Massachusetts

Farm Energy

Best Management Practices for Dairy Farms

Massachusetts Farm Energy Program

Conservation • Efficiency • Renewables

Massachusetts Farm Energy Best Management Practices

Berkshire-Pioneer Resource Conservation & Development Area
GDS Associates
Massachusetts Department of Agricultural Resources
Massachusetts Farm Energy Program
USDA Natural Resources Conservation Service

Amherst, Massachusetts · 2012

MASSACHUSETTS FARM ENERGY GUIDES BY FARM SECTOR

This guide is part of a series of farm energy Best Management Practice guides, available for the following sectors and topic areas:

Dairy Farms

Greenhouses

Maple Sugaring

Orchards & Vegetable Farms

Renewable Energy

BEST MANAGEMENT PRACTICES FOR DAIRY FARMS

In this guide, you will find the following best management practices:

Energy Efficient Lighting

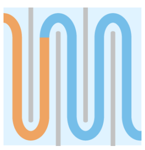
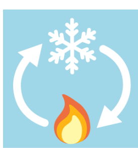
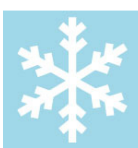


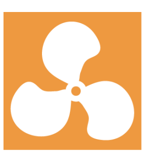
Plate Cooler (Well Water Pre-Cooler)



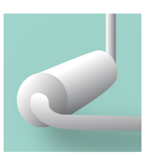
Refrigeration Heat Recovery (RHR) / Fre-Heaters



High Efficiency Refrigeration and Scroll Compressors



Energy Efficient Ventilation



Variable Speed (VS) Vacuum Pump

Low and No Energy Waterers


Whether you are a new or experienced farmer, energy expert, or agricultural service provider, we created this guide to save you time, effort, and ENERGY!
Jessica Cook, BP RC&D, 2010

Welcome to the Massachusetts Farm Energy Best Management Practices Guide

Practical solutions & entry points

This guide is about practical steps you can take immediately, with a focus on the most common and cost-effective equipment upgrades and systems currently available for farms in our region.

For farmers who are managing a constant flow of weather events and day-to-day business needs, we offer an entry point to on-farm energy savings and renewable systems that make use of the technical skills and systems-thinking of our local community.

Thinking of systems from the start

The farm energy guide is organized by sector, focusing on retrofits that work for existing farming operations. However, farmers can also apply the guidance provided in these pages to incorporate energy issues into the planning and initial design stages of new agricultural businesses.

There is an increasing amount of interest in energy among the state's farmers, and examples in this guide can provide a launchpad for more innovative energy systems in the future.

The goals of these energy best management practices are to:

Strengthen farm businesses
by lowering operating costs, reducing labor, and increasing profits over time.

Reduce environmental impacts
of the agricultural sector, with a focus on lowering carbon emissions.

Help farms transition
into the next generation by utilizing efficient technology and forward-thinking design.

Jessica Cook, BP RC&D, 2010

Sometimes you just need a place to start—
—based on good information and solid economics.

We hope that by breaking things down by process or technology—looking at average savings and commonly recommended measures—we offer readers a place to start their projects.

We know for many farms economic feasibility is the first question when it comes to on-farm energy projects—is the investment worthwhile?

We have highlighted estimated payback periods in the following pages, identifying the number of years an upgrade will take to pay for itself.

While we calculate the dollar savings in fossil fuels or other energy sources, it's important for you to consider other benefits on the farm, such as reduced farm labor or increased sales resulting from greener systems.

The examples in this guide are drawn from real life, based on averages across farms in Massachusetts who have worked with MFEP, so payback numbers are directly applicable to the scale of farms in our region.

Encouraging climate and resources

Forward-thinking energy policies at the state level have combined with supportive agencies and utility programs, financial incentives, and good partners to provide fertile ground for farm energy projects in Massachusetts.

We are enthusiastic about the energy future of the agricultural community in our region, and acknowledge the motivated farmers who are open to sharing their experiences, the willing auditors, and the proactive installers who are getting projects up and running.

We encourage you to take advantage of these key resources to move ahead with your own farm energy project!

— the Massachusetts Farm Energy Program team

Acknowledgements

This Farm Energy Best Management Practices Guide was compiled and written by GDS Associates, Inc. (GDS) for the Massachusetts Farm Energy Program (MFEP). Specifications and recommendations in this document are based on industry-specific research and informed by the audits and projects implemented with the assistance of the Massachusetts Farm Energy Program (MFEP) between 2008 and 2010.

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Contents


Catherine Ulitsky, NRCS, 2009

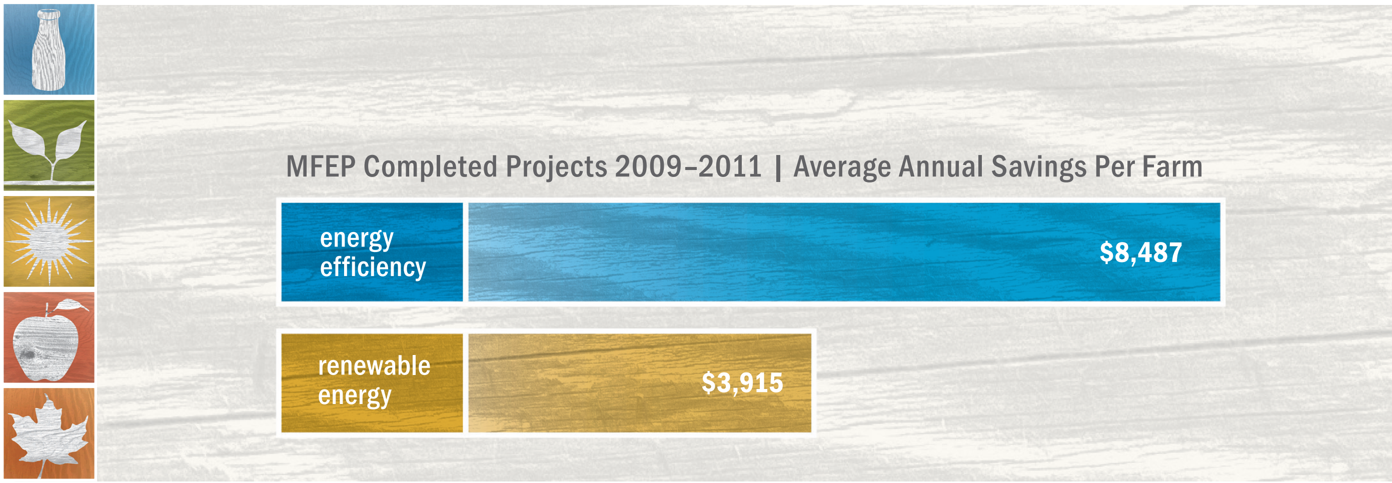
Introduction

The *Massachusetts Farm Energy Best Management Practices Guides* provide the Commonwealth's agricultural community with resources and methods to reduce energy use and produce renewable energy on farms. These recommended on-farm energy upgrades improve farm viability and minimize the environmental impact of the agricultural industry in Massachusetts by reducing energy consumption, operating costs, emissions, and dependence on fossil fuels.

These guides focus on conventional energy best management practices (BMPs)—cost-effective practices that offer significant environmental and economic benefits—for the four primary agricultural sectors represented in the Commonwealth: greenhouses, dairy farms, orchards and vegetable farms, and maple sugaring. They also cover considerations for on-farm renewable energy options, including wind, solar thermal, solar photovoltaic and biomass.

This document aims to be a practical resource for farmers and service providers alike, organized to help readers understand farm energy use, evaluate potential equipment upgrades, and prioritize energy efficiency and renewable energy applications. These recommendations can also be used to inform policy, technical assistance programs, and government agency and public utility cost-share programs for energy efficiency and renewable energy on farms.

The information in this guide is based on industry-specific research and Massachusetts Farm Energy Program (MFEP) data from more than fifty energy projects implemented between 2008 and 2010. For applications not covered in this document, additional information can be found by contacting MFEP.



Environmental Impact of Energy Use

Energy conservation and renewable energy systems on farms can help reduce the use of fossil fuels and related greenhouse gas emissions, and mitigate the contribution of Massachusetts agriculture to point-source pollution and global climate change.

Massachusetts' farmers can set an example for other industries in the region by making viable business decisions that improve operations and profitability while reducing negative environmental impacts of "business as usual."

MFEP's experience illustrates farms' improved environmental performance—through reduced carbon dioxide emissions—as a result of energy efficiency and renewable projects.

Economic Benefits of Energy Savings

New England farmers pay 23-56% higher rates for energy resources than the U.S. average. As farmers identify the source of their energy demand and make improvements to their systems, they can reduce their dependence on fossil fuels and improve their bottom line. MFEP's work with has assisted farmers do exactly that, thus having a direct impact on the financial viability of many Massachusetts farms.

The average net income of a Massachusetts farmer is just over $12,000 according to the National Agricultural Statistics Service. At the same time, average annual energy savings from farm energy efficiency projects facilitated through MFEP average out at $12,000 per farm in 2009–2010, thus making energy efficiency improvements a sound business decision that can have a significant impact on overall farm viability. The economic benefit of these savings is further multiplied as farmers reinvest in the local economy in a variety of ways as they maintain and build their businesses.

It is important to note that energy projects result in different rates of financial returns for farms, either through reduced energy use or offsetting fossil fuel use with renewable energy. Renewable projects can work out favorably in terms of overall return on investment for farms, particularly with the support of grant and payment programs. However, efficiency projects save 2.5 times more energy on average than renewable systems replace per dollar invested.

Catherine Ulitsky, NRCS, 2011

About the Massachusetts Farm Energy Program

What is the Massachusetts Farm Energy Program?

The Massachusetts Farm Energy Program (MFEP) is a full-service program for technical and financial assistance for farmers and agricultural businesses. It is a statewide collaborative effort, bringing together federal, state, industry, and private support to streamline resources available to Massachusetts farmers in order to:

1. increase on-farm energy conservation and efficiency,
2. promote alternative and renewable energy strategies for on-farm energy generation,
3. improve farm viability by reducing energy consumption and costs, and
4. reduce agricultural greenhouse gas emissions.

MFEP has offered a range of services to the farming community, including technical assistance, audits and consultations, financial incentives, and facilitation to leverage funds to bring projects from initial concept to implementation.

MFEP is a joint project of the following partners:

Massachusetts Department of Agricultural Resources (MDAR)
www.mass.gov/agr

USDA – Natural Resources Conservation Service (NRCS)
www.ma.nrcs.usda.gov

Berkshire-Pioneer Resource Conservation & Development Area (BPRC&D)
www.berkshirepioneerrcd.org

Why MFEP?

Electricity and fossil fuel costs have increased by approximately 30% in the last few years. The impact on farms has meant a dramatic increase in costs related to power, refrigeration, heating, ventilation, lighting, transportation, fertilizer, and feed. Rising energy costs reduce profit margins for all farmers and directly threaten the viability of farms across the Commonwealth.

