Making and Evaluating Energy Use Changes in the Dairy Barn

Jim Salfer[1], Erin Cortus[2] and Kevin Janni[3]

[1]University of Minnesota Extension, St. Cloud, MN
[2]South Dakota State University, Brookings, SD
[3] University of Minnesota, St. Paul, MN
Email: salfe001@umn.edu

Take Home Messages

- Audits show that 85 to 90% of all the electricity on dairy farms is used for the milking, ventilation and lighting systems.
- The lowest cost way to improve energy efficiency is through proper maintenance of the milking, ventilation and lighting systems.
- Well-designed systems using new technologies can increase energy efficiency and improve performance.
- Capital costs of installing the latest technologies must be considered along with the potential energy savings.
- Heat stress can greatly affect animal performance and welfare. Summer ventilation systems have high energy use but greatly improve animal welfare and productivity. Animal welfare and productivity should never be compromised.
- Energy efficiency can be evaluated and expressed in several ways, but minimizing energy use per liter of milk produced is one of the best options.
- There are several online tools to help evaluate and improve the energy efficiency of dairy farms.

Introduction

There is increased pressure from consumers for dairy farmers to minimize their impact on global warming by reducing energy consumption. Even though energy use is not a large portion of the total production costs on a dairy, it makes economic sense to make the most efficient use of energy on the farm.

■ Energy use in the barn

Given the differences in size, construction, components (i.e. milking cooling system, lighting) and management of dairy barns, there is not surprisingly a large range in energy use between barns and farms. Energy use on dairy farms in Ontario varied from 571 to 1946 kilowatt-hours (kWh) per cow per year (Clarke and House, 2010). On average, energy use was higher in tie-stall barns than freestall barns (1417 vs. 837 kWh per cow per year). Grazing and open lot dairies use less electricity than confinement dairies (Capareda et al., 2010). Table 1 shows the breakdown of electricity use within farms by two different auditing firms for system components. The majority of electricity is used in the milk harvesting and cooling process, ventilation and lighting.

Table 1. Energy use breakdown on farms.

Item	Ontario[1]	New York State Energy Research and Development Authority[2]
Ventilation	12%	24%
Lighting	14%	17%
Electric water heating	15%	5%
Milk cooling	21%	26%
Milk harvesting	23%	18%
Other	15%	10%

[1]Clarke and House, 2010
[2] Ludington and Peterson, 2005

The wide range in estimated energy use per cow and by system component highlights the opportunity on many farms to reduce energy use. There are many opportunities to make more efficient use of energy for one or more of the system components. We will discuss each of these in detail below. However, the first step is understanding energy use and efficiency for your type of operation.

■ Where Do I Start?

Figure 1 shows an energy pyramid developed by the major U.S. energy auditing firm EnSave. The figure presents a logical progression in how to develop an energy saving plan and ultimately use renewable energy.

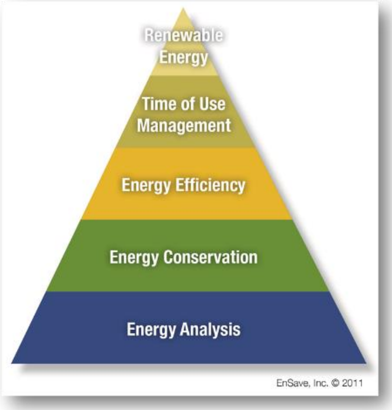

Figure 1. Energy Pyramid (Fournier)

An energy analysis or energy audit identifies the areas and magnitude of energy use on the farm and in the dairy operation. Most audit programs include suggestions for equipment and/or management practices to improve the energy efficiency and estimate the cost savings associated with the change. Some of the questions that may be asked during the audit include: Does the equipment have a regular maintenance schedule? Is the equipment in good working order? Is equipment being run even when not in use? There is a cost, but there are sometimes cost-share opportunities for these energy audits.

The second step on the pyramid is energy conservation. Some example suggestions might include installing automatic timers on lights and correctly staging ventilating and circulating fans to optimize animal welfare and save energy.

