months by repairing malfunctioning ventilation fan louvers.

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.

Recommendations

Step 1 – Install a thermostat

Thermostats are essential in maintaining an accurate temperature throughout the greenhouse. If you purchase a new thermostat or controller, 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 the 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.

Step 2 – Set a neutral zone

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.

Step 3 – 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 the afternoon, so deciduous trees planted on the western side create shade across the greenhouse as the day moves along, acting as natural air conditioning. 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.

Step 4 – Utilize computerized temperature controls

Computerized temperature controls optimize and automatically control the staging of heating and ventilation systems based on the growing requirements. Manage thermal curtains, lighting, irrigation systems, humidity controls and CO_2 using computerized controls. Record data to determine and monitor seasonal conditions. It reduces equipment run time, saving energy by 3 to 12% (2012, MFEP Best Practices). Work with a qualified expert to effectively program computerized temperature controls.

Variable frequency drives (VFDs) installed on well pumps significantly decrease greenhouse energy costs. In addition to reduced energy costs, greenhouses installing a VFD on their well pump can expect to see improved process control and extended usable life of the pump. VFDs can reduce a pump's energy use by as much as 50%. The VFD will pay for itself over time through the savings from reduced energy use. Usually, the payback will range from a few months to less than three years, making it a feasible investment for greenhouses.

Recommendations

Step 1 – Select the correct size

Ensure the VFD is sized correctly for the application. If a unit is oversized or undersized, it will not perform well nor yield the expected energy savings.

Step 2 – Ensure correct installation

A VFD is extremely sensitive to its surrounding conditions. Contain the electronic device in an approved enclosure to protect it from dusty and damp conditions. Lightning strikes can also damage VFDs, so they should be installed with proper grounding. Keeping the VFD in a clean environment heated in the winter will help to prolong its useful life. It would be best if you also located the VFD as close to the well pump as possible. You can reduce electromagnetic emissions when placed within ten feet of the pump.

Step 3 – Verify settings and controls

Match the minimum speed setting of the VFD to the system's needs. Operating a VFD below the manufacturer's recommended minimum speed may reduce the lifespan of the equipment.

Energy efficiency checklist

Lighting systems

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

Ventilation systems

- ❑ Utilize natural ventilation
- ❑ Use properly sized fans
- ❑ Locate fans appropriately
- ❑ Install continuous louvers
- ❑ Perform annual maintenance

Heating systems

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

Heat loss solutions

- ❑ Consider infrared (IR), anti-condensation treated films
- ❑ Insulate greenhouse side walls
- ❑ Install night curtains
- ❑ Reduce infiltration

Climate controls

- ❑ Install a thermostat
- ❑ Set a neutral zone
- ❑ Plant trees
- ❑ Utilize computerized temperature controls

Variable frequency drives

- ❑ Select the correct size
- ❑ Ensure correct installation
- ❑ Verify settings and controls

CROP FARMS

A significant component of energy consumption on a crop farm is the energy used to dry harvested crops. Grain typically has a moisture content of 20 to 30% during the harvest period. Drying the grain is necessary to reduce moisture to acceptable levels before selling the grain to the open market. Before long-term storage, grain drying is essential 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 than other crops such as soybeans or wheat. By implementing drying techniques to reduce the amount of energy needed to dry the grain, you can lower associated utility costs.

Types of grain dryers

Ambient air drying

This technique uses the natural drying potential of air instead of fuel energy which can result in an extended drying period. Tests have shown this process to use 25 to 50% 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% moisture content. Although ambient air drying consumes less energy than applying gas burners or electric heating coils to raise the air temperature, it is more expensive by using electricity to dry the grain using a low-temperature bin dryer.

High-temperature drying

This 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 can 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).