The agricultural community has not maximized energy savings in part due to challenges in navigating an ever-changing landscape of support programs. MFEP streamlines these resources and provides direct technical assistance through energy audits, renewable energy assessments, and incentives for implementation of audit recommendations, including those recommended by public utility programs.

As a result of complex partnerships between farm business owners, government agencies, for-profit practitioners, and public programs, farm energy upgrades are contributing to the region's environmental goals and stability and resilience of our agricultural communities.

Massachusetts Farm Energy Program
Conservation • Efficiency • Renewables

As a rule of thumb, dairy farms use between 700 to 1,200 kWh per cow-year, or about 3.5 to 6 kWh/cwt (hundredweight) of milk produced.[1]

How much does your farm use?

Jessica Cook, BP RC&D, 2009

Dairy farms have many practical opportunities for energy saving measures—including recycling the heat from milk, and from refrigeration, to heat water.

Best Management Practices for Dairy Farms

Dairy farms are an important part of Massachusetts agriculture, with about 310 farms and an annual commodity worth of $50,485,000 for milk and other dairy products from cows according to 2007 census data. **Proper energy management can help dairy farms decrease production costs, making for more viable farm businesses.**

The first step in proper energy management is to learn about best practices. This handbook will help you consider potential options and whether these options are applicable to your farm.

The second step is to consider an energy audit. An energy audit can help determine which energy efficiency measures are most appropriate for your facility and operations, based on existing conditions and equipment. The audit will point out the major energy users and ways to save money through energy conservation and efficiency.

To help you get started on what best practices to consider, ask yourself the following questions:

Do you...	Then...
Use long-day lighting or have an outdated lighting system that runs at least a few hours a day?	Consider replacing with energy efficient lighting.
Not use a plate cooler or a refrigeration heat recovery (RHR) unit?	Consider installing either a plate cooler or a RHR unit if fewer than 100 cows and consider both if over 100 cows (read both sections).
Have a refrigeration compressor that runs in excess of an hour after you finish milking?	Either your compressor is undersized and you should consider a plate cooler to decrease run time or your compressor has a low efficiency and you should consider a tune-up (read High Efficiency Refrigeration).
Have a compressor that failed, needs replacement soon, or has a low efficiency?	Consider installing a higher efficiency scroll compressor.
Have older ventilation fans that are poorly maintained?	Consider installing new higher efficiency fans and follow the recommended maintenance strategy.
Have a long milking time and/or think your vacuum pump is oversized?	Consider a variable speed for your vacuum pump.
Use old waterers that are poorly insulated and have large heating elements?	Consider new low or no energy waterers.


Diane Petit, NRCS, 2005

Energy Efficient Lighting

At a Glance:

- CFLs use 75% less energy, last 6–10 times longer
- 40% energy savings using HPT-8 compared to T-12
- Longer life means lower maintenance and labor costs

Appropriate and energy efficient lighting plays a large role in dairy performance. It can both increase milk productivity as well as improve working conditions, making it a safer and more productive place to work for employees.

When considering a lighting upgrade, it is important to choose the best light design possible, one that will provide the necessary amount of light for the given task at the minimum possible cost (both fixed and operating costs).

There is no one size fits all approach and a certified lighting professional should be consulted when considering a lighting upgrade.

In Massachusetts, farms can take advantage of electrical assessment programs and incentive payments through public utilities' participation in MassSAVE.

Simple lighting upgrades like replacing T-12 with T-8s can pay for themselves in less than a year with energy savings and utility incentives.

Individual Edison Style Light Bulbs

Used for over 100 years and most common in older facilities, the Edison style incandescent lights bulbs are very inefficient, converting only 5–10% of the used energy to light, with the rest wasted as heat. They also have a short life span (600–2,000 hours).

It is recommended to replace these with Energy Star certified compact fluorescent lamps (CFLs). CFLs are an easy and direct replacement for incandescent bulbs. They use 75% less energy and have a life span of 6,000–10,000 hours (6–10 times longer).

Guide to Replacing Incandescent Bulbs with Equivalent CFLs[2]

Incandescent Bulb (Watts)	CFL (Watts)	Light Output (Lumens)	Energy Savings (Lamplife)
40	13	490–510	$17
60	15	870–950	$33
75	20	1190–1300	$42
100	23–27	1500–1690	$62
120	26–30	1750–1920	$67
150	32–40	2050–2600	$70
200	45	2700	$94
240	55	3600	$114
300	68	4200	$117

Data from *Compact Fluorescent Lighting on Farms*, by the Focus on Energy program.

Energy Star-certified models come with a two-year warranty, have a minimum rated lifespan of at least 6,000 hours, and do not emit an audible noise (which can be common with cheaper CFLs).

Also, CFLs come with various temperature ratings and it is important to look on the box before purchasing. They are typically rated for either 32°F or 0°F. CFLs operating near their rated temperature may take a few minutes to warm up to get to full output.

Individual Edison Style Light Bulbs (continued)

In a dairy setting it is best practice to replace any open light fixtures with a sealed and gasketed fixture in order to be compliant with code. If replacing many old Edison style fixtures in the same room, consider upgrading to HPT-8 (see high and low bay lighting on following pages).

Cold cathode fluorescent lamps (CCFLs) are also an option in cases where either a dimmable light is necessary or where an extremely long life lamp life is important (rated for 25,000 hours).

GDS

They are ideal for applications where reduced maintenance and energy costs are desired (especially in hard to reach lighting installations).

Fluorescent lamps come in a range of colors, measured on the Kelvin scale. Use the following as a reference guide to pick the right color:[3]

Warm & Soft White		Cool & Bright White		Natural or Daylight	
Standard color of incandescent bulbs		Good for workspaces		Good for reading	
2700K	3000K	3500K	4100K	5000K	6500K


Diane Petit, NRCS, 2004

Low Bay Lighting (< 12 feet)

The most common type of light found in tie-stall barns and shops/buildings with ceilings lower than 12-feet are linear fluorescent tubes. They come in two lengths (4-feet and 8-feet) and in different diameters, measured in eighths of an inch. The old standard, found in most tie-stall facilities (or any low bay applications) that have not updated their lighting in the past 5–10 years, is the T-12 (12⁄8” or 1½” diameter) or T-8 (1”) which use magnetic ballasts.

The best practice for low bay lighting is to install a sealed and gasketed CEE certified HPT-8 lighting system. It is the safest, most efficient, and cost effective lighting application for low ceiling farm facilities.

The Consortium for Energy Efficiency (CEE) is a nonprofit public benefits corporation that promotes the manufacture and purchase of energy efficient lighting. They provide a listing of certified HPT-8 lamps and ballasts for 4-foot, 32-watt T-8 lighting systems and reduced-wattage T-8 systems.

State programs such as MassSAVE and public utility efficiency programs require that new HPT-8 systems be certified by CEE in order for customers to receive incentives. Be sure to check with your electric utility provider to determine if you are eligible for any incentives.

If increased light levels are needed in an area (such as in the center alley of a tie stall), T-5 high output (T-5HO) should be considered. They provide more lumens per fixture, reducing the number of necessary fixtures, but can also increase the chance of dark spots and shadowing if not designed properly.

High Bay Lighting (> 12 feet)

The most common type of high bay lighting in areas such as free-stalls, mechanical rooms, holding areas, and sheds is the "probe start" 400 watt metal halide.

The best practice is to install gasketed fixtures such as the pulse start metal halide (PSMH) or high ceiling fluorescents such as 3- to 6-lamp CEE certified HPT-8 fixtures. The 320-watt PSMH is a common direct replacement for the 400 watt metal halide and will use 25% less energy, have a slightly greater light output, faster warm up/re-strike, longer lamp life, up to 50% less light depreciation, and have less color variation.

When deciding between PSMH and HPT-8, work with an expert to consider upfront costs, maintenance, and lighting goals.

Be careful about installing T-5HO light fixtures with more than four bulbs due to issues relating to heat buildup in enclosed fixtures. Inquire of the manufacturer about whether the fixture has been temperature tested and rated for the conditions it will be placed in (cold to hot climates) and ensure the warranty will be honored for the given conditions.

Milking parlors are at the center of potential energy savings—efficient lighting, plate coolers, and variable speed drives for the vacuum system all link into milking time.

Applications & Limitations

Lighting upgrades are applicable in most cases. Cost-effective upgrades may be more limited if lights have minimal use over the year.

Minimum Standards & Recommendations

- Be sure to follow all local electrical codes. Older codes did not require fixtures to be enclosed and it can be common to come across open fixtures. Any new lighting upgrade should be accompanied by a sealed and gasketed or wet location rated fixture unless the area is a conditioned semi-clean work environment. An IP rating of 66 or 67 is recommended, meaning it is totally protected against dust and protected against strong jets of water. Utilizing these fixtures will minimize stray voltage concerns, reduce moisture and dirt facilitated failure, and allow for easier cleaning and upkeep.
- Choose HPT-8 lamps and ballasts that are CEE certified. It is recommended to choose a high lumen and long life lamp with a minimum initial lumens of 3,100 and a rated life of 24,000 hours.
- Be aware of typical mounting heights for a given fixture. Have a lighting analysis conducted for each system installed. Pick a fixture with a lens and reflector that promotes an even spread of light for a given area and height.
- Be sure to verify the temperature and humidity rating of the light fixture to ensure it will work as designed in the given environment. In cases where there is a chance of lamp breakage, it should be enclosed in order to protect it.
- Light levels gradually change as they age. Be sure to change lamps as recommended per the manufacturer to ensure adequate light levels are maintained as designed.
- It is recommended to install lighting controls such as timers, motion sensors, and daylight sensors as a conservation strategy to avoid light use when not required.

Energy Savings

Energy savings of a fixture can be calculated by the following equation:

Annual Energy Savings [kWh]=

$$\left[\frac{\text{old [watts]} - \text{new [watts]}}{1000}\right] \text{ x daily hours of use x 365 days}$$

When compared to a T-12 system, electricity savings of a HPT-8 system can be as high as 40%.

Lighting systems meeting the CEE specifications are generally 10–20% more efficient than standard T-8 systems. A 320 watt PSMH will save 25% of the energy use (115 watts) over a 400 watt metal halide.

Environmental Impact & Other Benefits

Be sure to properly recycle all lamps as required, including all fluorescent and high intensity discharge (HID) lamps such as metal halides and high pressure sodium (HPS).

For more information about proper recycling, visit: www.epa.gov/bulbrecycling.

Economic Benefits

The actual savings of installing new light can vary greatly depending on factors such as installed costs and annual hours of use.

To determine a simple payback, take the installed cost and divide by the annual energy savings (as determined from the above equation or the online calculator at www.ruralenergy.wisc.edu).

It is usually recommended to replace light fixtures when the simple payback is less than 5 years. New light fixtures with a long rated life can decrease maintenance and labor costs.

