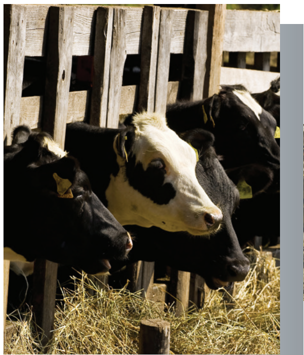
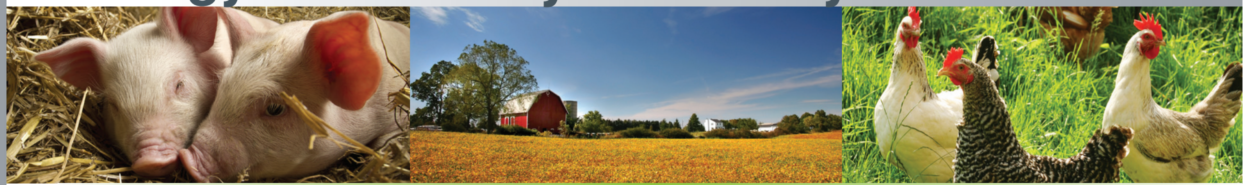


Energy Efficiency on Dairy Farms



Alberta Government

Introduction

Milk cooling, and system washing make up the largest part of the electricity used by dairy farms. As with any mechanical processes, as technology improves, there are generally gains to be made in energy efficiency. The main considerations in improving energy efficiency on a dairy farm include considering adapting new technology where appropriate, upgrading older, less efficient equipment and improving management practices.

On average, 44% of the electricity consumption in a dairy operation is attributed to milking (Figure 1). This equates to 48,840 Kilowatt-hours (kWh) for a 100 cow dairy. Assuming the cost of electricity is $0.10 per kWh, this equates to $4,884 per year. Electricity prices over the last five years have been unpredictable ranging from $0.06 to $0.15 per kWh (Figure 2). This equates to a range of $2,930 to $7,326 per year for a 100 cow dairy.

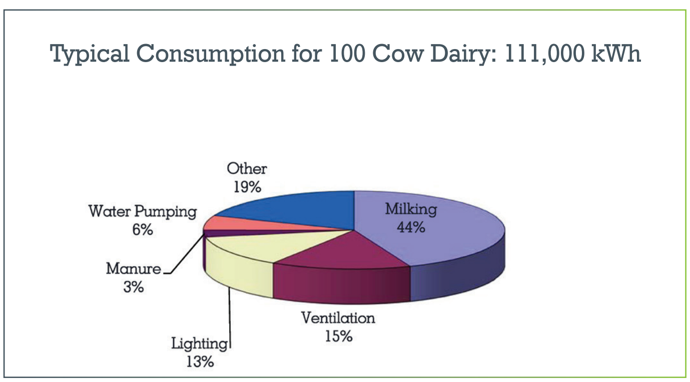


Figure 1. Electricity Usage and Distribution

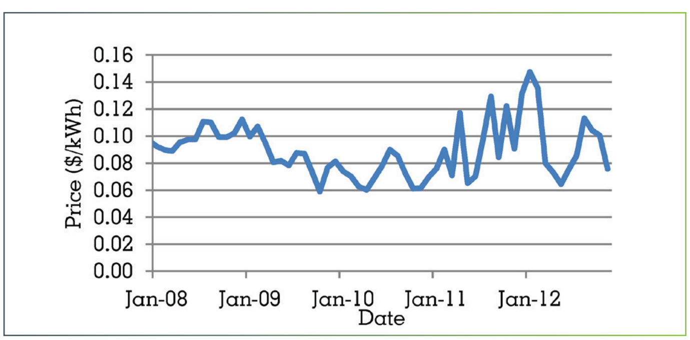


Figure 2. Alberta Price for Electricity from 2008 to 2012
Source: Alberta Agriculture and Rural Development

On average, 77% of the natural gas consumption in a dairy operation is attributed to water heating (Figure 3). This equates to 277 Gigajoules (GJ) for a 100 cow dairy. Assuming the cost of natural gas is $5.50 per GJ, this equates to $1,524 per year. Natural gas prices over the last five years have been unpredictable ranging from $1.40 to $10.50 per GJ (Figure 4). This equates to a range of $388 to $2,909 per year for a 100 cow dairy.