Mixed-flow drying

Mixed-flow dryers are column dryers with air flowing in counter and concurrent directions. By using multiple zones, these dryers use higher air temperatures without damaging crops. These dryers are usually self-cleaning and use about 40% less energy to dry a wide variety of grains, from small rapeseed to corn or soybeans. Mixed-flow style grain dryers are more fuel efficient and are scalable to increases in drying needs (Continuous Flow Grain Dryers, 2020).

Combination drying

This technique uses high temperatures to dry grain to approximately 20% moisture content and then finishes with ambient air or low-temperature drying. This practice can reduce energy use up to 60% when compared to high temperature drying alone and has been shown to improve grain quality. This technique is less expensive than ambient air or high-temperature drying (Madison Gas & Electric, 2015).

Recommendations

Step 1 – Delay harvesting

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

Step 2 – Clean the grain

Before 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.

Step 3 – Install moisture sensors

Use moisture sensors and an automatic monitoring system to verify moisture levels and avoid over-drying and excess energy use. Annual calibration of moisture sensors will ensure the readings remain accurate.

Step 4 – Upgrade the dryer and install a cooling bin

If your existing grain dryer is 20 to 30 years old, consider replacing with a newer, more efficient model. Maximize energy savings through mixed-flow or combination drying techniques. These methods of cooling help to reduce energy use, increase dryer capacity and achieve higher quality kernels. Choose models with heat recovery, differential roller speeds or other energy-saving features.

Step 5 – Perform routine 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 full combustion is occurring. If it is not, the burner needs a tune-up to correct the problem and return to its standard operating efficiency.

Irrigation is an essential component of farming and accounts for over 70% of electricity usage (Irrigation, 2020). The connection between efficiency and energy savings comes down to the way irrigation systems are designed or modified. Maintaining efficient irrigation systems and using energy-efficient equipment can reduce unnecessary water use contributing to additional energy savings.

Recommendations

Step 1 – Ensure proper spacing of low-pressure nozzles

Optimize your energy savings while providing adequate irrigation to crops. Water will spread less at low pressures, so space low-pressure nozzles close enough to irrigate the same area equally. Save energy by applying the same amount of water to crops in less time. In some situations, all of the necessary irrigation can occur overnight while reducing the amount of time needed to irrigate. It minimizes evaporation and also avoids operating electrical equipment during on-peak electrical times (UW-Extension, 2012).

Step 2 – Reduce the size of the well pump

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

Step 3 – Install a VFD on the irrigation pump

Another opportunity for energy savings is installing a variable frequency drive (VFD) on the irrigation pumps. A VFD on the irrigation pump allows the pump to speed up or slow down to provide uniform water application and maintain the correct pressures throughout the irrigation system(s). Typically a VFD will be most beneficial for systems with 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.

Step 4 – Reduce system pressure

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 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% reduction in energy costs (Madison Gas and Electric, 2015).

Step 5 – Consider irrigation scheduling

Irrigation scheduling is another option to cost effectively optimize crop production. A computer-based system along with moisture sensors can help 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 necessary.

Step 6 – Perform preventative maintenance

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

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

Recommendations

Step 1 – 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 meet the required airflow for your crops while remaining energy efficient. Table 5 below outlines different types of crops and the associated airflow recommendations.

Table 5: Crop farming 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

(Wilcke, 2013)

Step 2 – Opt for variable speed fans and motors

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

Step 3 – Select the appropriate type of fan

The four main types of ventilation fans in crop farms are **tube-axial** and **vane-axial**, **centrifugal**, and **in-line centrifugal**.

- **Tube-axial and vane-axial fans** are most commonly used for aeration and grain drying. They are relatively efficient and inexpensive; however, they create a lot of noise.
- **Centrifugal fans** are mainly used 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 due to the noise level in many applications (Madison Gas and Electric, 2015). They can be used in any application where large volumes of air are desired, and there is a low static pressure requirement.

Rule of thumb:

As the fan diameter increases, the fan energy efficiency also increases

Certain crops also benefit from energy-efficient HVLS fans. Refer to the Dairy and Livestock Ventilation section on pages 16 to 17 of this guidebook for information regarding energy-efficient ventilation for agricultural facilities.