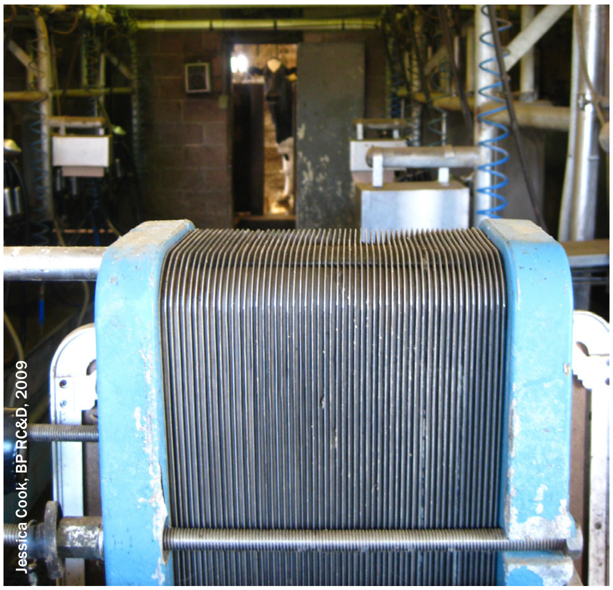
Some typical costs for various fixtures are:

Lighting Upgrade	Cost*
23 watt CFL	$4
320 PSMH	$240
Retro, (2) 4' HPT-8 lamps, (1) EB	$65
2-lamp, 4' HPT-8, vapor tight	$120
4-lamp, 4' HPT-8, vapor tight	$150
6-lamp, 4' HPT-8, vapor tight	$240
2-lamp, 4' T-5HO, vapor tight	$145
4-lamp, 4' T-5HO, vapor tight	$290

*Values will vary due to installation costs.


Jessica Cook, BF RC&D, 2009

Plate Cooler (Well Water Pre-Cooler)


Jessica Cook, BP RC&D, 2009

At a Glance:

- Pre-cools milk before enters bulk tank
- Saves 40–50% on cooling cost
- Reduces run time of refrigeration system, extending the life of the equipment
- Helps cool milk faster, increasing milk quality
- Produces warmed well water for watering or wash-down

A plate cooler is used on dairy farms to pre-cool milk before it enters the bulk tank. It is a heat exchanger that transfers heat between two fluids: warm milk and cool well water.

Warm milk enters the plate cooler at temperatures ranging from 95–98°F and well water enters at a temperature range of 50–55°F. While milk could potentially exit the plate cooler as low as 60–65°F, typically it is closer to 70–75°F (a 25–30°F drop in temperature).

Plate coolers save energy by reducing the run time of the refrigeration system, saving 40–50% on cooling costs. Water and milk flow rates are crucial to ensure that milk is being cooled properly and efficiently and to maximize the benefit of the plate cooler.

The fluids should flow in opposite directions to achieve lower milk temperatures. Plate coolers are sized by the number of plates they have and additional plates can be added to account for increases in milk production.

There is another type of pre-cooler, called "shell and tube." This type of heat exchanger is less common but operates under the same principle as a plate cooler. The shell and tube consists of many small tubes which sit inside a larger tube. They are inexpensive but come in fixed lengths (limiting future expansion) and are less effective because they have less overall surface area.

The warm discharged well water also has an indirect benefit as it can be used for watering cows, wash-down, or other purposes on the farm. It is less stressful (metabolically) for the cow to drink warmed water, and research has shown that cows will drink more water if it is warmer.

Water can be directly piped to waterers or stored in a plastic storage tank. Tanks should be sized to provide enough storage for all the water that goes through the plate cooler per milking (assuming the water will be used by the next milking).

A gallon of milk weighs 8.6 lbs. For a milking that produces 2,500 lbs. of milk, at least a 300 gallon tank is necessary, assuming a water-to-milk-flow ratio of 1:1. Oversizing the tank however, is recommended so a 400 or 500 gallon tank should be used in this case.

Applications & Limitations

Plate coolers and refrigeration heat recovery units (RHRs) are competing technologies. When considering the purchase of a plate cooler, it is important to have an energy audit completed to determine if the installation of a plate cooler or refrigeration heat recovery unit (RHR), or both, would provide greater savings as the choice is dependent on many factors (e.g. fuel source of water heater).

Based on current fuel and energy prices, a RHR unit provides greater savings compared to a plate cooler if using an electric water heater. If using a propane or natural gas water heater, an audit will help determine which would provide greater savings and the most benefit. As a general guideline, installing both a RHR unit and plate cooler may only be effective for a dairy herd size of 100 or greater.

It is also important to consider if the current water supply system (well, water pump, and piping) will have the capacity to keep up with the additional demands of a plate cooler. If not, a plate cooler may not be the best option.

A variable speed milk pump (VSMP) is an additional energy efficiency measure that can be implemented in combination with a plate cooler (see Variable Speed section for more information). VSMPs are used to slow down the flow of milk, increasing the water-to-milk ratio, resulting in increased cooling. They can also be beneficial for farms that have limited well water capacity and/or flow rate (30+ gpm).

In water systems with low capacity, increasing the size of the water system pressure tank or adding an additional pressure tank may be a solution to increase the short-term availability of water.

Not all models are easy or cost-effective to retrofit with the recommended efficiency upgrades. Considering that the life of a refrigerator or freezer is about 10 years, it is recommended to weigh retrofit costs against the cost of purchasing a new energy efficient model.

Minimum Standards & Recommendations

Plates, frames, and bolts should be stainless steel to prevent corrosion and to minimize maintenance requirements. The clean-in-place (CIP) for washing the milk pipeline will help keep maintenance costs low for the plate cooler.

A minimum water flow rate is important to ensure the effectiveness of a plate cooler. Typical 1, 2, and 3 horsepower milk pumps have flow rates of 35, 45, and 60 gallons per minute (gpm) respectively.

To achieve the maximum amount of cooling, the water-to-milk-flow ratio should be at least 1:1 up to 3:1. Water flow rate from a well is determined by the pipe diameter, pipe length, and water pressure. A minimum water line of 0.75 inches should be used, with a 1 inch water line recommended (based on a water pressure of 40 psi).

Pipe Diameter Guidelines for Minimum Water Flow[4]

Pipe Diameter	Equivalent Pipe Length	
	50 ft.	100 ft.
½"	9 gpm	6.1 gpm
¾"	27 gpm	18.6 gpm
1"	55 gpm	39.2 gpm
1 ¼"	105 gpm	71.1 gpm

Note: Water flow rate in copper and plastic pipes at 40 psi water pressure.

It is important to maximize water flow in order to take full advantage of the pre-cooler, but in order to minimize the total volume (not flow rate) of water used for pre-cooling, it is recommended to install a solenoid valve that controls well water flow and is activated only when the milk pump runs.

Another recommendation is to install a by-pass line to allow a trickle of water to run through the pre-cooler when not in use to keep the plates cool and increase overall performance (although this can also be accomplished by the solenoid valve running well water through the plates 5–10 seconds before the milk pump starts to operate).

It is recommended to either directly use the water or install a storage tank for the discharged warm well water and find a consistent use for it, rather than disposing of the water in the manure pit (incurring costs to be hauled away with the manure).

Energy Savings

A single pass plate cooler will typically cool the milk from 98°F to 71°F (a 27 degree drop), resulting in a 45% savings in energy use for cooling the milk. (These values can and will vary depending on the type of plate cooler, the size of the plate cooler, and the water-to-milk ratio.)

Also, savings will increase if a variable speed milk pump (VSMP) is installed to control the flow of milk through the plate cooler. If a RHR unit is already installed, or is being installed with a plate cooler, a more detailed analysis must be completed to determine actual savings since these technologies interact with each other.

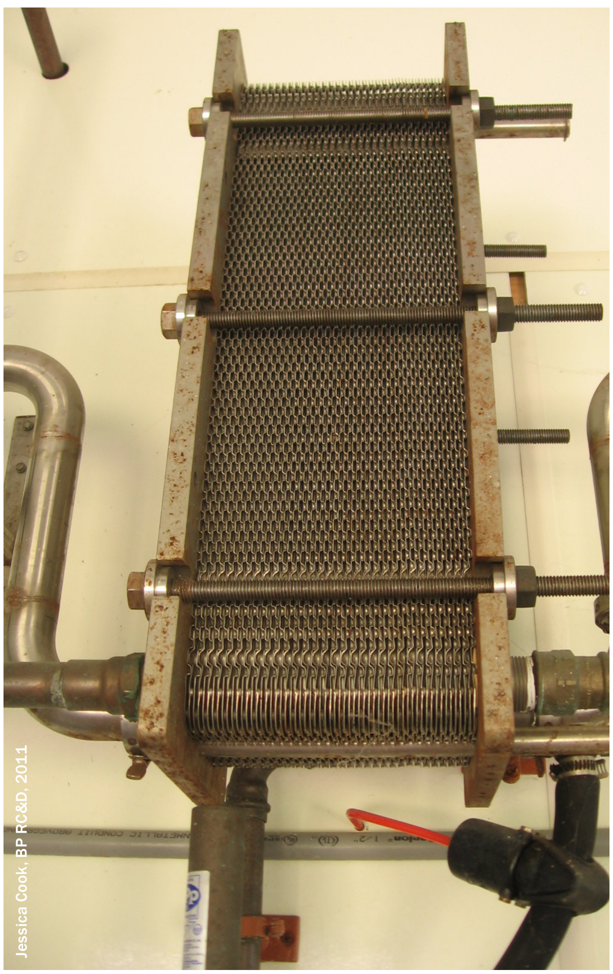
For more information regarding RHR units, please see the Refrigeration Heat Recovery section.

Environmental Impact & Benefits

- The energy savings and offset of electrical production achieved by installing a plate cooler will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the farm.
- Water conservation should be considered. Negative environmental impacts can be mitigated if plate cooler water is reused to offset drinking or wash-down water needs.
- Cooling milk down faster will help maintain higher quality milk and also impede bacteria growth.
- Reducing the run time of the refrigeration cycle can increase its operating life and reduce refrigerant leakage that has global warming and ozone depletion potential.

Additional Information

- It is important to complete an energy audit to determine the estimated energy savings and if a plate cooler is an economical option.
- Ask your dealer to guarantee the degrees of milk cooling based on the inputs (milk flow rate, water flow rate, and water temperature). If the amount of cooling cannot be guaranteed, then your actual savings may be questionable.[5]
- It is also important to talk to a plumber to ensure the current plumbing system, water capacity and flow rates will be able to handle the addition of a plate cooler.


Jessica Cook, BP RC&D, 2011

Economic Benefits

Based on an average 45% savings, the following table summarizes the potential savings based on daily milk production:

Daily Milk Production (lbs.)	Annual Savings (kWh)*	Annual Savings ($)**
2,000	2,291	$344
2,500	2,864	$430
3,000	3,437	$516
4,000	4,583	$687
6,000	6,874	$1,031
8,000	9,165	$1,375
10,000	11,456	$1,718
15,000	17,185	$2,578

* Based on 45% savings on cooling costs, compressor energy efficiency ratio (EER) of 8, and cooling milk from 98˚F to 38˚F. A lower compressor EER will increase savings.

**Based on $0.15/kWh

Estimated installed costs for a plate cooler in Massachusetts (2009–2010) ranges from about $4,500 to $5,500.