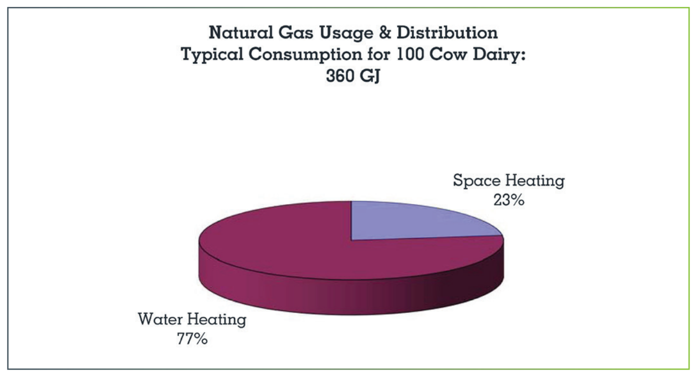


Figure 3. Natural Gas Usage and Distribution

Figure 4. Alberta Price for Natural Gas from 2008 to 2012
Source: Alberta Agriculture and Rural Development

The most logical and cost-effective time to adopt new technology or upgrade existing equipment, is at the end of the useful life of the equipment. Another time equipment changes may be cost effective is if the operation is expanding in size and new equipment is brought online. If the current equipment in use is only partway through the expected life, it may not necessarily be cost-effective to switch it out. A calculation should be done to compare the costs and help make this decision.

Energy Efficiency on Dairy Farms

When the overall cost of purchasing and operating a piece of equipment is considered, the upfront purchase price is usually extremely small relative to the ongoing operating (fuel) cost, in the relative range of 5% purchase cost to 95% operating cost. Spending a little more money to purchase equipment with a higher efficiency will save money over the lifetime of using the equipment.

Technology Basics, Terminology

Kilowatt (kW): The instantaneous power required by (or produced by, in the case of generators) a piece of equipment, usually indicated as a Rated, or Peak, value

Kilowatt-hours (kWh): The cumulative energy consumption (or production) of a piece of equipment over a time period such as a day, month, or year

Equipment Efficiency: The ratio of how much input energy was required to get out a certain level of output energy, usually listed as a percentage, almost always smaller than 100%, except in the case of some heat pump applications

Energy Utilization Indices (EUI): These were developed to provide a measurement of how efficiently electrical energy is being utilized on the dairy farm, and are often expressed in units of kWh per cow-year, or kWh per hundredweight of milk cooled

Variable Speed Drive (VSD): Also called variable frequency drive (VFD), is an electronic speed controller that varies the frequency and voltage supplied to a motor in order to increase or decrease its speed in response to feedback from a sensor loop

System Components

The major mechanical and energy-using components of a milking system include the Refrigeration Unit for the bulk storage tank, the Vacuum Pump, the Milk Transfer Pump, and the Water Heater. Pre-coolers may be included in the system but do not consume energy directly. Lighting can be a significant contributor to electricity usage.

New Technology and Energy Efficiency Upgrades

Vacuum Pump

Of all the equipment in the milking process, vacuum pumps are generally the second highest user of energy (after refrigeration). Historically it was very common to significantly oversize vacuum pumps to compensate for unreliable equipment and unplanned air leakage causing vacuum fluctuations, and for the washing process. The different styles of vacuum pumps commonly available have varying efficiencies.

When replacing a vacuum pump, the main considerations to get the best performance are:

1. Make sure it is properly sized: Do a new system analysis to calculate power requirements - as the old pump may have been oversized.

2. Choose a pump with the highest rated efficiency: In order of highest efficiency vacuum pump technology to least efficient, considering typical outputs: lobe/blower, sliding vane, water ring, and turbine. All vacuum pumps tend to decrease in efficiency with increasing vacuum level.