Step 4 – Perform routine maintenance

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)

Lighting systems

Please refer to the Dairy and Livestock Lighting section on pages 6 to 9 of this guidebook for information regarding energy-efficient lighting for agricultural facilities.

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.

Recommendations

Step 1 – Practice produce precooling

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

Step 2 – Ensure proper 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 the infiltration of warm air through doors, cracks and other openings.

Step 3 – Install energy-efficient equipment

Farmers should utilize energy-efficient compressors, heat exchangers, refrigerants and other pieces of equipment whenever possible.

Step 4 – Perform routine maintenance

Regular maintenance of the refrigeration areas and equipment will ensure energy costs do not increase over time. Keep refrigeration areas clean to avoid dust and debris build-up, which can retain heat. The owner should also inspect insulation as well as 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 leaks.

Conveyors, mixers and augers are essential for moving crops and other agricultural processes. Motors for these applications are typically sized to drive equipment at the maximum power needed for full load capacity. When conveyors or other constant torque equipment are operating at less than full load, energy can be saved by installing a variable frequency drive (VFD). Determine if a constant torque VFD is needed by answering the following questions:

- Is there a significant variance in the load amount a conveyor, mixer or auger has while operating?
- Does the equipment run more than 500 hours per year?

If you answer “yes” to both of these questions, then the equipment is a candidate for a VFD. Consult with your Trade Ally contractor and Energy Advisor to ensure a VFD is right for the specific application.

Recommendations

Step 1 – Turn equipment off when not in use

Avoid frequent motor replacements by reducing unnecessary runtime. Consistently turning off a motor, even 10% of the time, can save significant energy over the equipment's life. Consider installing automatic shutdown timers to turn motors off when running idle or unloaded for a specified period (Turn Motors Off When Not in Use, 2012).

Step 2 – Adjust VFD settings

When using VFDs, it’s critical to understand the application and match the drive accordingly. Consider the operating profile of the load. Constant torque applications, such as conveyors, mixers and compressors, must have careful attention brought to overload ratings. Avoid the risk of drive overload by sizing the VFD based on its maximum current requirements and peak torque demand. An oversized motor is less efficient than a properly sized motor (Selecting and applying VFDs, 2015).

Step 3 – Specify premium efficiency motors

Consider premium efficiency motors when choosing motor-driven equipment. Establish a premium motor replacement policy for future energy and cost savings (When to Purchase Premium Efficiency Motors, 2012).

Step 4 – Perform routine maintenance

VFDs should be kept clean and dry and made sure the connections are tight and secure. Inspections should be performed per the manufacturer's recommendations. In addition to visually inspecting the device, you should consider setting up a replacement schedule for expendable parts (How VFD Maintenance Can Save Your Bottom Line, 2020).

Energy efficiency checklist

Grain dryers

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

Irrigation systems

- ❑ Ensure proper spacing of low pressure nozzles
- ❑ Reduce the size of the well pump
- ❑ Install a VFD on the irrigation pump
- ❑ Reduce system pressure
- ❑ Consider irrigation scheduling
- ❑ Perform preventative maintenance

Ventilation systems

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

Lighting systems

- ❑ Correct light levels
- ❑ Upgrade to energy-efficient fixtures
- ❑ Utilize timers and motion sensors
- ❑ Implement long-day lighting
- ❑ Consider other lighting strategies
- ❑ Perform routine maintenance

Refrigeration systems

- ❑ Practice produce precooling
- ❑ Improve insulation to reduce infiltration
- ❑ Install energy-efficient equipment
- ❑ Perform routine maintenance

Constant torque motor VFDS

- ❑ Turn equipment off when not in use
- ❑ Adjust VFD settings
- ❑ Specify premium efficiency motors
- ❑ Perform routine maintenance

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