Diane Petit, NRCS, 2006

Refrigeration Heat Recovery (RHR) / Fre-Heaters

At a Glance:

- One of the most cost-effective purchases a dairy farm can make
- Pre-heats water to 110°F with "free" energy
- Cuts water heating costs by 45–55%
- Cools milk faster
- Increases longevity of water heater

Refrigeration Heat Recovery units (RHR) units are used to capture waste heat from compressed refrigerant.

This heat is typically discharged to the air using a condenser and circulation fans (air-cooled condenser), but an RHR (or Fre-Heater) transfers some of this heat to water, acting as a pre-heat, thereby reducing the energy use of the water heater.

Every pound of milk requires 56 BTUs of energy to be removed (to cool it from 98°F to 38°F). RHR units can capture 20–60% of the BTUs in the milk for pre-heating water (with 40% taken as the average).

An RHR unit is available in 50, 80, 114, and 120-gallon sizes.

The refrigerant gas, which can reach temperatures in excess of 200°F, is cycled through a heat exchanger to heat the water and then continues to the air-cooled condenser as it normally would without an RHR unit.

If sized correctly, it can heat well water from 55°F up to temperatures of 110°F or higher.

Applications & Limitations

RHR units are most efficient for farms that have an electric hot water heater, followed by propane and then natural gas.

Minimum Daily Milk Production for an 8-Year Payback Period

Fuel Source	Fuel Cost	BTU Content	Min. Daily Pounds of Milk*
Electricity (kWh)	$0.15	3,412	1,100 (>20 cows)
Propane (gallon LP)	$2.00	91,500	1,700 (>30 cows)
Natural gas (therm)	$1.10	100,000	3,400 (>60 cows)

*This is the minimum required pounds of milk to achieve an 8-year payback based on current fuel prices in Massachusetts, capturing 40% of the waste heat, installation cost of $3,000, combustion efficiency of 80% for a gas water heater and 99% for electric. The average dairy size in Massachusetts is around 50 cows.

RHR units and plate pre-coolers interact with each other and an energy audit is necessary to determine whether an RHR or a plate pre-cooler (or both) is most economical.

Minimum Standards & Recommendations

- Choose storage tanks that are UL certified with at least 2" of insulation (R-16). Do not install a heating element on the RHR unit; keep the RHR and water heater as two separate tanks in order to maximize the captured heat in the RHR unit.
- Size the RHR unit appropriately to achieve desired temperatures before the water is transferred to the water heater. Inventory the average daily hot water usage and then divide this by the number of milkings per day to estimate the size of the RHR unit that should be installed.
- Locate the RHR unit as close to the compressor as possible to minimize head pressure losses. It is also recommended to install a refrigerant reclaimer on the compressor so that the refrigerant is pulled back into the receiver when the unit is shut off.

Energy Savings

An RHR unit can reduce energy costs associated with water heating. If sized correctly, an RHR unit can heat water from 55°F well water to about 110°F, reducing energy use by about 45–55%.

Example: A farmer produces 2,500 lbs. of milk and uses on average 120 gallons of hot water per day (taking into account the bulk tank is washed every other day).

The energy required to heat the water is:

$$1\left[\frac{\text{BTU}}{\text{lb x °F}}\right] \text{x } 120 \text{ [gallons] x } 8.3\left[\frac{\text{lbs}}{\text{gallons}}\right] \text{ x } (170°\text{F} - 55°\text{F}) = 114{,}540 \text{ BTUs}$$

Based on 2,500 lbs. of milk produced per day and capturing 40% of the waste heat from the compressed refrigerant, an RHR unit is estimated to capture:

$$56\left[\frac{\text{BTU}}{\text{lb}}\right] \text{x } 2{,}500 \text{ [lbs] x } 0.40 = 56{,}000 \text{ BTUs}$$

56,000 BTUs/day will heat 120 gallons of hot water from 55°F to 111°F, reducing energy use to heat the water by about 48%. This is equivalent to an annual energy savings of 256 therms of natural gas, 279 gallons of LP, or 6,050 kWh depending on the fuel type.[6]

Actual savings will vary greatly depending on individual farm conditions, amount of water used, and the fuel type.

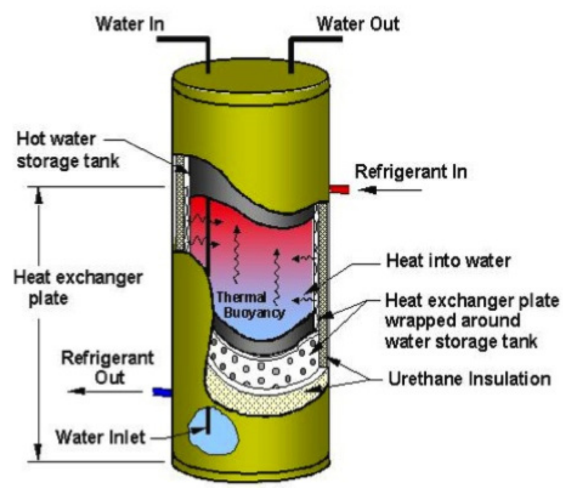

Diane Petit, NRCS, 2008

Environmental Impact & Other Benefits

The energy savings and offset of electrical production achieved by using an RHR unit will result in a reduction of greenhouse gas (GHG) emissions, and minimize refrigerant leakage which has been associated with global warming and ozone depletion

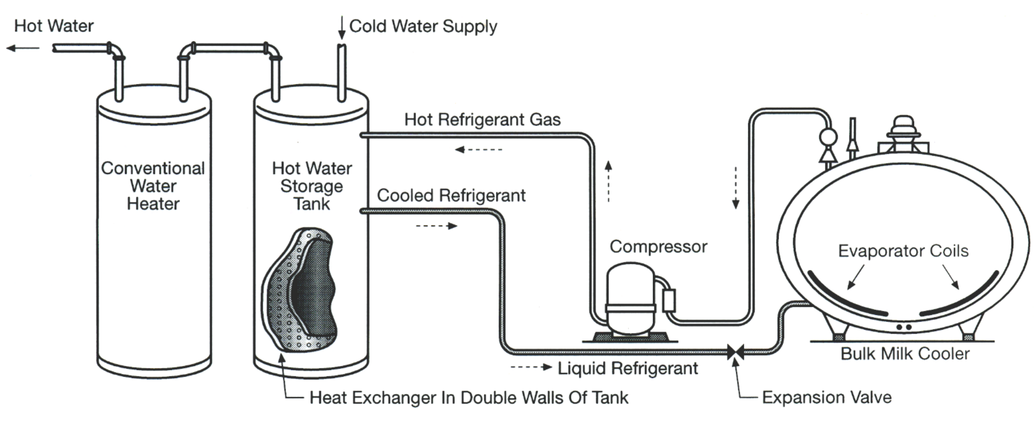
The above example with a savings of 56,000 BTUs/day would result in an annual reduction of 8,000 lbs. CO_2 assuming an electric water heater, or 3,560 lbs. CO_2 if heating with propane.

Schematic Diagrams



Focus on Energy

Above: Typical break out view of a RHR unit



Rural Electricity Resource Council: www.rerc.org

Above: Typical setup for a refrigeration cycle with an RHR unit

Economic Benefits

Monetary value of all benefits

Actual value of energy savings due to a reduction of water heating using fossil fuels is based on daily milk production, total daily water usage of a farm, type of fuel, and cost of fuel.

The table below provides examples of savings for the three main types of fuels used for water heating.

Estimated cost of implementation

An RHR unit can range from about $3,000 for a 50 gallon unit to $4,200 for a 120 gallon unit. Prices will vary depending on site conditions and installation fees.

Typical savings and payback period for a properly-sized RHR unit

Daily Water Usage (gallons)	Pounds of milk needed*	Estimated RHR unit cost	Annual Savings ($)			Electric Payback (without incentives)
			Electric	LP	Natural Gas	
100	2,040	$3,000	$733	$428	$236	4.1 years
120	2,450	$3,000	$879	$514	$283	3.4 years
160	3,260	$3,200	$1,172	$686	$377	2.7 years
180	3,670	$3,200	$1,319	$771	$424	2.4 years
220	4,480	$4,100	$1,612	$943	$518	2.5 years
240	4,890	$4,100	$1,758	$1,028	$566	2.3 years

*Based on capturing 40% of the waste heat from the RHR unit, this is the estimated number of pounds of milk required per day to achieve a rise in water temperature from 55°F to 110°F.

Please note: These are estimated values and will vary depending on actual milk production, amount of hot water used per day, amount of heat captured with RHR unit, etc.

Other benefits include increasing longevity of the water heater tank and compressor, cooling the milk faster (thus improving quality), and decreasing run time of the compressor.

Diane Petit, NRCS, 2010

Rejected heat from refrigerant can be used to preheat wash water and reduce hot water bills.

High Efficiency Refrigeration and Scroll Compressors

At a Glance:

- 15–20% more efficient
- Fewer moving parts
- Less maintenance
- Longer life expectancy
- Quieter
- Delivers more consistent cooling

Refrigeration compressors are installed on all dairy farms to cool milk and are one of the highest energy users on the farm. They come in many different forms, the most common type of compressor being a "hermetic reciprocating" (using a piston assembly), which are found on dairy farms that have not replaced their compressors in the past 5–10 years.

New scroll compressors are about 15–20% more efficient than reciprocating compressors. They have been used in the commercial industry for more than two decades with a proven and reliable track record, and have only recently (in the past 5–10 years) been introduced to dairy farms. The difference between the two types is that a reciprocating compressor has an oblong configuration when looking down from the top, while a scroll compressor has a round configuration.

Scroll compressors, unlike the standard piston assembly, use two scrolls, one orbiting in a circular movement around a fixed scroll in order to compress the gas.

Scroll compressors can directly replace a current reciprocating compressor if:

- Condenser unit is well maintained
- Capacity of the new compressor is within 5% of existing compressor
- Mounting and rewiring of controls can be accomplished

The incremental cost of a new scroll compressor compared to a new reciprocating compressor is about $300–$500, but energy savings result in a short payback period.

Application & Limitations

A scroll compressor should be installed on any farm if the existing reciprocating compressor fails and needs to be replaced.

Replacing a reciprocating compressor that works can be an expensive investment for small or medium size farms and results in a longer payback than other investments. It may be economically feasible for a farm with more than about 80–120 cows, but this largely depends on the efficiency of the existing compressors. (A refrigeration heat recovery unit or plate cooler is still applicable with a scroll compressor.)

An energy audit is always recommended to determine actual savings.

Diane Petit, NRCS, 2010

Minimum Standards & Recommendations

It is recommended to install a scroll or reciprocating compressor with the highest energy efficiency ratio (EER) as possible. The cost of purchasing a more efficient compressor will be well worth the energy savings over the life of the compressor.

The industry standard used to measure the EER for refrigeration compressors is based on a 130°F condensing temperature and a 45°F evaporating temperature. It is important to compare the EERs of the compressors at actual operating conditions used for refrigerating milk, which are typically set at a condensing and evaporating temperature of 110°F and 30°F respectively. This data is typically available from the manufacturer's website.