3. Consider using a Variable Speed Drive (VSD): Operating a vacuum system with a VSD can reduce the energy costs by up to 60% if the pump is properly sized and as high as 80% if replacing an over sized pump with a VSD system. A VSD will extend the life of the vacuum pump by using soft starts, and by reducing the pump speed. The noise level of the pump also tends to be lower. Lobe/blower and sliding vane pumps are the main pumps recommended for use with a VSD.

VSDs operate with a 3-phase motor but can operate on a single-phase power input when a power convertor is used.

The University of Wisconsin-Madison has calculated 5-year payback scenarios for VSDs installed on different sizes of vacuum pumps (Table 1). The larger the pump and/or the more hours a pump is used, the sooner a VSD will pay off.

Table 1. Calculated Payback Scenarios for Variable Speed Drives

Size of Vacuum Pump	Minimum Hours per Day Used *… that will Achieve a 5 year payback (based on the estimated installed cost of the equipment and electricity at $0.10/kWh)*
5 HP	12 hours or more
7.5 HP	8 hours or more
10 HP	6 hours or more
15 HP	5 hours or more
20 HP and higher	4 hours

Source: Scott Sanford, University of Madison-Wisconsin Outreach

Pre-cooler

A pre-cooler is a heat exchanger that cools milk prior to entering the bulk tank. The cooling fluid is typically water. The main types of milk pre-coolers are a plate heat exchanger or shell and tube heat exchanger. Heat exchangers are designed to maximize surface area of the heat transfer surfaces which increases friction and pumping heat.

If a system includes a pre-cooler, then generally speaking, it is worthwhile to add a VSD on the milk pump.

Milk Transfer Pump

A VSD can be used on the milk transfer pump, however, it usually only makes sense to do so if the milking system includes a pre-cooler. The VSD gives the ability to slow the flow rate of the milk through the plate cooler, which greatly increases the cooling of the milk. It has been estimated that the additional cooling provided by using a VSD on the milk pump is an additional 8 to 11˚C. A higher volume of cooling fluid, usually water, would be required in this situation, to accept the extra heat.

Refrigeration Unit

Refrigeration systems operate using a vapour-compression cycle of a refrigerant gas. The compressor is the component in the refrigeration system that consumes electricity. Replacing an end-of-life reciprocating compressor with a scroll compressor can save from 15 to 20% in cooling costs because of the lower electrical demand. This is a fairly straightforward replacement if the new compressor is within 5% of the capacity of the existing compressor and the condenser unit has been well-maintained.

Refrigeration Heat Recovery Units

A Refrigeration Heat Recovery Unit (RHR) uses a heat exchanger to transfer waste heat from the hot refrigerant in the main refrigeration line to water in a tank. This water can then be used as a pre-heated water source feeding into the water heater. An RHR unit can recover from 20 to 50 % of the energy that would be needed to cool the milk for storage. If a decision is made to include an RHR, the usual recommendation is that the RHR be sized to provide enough hot water for one milking, including washing the system and the bulk tank. This is because it is generally more expensive to heat up the water than to cool down the milk. However, if the RHR tank is oversized, savings will decrease.

The RHR chosen could be either a desuperheating or fully condensing type. A fully condensing unit is the preferred type, as nearly all of the available refrigeration heat is recovered as hot water, which allows it to reach higher temperatures in the range of 40 to 60˚C.

Equipment Interactions

In terms of selecting energy-efficiency components, it's important to realize there are competing functions, such as with a Pre-Cooler and a Refrigeration Heat Recovery unit. In this case, they would both be taking waste heat from the milk to use for other purposes such as water heating.

The University of Wisconsin-Madison generally recommends that dairies with less than 100 cows use either a pre-cooler or RHR but not both. The selected component should be sized according to water heating needs and not to cooling ability. They suggest that on dairies with more than about 150 cows it may make sense to use both a pre-cooler and RHR unit, and it is worth doing an energy savings estimate. If water heating is provided using another technology, such as a tankless water heater, then the choice of using just the pre-cooler may make more sense.