Energy efficiency is the third step on the energy pyramid. Regular equipment maintenance can have a major impact on how efficiently energy is being used. Upgrading to more energy efficient equipment requires an initial investment, but may be less costly in the long run because of energy savings.

The top two steps are time-of-use management and renewable energy. These are beyond the scope of this paper.

■ Ventilation

Properly designed ventilation systems are important for animal health, well-being and production. The ventilation system removes heat, humidity and gasses while providing fresh air for the animals. In the summer the primary purpose of the ventilation system is to remove as much heat as possible.

Many farms have inadequate summer ventilation systems and the cows experience heat stress. A well-designed, well-maintained summer ventilation system will make the most efficient use of energy while maximizing milk production and animal well-being.

Temperature-humidity index (THI) is a common indicator for the degree of heat stress in livestock. The latest research estimates that heat stress on dairy cows begins when the THI reaches 68 (Collier et al., 2011). In a later study the authors reported that lactating dairy cows producing more than 35 kg of milk begin to have milk yield losses when the THI is 65 or greater, or when the average THI is 68 or more for more than 17 hours per day. Summers throughout North America are becoming warmer and more humid (Collier et al, 2012.). Night time temperatures are staying higher. As dairy cows increase in production they increase heat production associated with digestion of increased amounts of feed. These two factors have resulted in increased heat stress on our dairy cows. Below are some of the animal welfare and performance impacts of an inadequate summer ventilation system.

▪ Heat Stress Impacts

Dairy cows exhibit behavioral changes in response to heat stress. Cook et al. (2007) showed that lying time decreased from 10.93 hours/day when the THI was 56 to 7.91 hours when the THI increased to 73.8. In this study, the cows were generally spending more time standing in the alleys. Observations also indicate that cows under heat stress are more likely to stand and bunch together in certain areas of the barn.

Heat-stressed cows have increased respiration rates and often pant in an attempt to dissipate heat. Increased respiration rates can result in metabolic acidosis with a resultant decrease in bicarbonate in the saliva. This, along with decreased saliva production because of less rumination, can result in an increase in sub-acute rumen acidosis (SARA). The combination of increased standing and acidosis can result in increased lameness for several months after the heat stress occurred.

High producing cows experience more heat stress than lower producing cows. Research shows that at similar THI levels, high producing cows' body temperatures will increase more than low producing cows (Santos and Staples, 2012).

Heat stress adversely affects reproduction by reducing estrus expression, decreasing embryo quality and impairing immune function (Bilby, 2012).

Recent research has shown that heat stress in dry cows has a dramatic effect on calf health and milk production in the subsequent lactation. Nine studies have been conducted and all have shown that cows cooled during the dry period produced from 2 L/cow/day to 8 L/cow/day more milk in the subsequent lactation than non-cooled cows. Cooled cows also had better immune function the following lactation (Tao and Dahl, 2013).

Florida research showed that cows that were heat-stressed during the dry period had shorter gestation lengths, resulting in lower birth weight calves. Calves also had lower apparent efficiency of IgG absorption (33.6% vs. 19.2%), resulting in lower plasma protein and serum IgG (Tau et al., 2012). Heifer calves born from these heat-stressed cows produced an average of 4.5 L less milk per day for the first 30 weeks of lactation when they entered production (Tau et al., 2013.).

▪ Evaluating Your Ventilation System

Evaluating the ventilation system is an important first step in reducing energy usage. Are the fans running, and running according to the appropriate temperature and time schedule? Are mixing fans directing air toward the cows rather than above them? Are there noticeable and appropriate air speed differences in different parts of the barn? Are heat stress behavior indicators more prevalent in one part of the barn than another? Identifying and addressing these types of issues within your current system can help use your energy more efficiently. We have developed a planning guide to help evaluate heat stress and the energy use of your ventilation system (Carrol et al., 2014).