Maintenance

All refrigeration compressors need annual maintenance. A tune-up is recommended for any current compressor that has not had one in the past year, especially if the compressor runs for longer than an hour after milking has finished. A tune-up can increase operating efficiency of a compressor by 5–20% as well as increase its lifespan.

Among other things, a tune-up should include the following maintenance items (as applicable):

- Check/adjust refrigerant level
- Check suction pressures & temperatures
- Adjust head pressure controls
- Check oil level, pressure, cleanliness
- Check sub-cooling & super heat
- Clean condenser and evaporator coils
- Clean/replace drain pan, fans, screens, filters, belts, and bearings
- Straighten fins
- Repair damaged insulation on suction line
- Check compressor motor and condenser fan amp draw
- Repair any refrigerant leakage

Compressors run poorly when the ambient air is warm. It is recommended that the compressor be located where it is allowed to "breathe" cool outside air if possible. If the setup is designed to reject waste heat to help warm the milk room in the winter months, the compressor should be located in an area with vents to outside air during summer months.

Energy Savings

On average, scroll compressors are 15–20% more efficient than a standard reciprocating compressor.[7]

To determine actual energy savings of a new scroll compressor, it is necessary to know the EER of the current compressor. To find this, the operating wattage of the compressor must be known. This can be found using a multimeter/amp meter and knowing the voltage of the circuit or it can be estimated from manufacturer data. Multimeters can also read the voltage. Wattage is the estimated volts multiplied by the amp reading.

The following equations can be used to determine the EER:

$$\frac{\text{BTU}}{\text{Hr}} = \left(\frac{\text{lbs. of milk per milking} \times 0.93 \times (T_{initial} - T_{final})}{\text{Compressor run time from start of milking until it shuts off}}\right)$$

Where: $T_{initial}$ is usually 95-98°F if no plate cooler, and T_{final} is usually 38°F. 0.93 is the specific heat capacity of milk in Btu/lb -°F, where water is 1.0 btu/lb - °F.

$$\text{EER} = \frac{\frac{\text{BTU}}{\text{Hr}}}{\text{Operating wattage}}$$

This value should be compared to the expected EER of the compressor from manufacturer data. If it is low, a tune-up may be required. The EER value of the existing compressor can be used to determine the energy savings of replacing the current unit with a high efficiency compressor.

Diane Petit, NRCS, 2005

Environmental Impact & Benefits

The energy savings from installing scroll compressors will result in a reduction of greenhouse gas (GHG) emissions, reducing the farm's environmental footprint.

A tune-up of the current compressor (or its replacement with a new high efficiency compressor) can have other environmental benefits if properly maintained and refrigerant leaks eliminated. R-22 (HCFC-22), the common refrigerant used in compressors found on dairy farms, is scheduled to be gradually phased out in accordance with the Montreal Protocol and the Clean Air Act because HCFC refrigerants are an ozone depleting substance (ODS) and have global warming potential (GWP).[8] Manufacturers are switching to HFC refrigerants, such as R-410A, to comply with the Clean Air Act.

A new high efficiency scroll compressor will also reduce (but not eliminate), the required annual maintenance to keep the system performing efficiently.

Economic Benefits

Based on an average daily milk production of 2,500 and 5,000 pounds, the tables below summarize the potential savings from updating an old reciprocating compressor of various EER values with a high efficiency scroll compressor (assumed EER of 10.6).

The installation of a high efficiency scroll compressor is typically only economically feasible if:

- The current reciprocating compressor fails or has a very low calculated EER value. (A tune-up should be recommended in this case before replacing the entire unit.)
- A farm has a high daily milk production (6,000 lbs. or more). For a farm with 100 milking cows, the payback can be less than 5–7 years. A plate cooler should also be considered if not already installed.

Potential Savings with Scroll Compressors

Milk Production at 2,500 lbs			
Current EER	kWh Savings	Annual Savings ($)	Payback (years)*
6	4,780	$717	6.3
6.5	4,030	$605	7.4
7	3,380	$507	8.9
7.5	2,810	$422	10.7
8	2,320	$348	12.9
8.5	1,890	$284	15.9
9	1,500	$225	20.0

Milk Production at 5,000 lbs			
Current EER	kWh Savings	Annual Savings ($)	Payback (years)*
6	9,570	$1,436	3.1
6.5	8,050	$1,208	3.7
7	6,751	$1,013	4.4
7.5	5,630	$845	5.3
8	4,640	$696	6.5
8.5	3,770	$566	8.0
9	3,000	$450	10.0

*The payback for both tables is based on an installed cost of $4,500, the approximate cost for the installation of a packaged 5 hp scroll unit. If only replacing a compressor, an approximate price is about $1,500–2,000.

Please note: This table assumes no RHR unit or plate cooler is present. Each of these technologies will have an impact on actual savings. An energy audit should be completed to determine if a new scroll compressor is appropriate and will provide sufficient energy savings. A plate cooler could potentially reduce the savings by 40–50% due to reduced compressor run-time.
The average MA farm produces around 5,000 pounds or 550 gallons per day based on the Massachusetts Association of Dairy Farmers figures of 38 million gallons per year on 189 farms.


GDS

Energy Efficient Ventilation

At a Glance:

- Save 60–80% by installing HVLS fans in free-stall barns
- Save up to 75% by replacing old high speed fans
- Save energy by using fan controls to prevent unnecessary use
- Increase efficiency by up to 40% with proper maintenance

Animal facilities require ventilation to keep cows comfortable, healthy, and productive.

Ventilation is used to:

- Prevent heat stress in the summer
- Bring in fresh oxygen for the animals
- Remove and dilute moisture, dust, undesirable gasses and odors, and airborne disease organisms

Factors that affect the efficiency of a ventilation system:

- Use of energy efficient fans
- Use of fan controls
- Proper maintenance

Energy Efficient Fans

High Speed Fans

Fan efficiencies vary greatly depending on motor efficiency, shutters, guards, discharge cones, and diffusers. Tests conducted at the University of Illinois Bioenvironmental and Structural Systems (BESS) Lab identified a 100% difference in the energy efficiencies of two similar fans. Exhaust ventilation fans are rated by BESS Lab in cfm/watt (cubic feet per minute per watt).

Relative Efficiency of Standard Fan Sizes

Fan Diameter	Efficiency Range (cfm/watt)*	High Efficiency (cfm/watt)*
24"	8.7–19.4	16
36"	12.7–23.7	20
48"	13.5–27	20
50”– 54"	16.1–33	23

*@0.05" static pressure, 230 V single phase electrical power

When replacing or installing new fans, purchase fans with the highest efficiency (cfm/watt) and air flow ratio (AFR). The AFR is determined by dividing the airflow at 0.20” SP by the airflow at 0.05” SP. For 48” fans, the air flow ratios range from 0.28 to 0.87 with an average of 0.74. A high AFR provides fairly constant airflow at a wider range of static pressures and as the wind changes direction and speed.


Diane Petit, NRCS, 2010

Energy Efficient Fans (continued)

High Speed Fans (continued)

Test performance data can be obtained from BESS Lab: http://bess.illinois.edu/

Fan selection tips for high speed fans:[9]

- Select fans with a high efficiency (cfm/watt) rating
- Larger fans are generally more efficient
- Select fans with a high air flow ratio (AFR)
- Fans with a discharge cone are more efficient
- Machete or straight and teardrop blade designs are more efficient and accumulate less dust than cloverleaf shaped fan blades
- Fan speeds greater than 4,500 feet per minute will create excessive noise levels. To keep noise levels low, follow the suggestions in the table below.

Suggested Fan RPM for Quiet Operation by Diameter[10]

Fan Diameter	Suggested RPM for Low Noise
24"	720 rpm
36"	480 rpm
48"	360 rpm
54"	320 rpm

Energy Efficient Fans (continued)

High-Volume, Low-Speed (HVLS) Fans

HVLS fans are overhead fans with large diameter paddle fans (ranging from 8'–24' diameters) that operate at slower speeds (rpms). They have been in the agricultural market since the late 1990s. They are intended to be installed in free-stall or loose housing facilities with high ceilings.

It is recommended to space 24' HVLS fans 60 feet apart at a 16' ceiling height. This is equivalent to implementing about six to eight 48" circulation fans in the same area, and can reduce energy costs by up to 80%.

Annual Cost Savings of HVLS Fans

Fan size (ft)	Rated demand (kW)	Equiv. # of 48" fans	kW savings	kWh savings	Annual savings per fan ($)
24	1.5	7	5.5	13,680	$2,050
20	1.3	6	4.7	11,701	$1,750
18	0.9	5	4.1	10,300	$1,540
16	0.9	4	3.1	7,820	$1,170
14	0.9	3	2.1	5,192	$780
12	0.7	2	1.3	3,323	$500
10	0.7	2	1.3	3,353	$500
8	0.7	2	1.3	3,257	$490

Notes: Rated demand based on average value from several manufacturers. Estimated number of equivalent 48" fans based on best practices with spacing HVLS and circulation fans. kW savings based on a 48" fan that uses 1.0 kW demand. kWh based on running fans 2500 hours annually. Annual savings based on $0.15/kWh. Actual savings will vary depending on actual barn ventilation strategy and design.

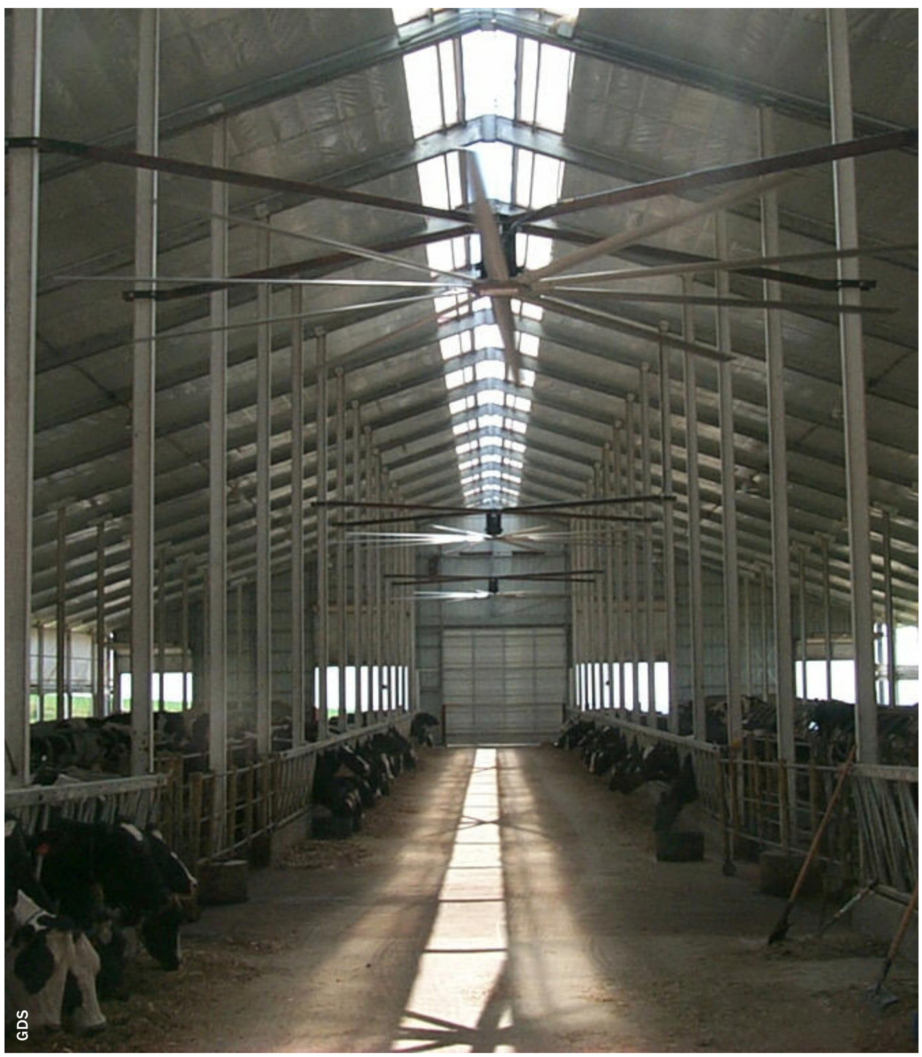
Diane Petit, NRCS, 2010

Energy Efficient Fans (continued)