Water Heater

Natural gas water heaters are available in standard efficiency of around 85% or high efficiency condensing units of around 94% efficiency. Electric water heaters have a higher appliance efficiency of about 98%. Regardless of the appliance efficiency, tank water heaters have different levels of insulation. A standard insulated tank experiences standby heat loss of around 60% per day, and the best-insulated tanks experience standby heat loss of around 24% per day.

A recent entry into the water heating market is the instantaneous water heater (Figure 5), also called a tankless water heater. Tankless water heaters heat the required amount of water on demand, and do not have any storage tank, so standby losses are eliminated. They have to be sized quite large, and more than one unit might need to be installed in series to stage the heating process. They are available in natural gas and electric, but the electric version would be impractical for this use because of the high power demand they would create. Alberta Agriculture and Rural Development (ARD) recently completed a case study on a natural gas conventional hot water tank with a tankless hot water heater in a 90 head dairy. Savings of 60% were realized with the tankless hot water heater.

Figure 5. Tankless Hot Water Heaters

Lighting

The most important points to keep in mind with lighting are:

1. Use the lowest wattage equipment that performs the job for the specific application, and

2. Make sure they are turned off when not in use.

Most lighting functions in a dairy can be achieved with a move away from incandescent lights to higher efficiency alternatives such as compact fluorescent, light-emitting diode (LED), improved tubular fluorescent, or for some applications, cold cathode fluorescent lamps (CCFL). Higher efficiency lighting gives the same or comparable light output for a lower power input. An excellent application for high efficiency lighting is in a barn that has gone to long day lighting hours (16 to 18 hours of lighting) to increase milk production.

Not using lights at all, when they are not required, will create the most noticeable savings. Examples can include using natural daylight when it is available, which works especially well with naturally ventilated barns. Natural daylight can be tied in to the use of a photocell, which senses the total amount of light available and can turn on artificial lights only when supplemental light is required. Making sure lights are turned off when not required can be achieved by employee training, but the use of automatic timers and/or occupancy sensors would ensure the most consistent results.

Management Practices with Equipment

The main management practices that will provide a noticeable improvement to energy efficient operation of existing equipment are to ensure:

1. That equipment is shut off or turned down when not needed (by use of timers or controls), and

2. That there is scheduled equipment maintenance.

Equipment Maintenance

Whether a farm is using standard or high-efficiency equipment in all cases a regular maintenance schedule should be followed to ensure continued efficient operation of the equipment, and longer equipment life, both of which will result in cost savings.

This equipment maintenance schedule should be established as per the equipment manufacturers' recommendations or warranty requirements. If there are no recommendations available from the manufacturer, the minimum recommendations from "SCE's Dairy Farm Energy Management Guide", from Wisconsin's Rural Energy Management Council's Dairy Farm Energy Management Handbook, and from the University of Wisconsin-Madison Outreach, can be used. To view the document, follow this link: http://datcp.wi.gov/uploads/Farms/pdf/dfemh.pdf

Energy Efficiency Summary

Table 2 lists the various energy savings technologies that can be used in dairy barns

Table 2. Energy Saving Technologies Available for Dairy Barns

Old Technology	New Technology	Typical Energy Savings
Oversized vacuum pump	VSD with properly sized vacuum pump	Up to 80%
Properly sized vacuum pump	VSD with properly sized vacuum pump	Up to 60%
Reciprocating refrigeration compressor	Scroll refrigeration compressor	15 to 20%
None	RHR with water storage tank	20 to 50%
Conventional hot water tank	Tankless hot water heater	60%

References

"SCE's Dairy Farm Energy Management Guide", from Wisconsin's Rural Energy Management Council's Dairy Farm Energy Management Handbook, and from the University of Wisconsin-Madison Outreach

Sieniewicz, O. (2012) Tank-less or On Demand Hot Water Heater. Alberta Agriculture and Rural Development