One key to maximizing the energy efficiency of your ventilation system is fan selection and maintenance. When purchasing and installing fans it is important to consider how energy efficient they are. The University of Illinois BESS lab conducts independent third party testing of agricultural ventilating and circulating fans. Test results are available online at http://bess.illinois.edu. BESS lab reports the performance parameters, including ventilation efficiency rating in CFM per watt, for the various fan makes and models. There is wide variation in energy efficiency of fans. For example, BESS lab reports the energy efficiency ratings of 48” fans ranges from 12.7 to 23.4 CFM/Watt. Proper maintenance of the ventilation system is important to optimize performance. Research has shown that dusty and dirty shutters and blades can reduce fan flow rates up to 40% (Janni, 2014). Designing and matching the inlet area with fan output will maximize air for the amount of energy used.

BESS lab also tests and reports circulating fan performance and energy use. An important parameter for circulating fans is thrust efficiency ratio, which indicates how efficiently the fan transfers electrical power into air movement. It also reports centerline air velocities at standard distances downstream of a circulating fan. Thrust efficiency ratios for 36” fans range from 10.4 to 22.4

lbf/kW and centerline velocities at 15 feet downstream range from 560 to 1540 feet per minute. This is a large range for one size of fan!

▪ Milking System

Audits show that about half of the electricity in the dairy operation is associated with the milking process and cleaning the milking system. This provides several opportunities to reduce energy use.

Fix any leaking water faucets. Even slowly dripping hot water faucets will leak several gallons of water per year. It takes minimal costs to repair and keep all faucets working correctly. Consider installing an insulating blanket on the water heater and insulate the hot water pipes leaving the heater. Locate water heaters to avoid long hot water lines to reduce heat lost from those lines.

Proper location and maintenance of the compressor. In the summer, it is best to locate the compressor in a well-ventilated area for increased efficiency. Cleaning compressor fins quarterly can reduce milk cooling costs by 3-5% (E Source). Technologies that will improve energy efficiency during the milk cooling process include refrigeration heat recovery systems and plate coolers. A refrigeration heat recovery system uses compressor heat to pre-heat water and the plate cooler uses well water to cool the milk. Plate coolers can pre-cool the milk as much as 16^{o}C and reduce cooling costs by 50% (E Source, 2010). A recent model showed that when all costs were included, it appeared that the refrigeration heat recovery system was the most cost effective on farms up to a total milk volume of 6100 hL per year. At higher milk volumes the heat recovery system and plate coolers combined provide the greatest savings (Corscadden et al., 2014).

Variable speed drives for the vacuum pump and milk pumps are an excellent investment on many dairies. Variable speed vacuum pumps typically use 65-70% less energy that non-variable speed pumps. Table 2 shows the estimated payback of variable speed vacuum pumps. The payback will depend on initial cost, hours of operation and electricity cost. An added advantage of a variable speed milk pump is that, when combined with a plate cooler, the milk speed is slowed through the plate cooler resulting in cooler milk entering the bulk tank. Newer scroll compressors on bulk tanks can reduce compressor energy costs as much as 20% compared to older reciprocating compressors (E Source). When equipment needs to be replaced consider equipment with higher energy efficiency ratings.

Table 2. Minimum operating hours for a 5-year payback period[1]

Vacuum pump size, hp	Minimum operating hrs/day
5	12
7.5	8
10	6.5
15	5
20	3.5

[1]Clarke and House, 2010

There has been a rapid increase in the installation of robotic milking systems throughout North America. Because the robots are operating 24 hours per day there are questions about energy use compared to conventional milking systems. The Iowa Dairy Center in Calmar, Iowa, recently conducted an energy audit at their facility that has both a parlor and robotic dairy. Energy use was 1592 vs. 1470 kWh/cow and 0.122 vs. 0.116 kWh/L of milk for the parlor vs. robot system, respectively. Other research has shown that robotic milking systems use more electricity than conventional milking systems (Kaurich, 2010). Kaurich found a wide variation in energy use on three robotic milking farms and attributed it to differences in design and management. Consider energy use when designing any new dairy facility.