High-Volume, Low-Speed (HVLS) Fans (continued)

In addition to economic and environmental benefits, research on HVLS has identified the following farm improvements:[11]

- Noticeable improvement in air quality
- Reduced noise
- Dryer alley floors
- Fewer flies and birds
- May prevent loss of milk production during periods of high heat and humidity compared to no fans in free-stall


GDS

Fan Controls

Thermostats

Install thermostats to control fans so they are only used when needed. This will save energy and increase productivity by minimizing heat stress in animals.

Research has shown that cows show mild heat stress at a temperature of about 75°F with a relative humidity between 60–70% (typical humidity range for Massachusetts in summer).

It is recommended to control fans so they provide the maximum ventilation as necessary at about 72–75°F and be staged to turn off at lower temperatures.

When installing thermostats:

- Install ones that are designed for use outdoors in damp and dusty environments and out of direct sunlight.
- Mount thermostats out of reach of animals but in close proximity to accurately measure air temperature.
- Clean thermostats monthly to ensure an accurate temperature reading as dust can act as an insulator.
- Calibrate thermostats once a year to ensure they are working properly.

Diane Petit, NRCS, 2010

Fan Controls (continued)

Variable Speed Fans

Variable speed fans use a variable frequency drive (VFD) to vary the speed of a fan. This strategy can be used to help maintain a temperature set point instead of cycling constant speed fans on and off using a thermostat. Using variable speed fans reduces excessive ventilation, energy usage, and temperature fluctuations and drafts.[12]

Based on hourly weather data for Massachusetts, the following table lists the approximate number of annual hours above the listed temperatures. These values can be used to determine the annual energy usage for fans that are programmed to turn on with a thermostat at a desired temperature.

Data for Calculating Energy Use of Variable Speed Fans (Massachusetts)

Temperature (°F)	Total Annual Hours Above Temperature
50	4,300
55	3,600
60	2,900
65	2,000
70	1,300
75	700
80	400

Note: On average, a fan may run approximately 2,200 hours a year. This provides adequate ventilation for bringing fresh air in the winter and to prevent heat stress in summer.


Catherine Ulitsky, NRCS, 2010

Maintenance

Ventilation fans require routine maintenance in order to keep operating at the designed efficiency. A poorly maintained ventilation system can reduce fan efficiency by as much as 40–50%.

The following maintenance is recommended:

- Clean fan blades, shutters, and guards. Lubricate with graphite to reduce dust accumulations. Make sure shutters can freely open/close; lubricate hinges with graphite. Poorly maintained fans can reduce fan performance by almost 40%.
- Make sure air inlets and fan outlets are free of obstructions (brush, weeds, bird nests, etc.). Obstructions can prevent proper airflow and reduce efficiency.
- Clean motors and thermostats. Dust can act as an insulator, causing the motor to overheat and the thermostat to incorrectly read temperatures.
- Check/replace belt, tension, and alignment. A slipping and worn out belt can reduce fan efficiency by as much as 30%.
- Cover unused fans in the winter with an insulating material or plastic.
- Disconnect fans that are not in use.

Energy Savings

Older fans made in the 1980s or earlier can have efficiencies (CFM/watt) less than 75% of newer high efficiency fans.

The following equation can be used to estimate the yearly energy savings (kWh) from a fan change-out:

$$\text{Annual kWh savings} = \frac{CFM_{old}}{CFM/watt_{old}} \times \frac{CFM_{new}}{CFM/watt_{new}} \times \frac{1\ kW}{1{,}000\ watts} \times Hrs$$

Where CFM = cubic feet per minute; Hrs = annual hours of operation

Environmental Impact & Benefits

The energy savings and offset of electrical production achieved by installing energy efficient ventilation will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the farm.

Proper ventilation will prevent heat stress in animals and bring in fresh oxygen, improving the productivity of milking cows. It will also increase the air quality by removing moisture, dust, gasses, odors, and airborne disease organisms.

Decreasing the speed of a fan (by using a VSD or HVLS) can reduce the noise level inside a facility.

Diane Petit, NRCS, 2008

Economic Benefits

To estimate energy and cost savings, refer to the USDA-NRCS calculator for ventilation, located at: www.ruralenergy.wisc.edu.

There is a large range in sizes, options, and manufacturers for ventilation systems. Contact your dairy supplier for cost estimates for equipment.

Some approximate costs are:

- $4,500 for a 20'–24' HVLS fan
- $900–$1,200 for a 48" high speed ventilation fan
- $400 for a VSD for a 1 hp fan


Diane Petit, NRCS, 2008

Variable Speed (VS) Vacuum Pump

At a Glance:

- Regulates speed of pump motor
- Reduces energy use by 40–70%
- Increases operating life of pump
- Helps maintain a stable level of vacuum
- Reduces noise

A vacuum pump operates during milking or washing of the milking equipment. On a typical dairy farm in Massachusetts (30–100 cows), vacuum pumps:

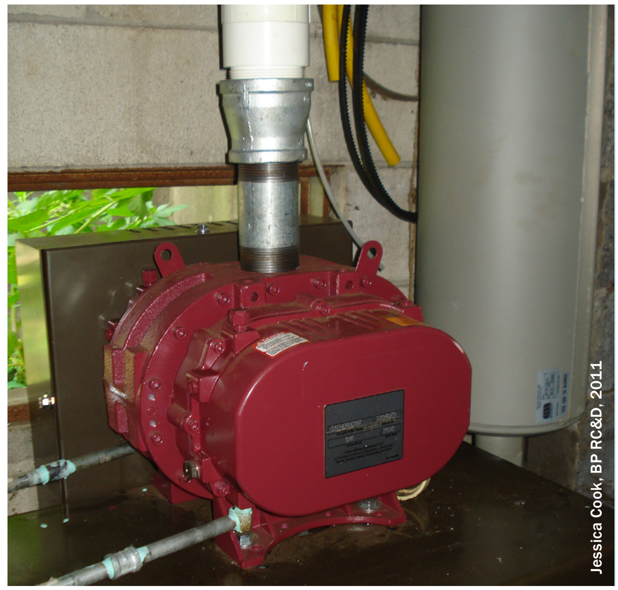
- Range from 5–10 hp
- Operate between 3–5 hours a day
- Consume about 20% of a dairy farm's electricity use

A vacuum pump works by continuously removing air from the milking system to create a negative pressure (vacuum) that pulls the milk through the pipeline to the receiver jar.

The pump is designed to provide enough vacuum to meet the maximum demand. This sizing exceeds the normal operating requirements of the system and is primarily designed to ensure proper washing.

To maintain a stable vacuum (fluctuating pressures can be harmful to the cow), air must be removed from the system at the same rate it enters through the pulsators, claws, leaks, and unit fall-off.

In a conventional system, the pump motor runs at a constant speed (full power) at all times of operation and admits air through the vacuum regulator as necessary to maintain the stable vacuum.



Jessica Cook, BP RC&D, 2011

Instead of having the motor run at full speed and admitting air through the regulator to adjust the pressure, a variable speed drive (VSD) can be installed between the vacuum pump and the switch that controls the motor.

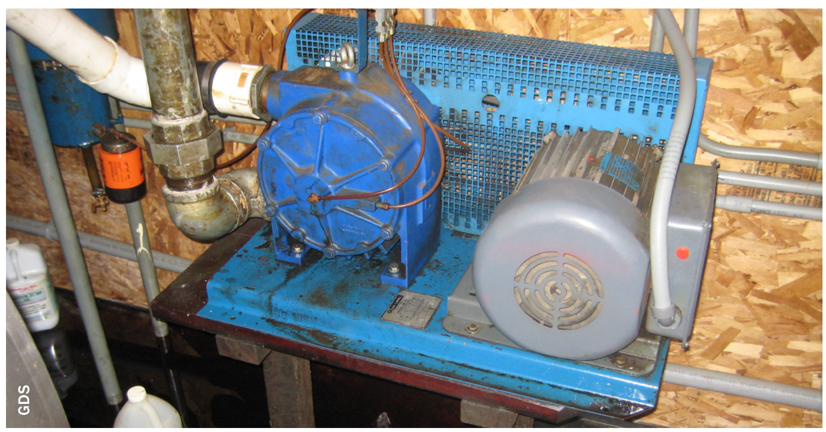
The VSD is used to control the speed (rpm) of the vacuum pump. Also known as a variable frequency drive (VFD), it can control the electrical pump motor to run at slower speeds, therefore controlling the vacuum level.

There is a pressure transducer installed in the vacuum line that is used to monitor the vacuum level and this sends a signal to the VSD that changes the speed of the motor as necessary. A VSD will increase the speed of the vacuum pump when there is a demand for greater capacity and will slow the vacuum pump speed when the demand is less.

On average, a VSD slows the pump down to 50% the rated operating speed. This regulation reduces energy consumption, noise levels, and vacuum pump wear.

Application & Limitations

- A variable speed vacuum pump may only be applicable on farms with long enough milking time and/or if the current vacuum pump is oversized.
- A VSD should only be installed on blower or lobe style pumps (although they have been installed successfully on rotary vanes if a minimum rpm is programmed in to prevent overheating).
- An energy audit can help evaluate the actual energy savings of installing a VSD and determine the payback period.
- If the existing motor is 1-phase, having to switch to a 3-phase motor can increase the cost and payback, limiting its application for smaller farms.



An example of oil contamination in a variable speed pump with sliding oil vane (above).

Variable speed pump (below).

Minimum Standards & Recommendations

It is important to install a system in accordance with ASABE guidelines. Use a 3-phase, inverter-duty rated motor, vacuum sensing system, and lobe pump.

Pump manufacturers typically do not recommend VSDs for sliding vane rotary pumps (oil vane) or water-ring type vacuum pumps. If the style of pump is unknown, rotary oil vane pumps can usually be identified by oil contamination in the area near the exhaust vent. If it is not a rotary oil vane pump, the other most common pump used on dairy farms is the blower type. Oil vane pumps have high efficiencies but require oil for lubrication, and if they operate at too low of a speed they can overheat, causing damage to the pump. It is recommended to use a VSD with a blower or lobe type vacuum pump. They use grease as the lubricant and can operate at lower speeds.

It is important to size the vacuum pump correctly. Too large a vacuum pump will minimize savings since it cannot be slowed down enough without the risk of overheating. (Although blower or lobe type vacuum pumps can run at lower speeds than oil vane pumps, they still have a minimum operating speed per the manufacturer.) Too small a vacuum pump will not perform properly for when maximum demand is required and will also minimize energy savings.

Recommended sizing for vacuum pump systems is 35 cubic feet per minute (cfm) plus 3 cfm per milking unit for systems with fewer than 32 units, and 70 cfm plus 3 cfm per milking unit for systems with 32 units or more up to a maximum of 120 cfm .[13] Sizing should also include allowances for equipment such as the milk meters and vacuum operated automatic take-offs. Previous guidelines have specified capacities of up to 10 cfm per milking unit. The vacuum pump should list its rated cfm. As a general guideline, it can be approximated at 10 cfm/hp.

The VSD is sensitive to dusty and damp conditions and can be damaged by lightning strikes. It is recommended that the electronic device be placed in a NEMA rated enclosure that can handle these conditions. It should also be installed with proper grounding in a location that is dry, dust-free, and heated in the winter.

It is recommended to only use 3-phase motors with a VSD.

Energy Savings

Actual energy savings are highly dependent on hours of use and the vacuum pump size, but energy savings of 50–65% are typical.[14] kWh savings can be estimated by the following equation:

Annual kWh savings =

(vacuum pump size [hp] - {0.25 x No. of milking units}) x 0.9 x daily hours of operation [hrs] x 365 [days]

Where 0.25 is the hp vacuum demand per milking unit and 0.9 is the regulator efficiency.

Please note: using hp in the equation is roughly equivalent to converting to kW and taking motor efficiency (80%) and load factor (95%) into account.

Environmental Impact & Benefits

The energy savings and offset of electrical production achieved by installing a variable speed vacuum pump will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the farm.

Maintenance

To ensure a long-lasting vacuum system, be sure to properly maintain it. Check oil levels, grease drive gears, clean air filters, check and replace seals as necessary, as well as any other instructions per the manufacturer.

A VSD can slow the speed of a pump to less than 50% the rated constant speed. This reduces wear and tear, maintenance costs, and noise, therefore increasing the life span of the pump.


Diane Petit, NRCS, 2011

Economic Benefits

Annual Cost Savings of Variable Speed Vaccuum Pumps

	Daily Hours of Operation (Milking Only)				
	2	3	4	5	6
Vacuum Pump Size (hp)	Annual Savings ($)*				
5	$267	$400	$534	$667	$800
7.5	$400	$600	$800	$1,000	$1,200
10	$530	$800	$1,070	$1,330	$1,600
15	$800	$1,200	$1,600	$2,000	$2,400
20	$1,070	$1,600	$2,130	$2,670	$3,200

*Based on $0.15/kWh, 55% energy savings, vacuum pump efficiency of 80%, and a load factor of 95%.

Estimated Cost of Implementation and Typical Payback

- The estimated cost for a VSD controller is about $3,000.
- A 3-phase electric motor can range from about $600 for a 5hp to $900 for a 10hp.
- A blower style vacuum pump can cost between $3,000-$4,000.
- For a complete package 7.5 hp unit (VSD, motor, and pump), an estimated installed price is $7,800.

Typical payback is highly dependent on hours of use, cost of installation, and actual energy savings. For an approximation, take the estimated cost of installation and divide by annual savings from the table above.


Diane Petit, NRCS, 2010

Jessica Cook, BP RC&D, 2010

Low and No Energy Waterers

At a Glance:

- Increased insulation prevents water freezing and reduces heating requirements
- Reduces energy usage by 50–100%, saving up to $200 per waterer per year
- Warmer water increases cow intake and productivity

A reliable supply of drinking water is critical for cold winter months in Massachusetts. A waterer (water fountain or trough) can cost anywhere from nothing to several hundred dollars to operate.

Energy efficient waterers have increased insulation to limit heat loss, therefore reducing (or eliminating) the energy required to keep the water from freezing.

New open troughs have a range of 2–4 inches of polyurethane insulation while old troughs may have no insulation at all. Many of the old troughs were not sealed adequately and it is common to find insulation cavities that have been invaded by mice or have lost effectiveness due to water damage.

There are also closed troughs where the top has a compressible lid on the water fountain (typically a spherical ball) which the animals must push down before drinking.

This additional layer of insulation will act as a barrier to the ambient air and prevent further heat loss. Closed troughs can often be heating-element free if sized correctly to the herd size and water usage.

GDS

Application & Limitations

- Well-insulated waterers should be considered by any farm that currently uses a poorly insulated waterer.
- A low wattage element may be necessary for enclosed waterers if there is not enough turn-over of drinking water. (Water needs to keep moving through the valve and waterer to prevent freezing.)
- It is important to size the waterer for the intended application and herd size.
- Application may be limited in rotational grazing and open pasture conditions where fixed locations for waterers are not feasible.

Minimum Standards & Recommendations

In colder climates such as Massachusetts, a minimum of two, preferably three inches of insulation, is recommended. Locate the waterer in sheltered areas out of the wind to prevent convectional heat loss.

A riser tube with a 12-inch diameter should be installed on the riser pipe for all tanks, and should reach 1-foot below the frost level (which is at approximately 4-foot total for Massachusetts) and a minimum of a 12-inch-diameter is recommended. This tube shields incoming ground water from cold as it passes through the frost level and provides radiant warmth from the ground temperature.

If an element is necessary, it is best to use a thermostatically controlled heater and adjust to just above freezing (32–34°F). Thermostats need constant checking to ensure proper calibration. Most waterers keep the water temperature too warm, resulting in excessive energy use and operating costs.

The size of the element is not critical if it is thermostatically controlled, since it will take the same amount of energy to keep it above freezing. In either case, it will turn on and off as necessary. Shut off electricity to water fountains when the heating element is no longer needed to ensure it is not drawing any power.

Energy Savings

It is difficult to quantify actual energy savings for new waterers. Manufacturers claim the new waterers use 50% as much energy as earlier models and closed waterers can eliminate 100% of the energy use.

One manufacturer lists expected energy costs on their website: http://www.ritchiefount.com/energyusage.html.

Environmental Impact & Benefits

The energy savings and offset of electrical production achieved by installing low and/or no energy waterers will result in a reduction of greenhouse gas (GHG) emissions, reducing the environmental footprint of the farm.

There are also other additional benefits. Closed troughs may not need a heating element if sized correctly, decreasing the required maintenance of having to remove the heating element to clean any build-up that may have accumulated over winter.

Also, reducing the need for a heating element can provide flexibility in locating the waterer in areas without direct access to electricity.

Diane Petit, NRCS, 2010

Economic Benefits

The actual value of savings is difficult to determine.

In research, it has been found that a poorly maintained water fountain can consume $200 or more in electricity per season, while a properly insulated and maintained unit will use $60–$100 worth of electricity.[15]

A correctly sized, well insulated closed waterer that is element free could save up to $200 annually in energy costs.

The estimated cost of a new waterer is $300–$800 depending on the size.

A simple payback usually ranges between 3–6 years depending on the condition of the existing waterer.

Reviewing the *Massachusetts Farm Energy Best Management Practices Guide* is the first step in reducing energy use and saving money.

Below are some steps to keep in mind for successful energy management:

1. **Learn about energy conservation, energy efficiency, and renewable energy.**
   Learning about your energy use and ways to reduce it or supplement it with renewable energy is the first step. There is much information available about reducing energy use as well as case studies of farms that have taken action.

2. **Apply for a farm energy audit or renewable energy assessment.**
   An energy audit can help determine where energy is being wasted by inefficient equipment and practices and can recommend solutions. After reading about energy audits on the Berkshire Pioneer RC&D website, complete an application to apply for an MFEP energy audit or renewable energy assessment. The application can be found at: www.berkshirepioneerrcd.org/mfep/forms/application.php.

3. **Apply energy conservation practices.**
   The easiest and most cost effective method of achieving energy savings is through energy conservation. Energy conservation means using energy wisely and eliminating energy waste, such as running a heater or a ventilation fan when it's not necessary.

4. **Apply recommended energy efficiency practices.**
   Energy efficiency means using less energy to produce the same end result. This manual focuses on conventional energy efficiency measures using current applicable technology. Energy efficiency measures should be taken before considering renewable energy. Reducing the amount of energy used is more cost effective than purchasing renewable energy to power inefficient devices.

5. **Focus on Time-of-Use management (for cost savings, if applicable).**
   With proper Time-of-Use energy management, it is possible for agricultural producers to reduce their energy bills. Load demands change dramatically throughout the day, but utility companies must have the capacity to provide enough electricity for on-peak demand (typically aligning with summer months and daylight hours). In order to spread out this peak demand more evenly over the 24-hour day, electric utility companies provide a Time-of-Use (TOU) pricing structure. In a TOU billing structure, kWh prices are increased during on-peak hours and are reduced during off-peak hours to encourage customers to change behavior by using energy intensive equipment outside of peak hours.

6. **Install renewable energy.**
   After the previous steps have been exhausted, renewable energy is the final step. Renewable energy has a much lower environmental impact than conventional sources of energy production and decreases the US dependence on a fossil fuel economy. It also helps stimulate the economy and create job opportunities. Money spent on renewable energy is spent on materials and staff that build and maintain the equipment instead of importing non-renewable fossil fuels. This manual focuses on solar thermal, photovoltaic, wind, and biomass. Other technologies include, but are not limited to, anaerobic waste digesters (biogas), geothermal, and hydro.

Where to Start—Information & Resources

Massachusetts Farm Energy Program (MFEP)

www.berkshirepioneerrcd.org/mfep

413-256-1607

MFEP provides technical assistance and funding referrals for farmers looking for financial resources to support energy efficiency or renewables projects. MFEP staff are up-to-date on the evolving funding opportunities and offer an initial one-stop shop for funding resources for farm energy projects.

Massachusetts Department of Agricultural Resources (MDAR)

www.mass.gov/agr/programs/energy

617-626-1703

MDAR offers energy related grant opportunities through the Ag-Energy Grant Program from May to June of each year, in addition to farm viability and business development grants that may consider energy projects as a component. MDAR also offers support for farms interested in energy efficiency, conservation, and renewables through their renewable energy coordinator position.

More information and technical resources are available online.

Farm Energy Discount Program

www.mass.gov/agr/admin/farmenergy.htm

617-626-1733

All agricultural ratepayers in Massachusetts enjoy a mandated 10% reduction on their energy bills for electricity and natural gas supplied by public utilities as a result of legislation enacted to restructure the utility industry.