■ Lighting

Proper lighting is important for optimum cow performance and providing a safe and pleasant work environment. All farms should implement long-day lighting (18 hours of light above 15 foot candles) in the lactating cow housing area to maximize milk production. Managers, veterinarians and workers need sufficient light for observing cows, doing cow care tasks and assessing cow cleanliness before milking. Uniform lighting that minimizes shadows and dark entrances will minimize cows stopping or slowing down to investigate as they enter dark areas.

Because lights are on a substantial portion of the day, energy efficient lighting is an easy way to reduce energy costs. It is important to replace burned out bulbs and wash light fixtures on a periodic basis to maintain recommended light levels.

If incandescent bulbs are still used, they can simply be replaced with compact florescent bulbs which use one quarter of the energy and last much longer. The older T12 florescent tubes are 35% less energy efficient per lumen than newer T8 lights and cost minimally more to install (E Source). Newer T5 lights are currently the most energy efficient florescent bulbs available, but cost considerably more that T8s. The newest technology is light-emitting diode (LED) lights. LED lights are very energy efficient and can last 60,000 hours or more. They operate well in cold temperatures and are essentially instant-on devices. The main disadvantage is the initial cost. LEDs commonly cost 2 to 3 times more than comparable fluorescent lamps. The long useful life reduces replacement lamp cost and labor costs to replace lamps. This, along with the higher energy efficiency, means LEDs potentially can be more economical over their life than other lights. Many factors should be considered when comparing lighting options and costs (Janni and Lazarus, 2014).

Many power companies in the US offer rebate programs to upgrade to more energy efficient lights.

■ Evaluating Overall Energy Efficiency

Energy efficiency can be evaluated and expressed in several ways, but we will focus on minimizing energy use per liter of milk produced. Any decrease in energy use per liter of milk produced is an improvement. To provide you with as much information as possible to make a fair assessment, we offer the following basic practices. There are many alternatives to this method.

- Accumulate monthly milk production, energy use, and temperature data. Use as many prior years of data that you are comfortable with, keeping in mind other changes to your operation that may have impacted the numbers. Climate data is available through multiple sites.
- Divide monthly energy use values by milk production for the same time period.
- Plot the energy use per milk production numbers calculated previously against average temperature or THI values for the same period.

Figure 2 shows the energy efficiency on a farm that emphasized better maintenance of the ventilation system during the summer of 2013. On this farm, the energy efficiency per liter of milk was highest during 2013.

Evaluating energy use per L of milk produced is designed for long-term evaluation of energy use. There are many factors that affect milk production, and this method will not necessarily separate out the effect of individual changes (i.e. if lights and the milking system were changed out in the same year).

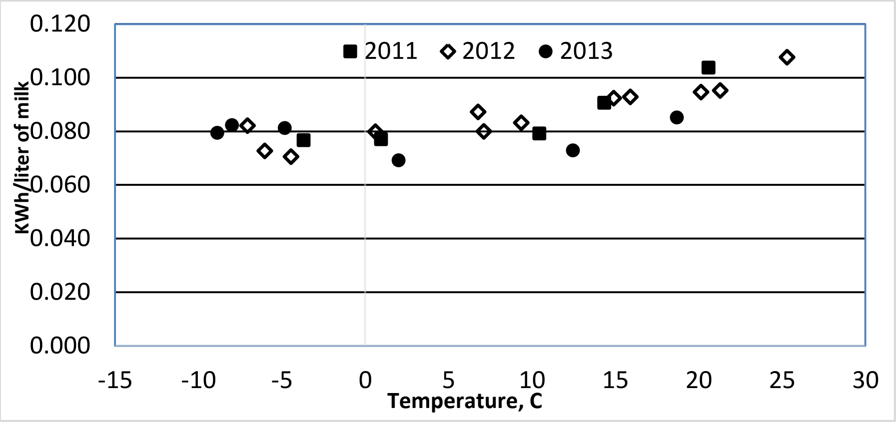

Figure 2. Energy efficiency per liter of milk from 2011 to 2013

▪ Evaluating The Economics Of Potential Changes

There are several online tools that can assist in determining if investing in an energy saving technology is cost effective. Below is a list of internet resources that can help determine the payback on different technologies:

- This link will allow producers to do a farm energy self-assessment. http://z.umn.edu/ra3
- This link provides users with the estimated annual energy saving compared to the current equipment and management. http://ahat.sc.egov.usda.gov/
- This link has various energy savings calculators including installing a variable speed vacuum pump and milk-pre-cooler installation http://z.umn.edu/ra1

▪ Conclusion

The biggest uses of energy on dairy farms are the milk harvesting and cooling process, lights and the ventilation system. There are opportunities in each of these areas to improve energy efficiency while maximizing milk quality and animal well-being. Energy audits (either a self-audit or by a third party) can determine if changing management or investing in new technologies is cost effective to implement. Proper maintenance will maximize performance and energy efficiency. Energy use changes can start small. Considering the energy use and production numbers simultaneously provides a different perspective to energy use.

References

Bilby, T.R. 2012. Strategies to improve reproduction during summer. http://z.umn.edu/ilf

Capareda, S.C., S. Mukhtar, C. Engler, and L.B. Goodrich. 2010. Energy usage survey of dairies in the Southwestern United States. Amer. Soc. of Agric. and Bio. Eng. 26:667-675

Clark, S. and H. House. 2010. Using less energy on Dairy Farms. Factsheet from Ministry of Agriculture, Food and Rural Affairs. http://z.umn.edu/r9f

Collier, R.J., R.B. Zimbelman, R.P. Rhoads, M.L. Roads, and L.H. Baumgard. 2011. A re-evaluation of the impact of Temperature Humidity Index (THI) and Black Globe Humidity Index (BGHI) on milk production in high-producing dairy cows. Pages 113-125 in: Proc. Western Dairy Mgmt Conf. Reno, NV. March 9-11.

Collier, R.J., L.W. Hall, S. Rungruang and R.B. Zimbelman. 2012. Quantifying heat stress and its impact on metabolism and performance. Online at http://dairy.ifas.ufl.edu/rns/2012/6CollierRNS2012a.pdf. Accessed July 29, 2013.

Cook, N.B., R.L. Mentink, T.B. Bennet and K. Burgi. 2007. The impact of milk heat stress and lameness in the time budgets of dairy cattle. Proc. Sixth International Dairy Housing Conf. Minneapolis, MN. June 16-18.

Corscadden, K.W., J.N. Biggs, and M. Pradhanang. 2014. Energy efficient technology selection for dairy farms: milk cooling and electric water heating. Amer. Soc. of Agric. and Bio. Eng. 30(3): 375-382.

E Source. 2010. Managing energy costs in dairy farm facilities. http://z.umn.edu/r9x

Fournier, Z. 2014 personal communication. ZacharyF@ensave.com

Iowa Dairy Center. 2014. Milking system energy assessment. http://z.umn.edu/iads

Janni, K. 2014. Fan selection and maintenance. http://z.umn.edu/ra2

Janni, K., and W. Lazarus. 2014. Lighting up your barn but not your wallet. Hoard's Dairyman. May 25, 2014. 159(10):376.

Kaurich, J. 2010. Energy efficiency recommendation for robotic milking systems. ASABE 2010 International conference. Paper 1008961.

Ludington, D., R. Peterson. 2005. How much energy does your dairy use. http://z.umn.edu/nyaudit

Monteiro, A.P.A., S. Tao, I.M. Thompson, and G.E. Dahl. 2013. J. Anim. Sci. 91(Suppl. 1):184

Santos, J.E.P. and C.R. Staples. 2012. Nutritional programs for lactating dairy cows under heat stress. DAIReXNET.

Tao, S., and G.E. Dahl, 2013. Heat stress effects during late gestation on dry cows and their calves. J. Dairy Sci. 96:4079-4093.

Tao, S., A.P.A. Monteiro, I.M. Thompson, M.J. Hayen, and G. E. Dahl. 2012. Effect of late-gestation maternal heat stress on growth and immune function of dairy calves. J. Dairy Sci. 95:7128-7136.