Individual and corporations that are "principally and substantially engaged in the business of production agriculture or farming for an ultimate commercial purpose" are eligible.

A two-page application is available online.

DSIRE—Database of State Incentives for Renewables and Efficiency

www.dsireusa.org

This online database provides up-to-date resources on financial incentives for renewables and efficiency projects from state and federal sources, many of which are applicable to farm businesses.

Installers and Contractors

Independent equipment installers, dealers, and contractors are a good source of information related to financial incentives for energy projects. Particularly in the case of renewable energy, installers need to track funding programs and realistically estimate how they affect the payback period for the project in order to maintain a competitive advantage in their field.

Energy Efficiency Financial Resources | Massachusetts State Resources

Public Utility Energy Efficiency Programs

Contact your municipal utility company

Customers of investor-owned public utility companies pay into conservation, efficiency, and renewable energy funds and therefore have access to energy efficiency programs. These "public" energy conservation programs are regulated by the MA Department of Public Utilities. Typically utilities offer energy assessments, performed by employees or contractors, as well as financial incentives (cost-share) on cost-effective energy efficiency measures.

There are four investor-owned electric utility companies in Massachusetts: National Grid, NSTAR, Unitil (Fitchburg Gas & Electric), and Western Massachusetts Electric Company. In addition, Cape Light Compact operates the regional energy efficiency program for the Cape and islands. Natural gas companies include Berkshire Gas, Columbia Gas of Massachusetts (formerly Bay State Gas), National Grid (formerly Keyspan Gas), and NSTAR.

For contact information related to farm energy assessments and incentives, look online or call the Massachusetts Farm Energy Program.

Municipal Utilities

Contact your municipal utility company

Customers that are serviced by the 40 municipal electric and gas utility departments in the state typically do not pay into conservation or renewable energy funds. Some municipal utility companies have developed fee for service audit programs. Contact your individual municipal utility company to see what programs are available.

Energy Efficiency Financial Resources | Federal Resources

USDA-Rural Energy for America Program (REAP)

www.rurdev.usda.gov/BCP_Reap.html

Contact your local USDA-RD office

USDA-Rural Development (RD) administers competitive grants for energy efficiency and renewable energy projects at 25% of eligible project costs, as well as guaranteed loans, to farmers and rural small businesses.

Energy efficiency project applications to REAP require an energy assessment or audit, and renewable projects require technical reports from installers. Farmers are strongly encouraged to prepare REAP applications during slower seasons on the farm. In addition, MFEP strongly encourages producers to work on preparing the application during slower seasons on the farm.

For more information, look online or contact your local USDA-Rural Development Area Office.

USDA-Environmental Quality Incentives Program (EQIP)

www.ma.nrcs.usda.gov/programs/airquality/

Contact your local USDA-NRCS office

Under the 2008 Food, Conservation and Energy Act the USDA Natural Resources Conservation Service (NRCS) can provide eligible producers with program support through the Environmental Quality Incentives Program (EQIP) to implement cost-effective and innovative practices that improve air quality.

Individuals, groups and entities who own or manage farmland, pastureland or non-industrial forest land are eligible to apply. Producers with an annual minimum of $1,000 of agricultural products produced and/or sold from their operation are eligible to apply.

In 2009, EQIP provided funding for specific conservation practices related to anaerobic digestion, greenhouse energy screens and horizontal air flow, and cranberry auto-start systems.

Renewable Energy Financial Resources | Massachusetts State Resources

Department of Public Utilities (DPU) Net Metering

Contact your local utility company

Net metering for wind, solar and agricultural energy installations encourages public utility customers to install solar panels and wind turbines, by allowing them to earn credit on their electric bills if they generate more power than they need. Farms are also encouraged to install additional renewable technologies such as anaerobic digesters.

Under the Green Communities Act signed by Governor Patrick in 2008, utility companies must compensate their customers for up to two megawatts of excess electricity at the retail rate rather than the lower wholesale rate. Additionally, customers may allocate their credits to other customers.

To find out how you can apply for net metering contact your local eligible utility (NGrid, NSTAR, WMECO or Unitil), or work through your renewable energy installer.

Municipal utility customers planning to install a renewable energy project to produce electricity will need to contact their suppliers to review net metering and interconnection policies.

Massachusetts Clean Energy Center (MassCEC)

www.masscec.com

617-315-9355

The Green Jobs Act of 2008 created the Massachusetts Clean Energy Center (MassCEC) to accelerate job growth and economic development in the state's clean energy industry. The Renewable Energy Generation division of MassCEC is responsible for supporting renewable energy projects throughout the Commonwealth.

MassCEC has awarded funds to hundreds of businesses, towns, and non-profits for feasibility and/or design and construction of solar panels, wind turbines, biomass systems, hydroelectric systems, and other clean energy systems.

Contact MassCEC to learn about current programs like Commonwealth Wind and Commonwealth Solar.

Renewable Energy Financial Resources | Massachusetts State Resources (continued)

Renewable Energy Certificates (RECs)

www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/

RECs are a means by which the environmental benefits, also known as the renewable attributes, of energy production by eligible renewable energy technologies can be sold to retail electric suppliers (RES) who are required to buy a minimum amount of these attributes to meet Massachusetts' renewable portfolio standard (RPS) requirements. For more details regarding eligible technologies and how prices are determined, refer to the MA Department of Energy Resources (DOER).

Solar Renewable Energy Certificates (SRECs)

www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/

The SRECs program is a market-based incentive program to support the development of 400 MW of solar photovoltaic (PV) infrastructure across the Commonwealth. SRECs are a means by which solar energy producers can sell the environmental attributes of solar generation to public utilities which are required to buy a minimum amount to meet Massachusetts' renewables portfolio standard (RPS) requirements. The sale of these certificates allows for a consistent cash flow for a ten-year period.

Massachusetts State Tax Deduction

www.dsireusa.org

Contact a tax consultant for details

Businesses in Massachusetts may deduct from net income, for state excise tax purposes, the installed cost of renewable energy systems. See DSIRE or contact a tax consultant for more details.

Renewable Energy Financial Resources | Federal Resources

USDA-Rural Energy for America Program (REAP)

www.rurdev.usda.gov/BCP_Reap.html

Contact your local USDA-RD office

The Section 9007 of the 2008 Farm Bill provides funding for renewable energy systems and energy efficiency improvements. USDA-Rural Development (RD) administers these funds and offers competitive grants at 25% of eligible project costs, as well as guaranteed loans, to farmers and rural small businesses.

The annual application deadline is generally in the spring. For more information, look online or contact your local USDA-Rural Development Area Office.

Business Investment Tax Credit (ITC) and American Recovery and Reinvestment Act of 2009 (ARRA)

www.irs.gov/newsroom/article/0,,id=206871,00.html

Contact a tax consultant for details

The federal business energy investment tax credit available under 26 USC § 48, and expanded by the Energy Improvement and Extension Act of 2008 (H.R. 1424) in October 2008 and the American Recovery and Reinvestment Act of 2009 in February 2009, provides tax credits for a range of renewable energy projects, ranging from 10%-30% of the eligible costs of renewable energy projects.

Deadlines: Credit Termination Dates vary by technology, but are generally available for eligible systems placed in service before January 1, 2017 (with the exception of large wind 1/1/13 and biomass 1/1/14).

Federal Accelerated and Bonus Depreciation

www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F

Contact a tax consultant for details

Under the federal Modified Accelerated Cost-Recovery System (MACRS), businesses may recover investments in certain property through depreciation.

Disclaimers

Mention of trade names and products is for information purposes only and constitutes neither an endorsement of, recommendation of, nor discrimination against similar products not mentioned.

Although this guide contains research-based information and the contributors have used their best efforts in preparing this guide, the contributors make no warranties, express or implied, with respect to the use of this guide. Users of this guide maintain complete responsibility for the accuracy and appropriate application of this guide for their intended purpose(s).

In no event shall the contributors be held responsible or liable for any indirect, direct, incidental, or consequential damages or loss of profits or any other commercial damage whatsoever resulting from or related to the use or misuse of this guide.

The contributors emphasize the importance of consulting experienced and qualified consultants, advisors, and other business professionals to ensure the best results.

Project costs presented in this report are estimates only, based upon available pricing information at the time of compiling this report. Actual costs will likely vary due to many different variables.

Energy and Fuel Prices

Energy and fuel prices are constantly fluctuating. Actual prices will affect the economic feasibility of a project. The following energy prices have been used for purposes of the calculations throughout this manual:

- $0.15/kWh
- $1.10/therm
- $2/gallon propane (LP)
- $2.5/gallon fuel oil
- $200/full cord of wood (measured as 4' x 4' x 8')

For more information, contact the Mass Farm Energy Program at Berkshire-Pioneer RC&D: www.berkshirepioneerrcd.org/mfep or 413-256-1607.

Massachusetts Farm Energy Program
Conservation • Efficiency • Renewables

Notes

1. Taken from *Dairy Farm Energy Audit Summary*, NYSERDA and *Farm Energy Audits.* Wisconsin Department of Agriculture, Trade and Consumer Protection.

2. Data from *Compact Fluorescent Lighting on Farms*, by the Focus on Energy program.

3. Data and concept taken from Focus on Energy program.

4. Data from *Heating Water on Dairy Farms,* Scott Sanford, 2003.

5. According to Scott Sanford, *Heating Water on Dairy Farms*, 2003.

6. Based on a combustion efficiency of 80% for gas water heaters and 99% for electric; 1 therm = 100,000 BUTs, 1 gallon LP = 91,500 BTUs, 1 kWh = 3,142 BTUs.

7. Comparing same horsepower, refrigerant, phase, voltage, and application, a Copeland scroll compressor model ZB38KC-PFV has an EER of 10.6 compared to the Tecumseh reciprocating compressor model AGA5568EXN with an EER of 9.2. This equates to a 15% increase.

8. From U.S. Environmental Protection Agency, *The Phaseout of Ozone-Depleting Substances*, 2008.

9. From Focus on Energy, *Ventilation Fans for Animal Housing*, 2002.

10. Data and concept from Focus on Energy, *Ventilation Fans for Animal Housing*, 2002.

11. From D.W. Kammel, M.E. Raabe, J.J. Kappelman, University of Wisconsin-Madison, *Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns*, 2003.

12. From Scott Sanford, *Ventilation and Cooling Systems for Animal Housing.*

13. This based on the ASAE standard S518.2 Feb 03, Milking Machine Installations – Construction and Performance.

14. From Scott Sanford, *Variable Speed Milk Pumps*, 2004.

15. From the Wisconsin Department of Agriculture, Trade, and Consumer Protection, *Dairy Farm Energy Management Handbook,* 2006.

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The Rural Electric Resource Council is a national resource for knowledge on rural electricity topics: www.rerc.org.

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MASSACHUSETTS FARM ENERGY PROGRAM

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Jessica Cook, BP RC&D, 2009

Massachusetts Farm Energy Program

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