

**Project Title: Optimizing Renewable Electric Energy Generation on Minnesota Dairy Farms**

Contract Number: RDF4-2 Milestone Number: 4 Report Date: 12/7/2017

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Congressional District: (Project location) 7<sup>th</sup> District

## MILESTONE REPORT

### Executive Summary:

This project has three primary goals: to increase the market penetration of renewable electric energy resources on Minnesota dairy farms by developing an optimized and integrated on-site electrical generation system, to support Minnesota companies through field testing and validation of their commercial, or soon to be commercial, renewable electric generation systems and components, and to reduce the carbon footprint and increase the long-term profitability of Minnesota dairy farms through on-site renewable electricity generation.

The fourth milestone for this project involves completing installation of the solar PV and small-scale wind renewable energy systems as well as a SCADA system for dairy thermal energy management. Other deliverables are an initial Life Cycle Analysis (LCA), presenting the project at a regional meeting, and establishing a web page for the project.

Construction of the solar PV array is complete and it was interconnected to the utility grid on October 4<sup>th</sup>, 2016. Installation of two 10 kW Ventura wind turbines as well as 4 kW of pole-mounted solar PV panels is complete and these systems were interconnected to the utility grid on June 6<sup>th</sup>, 2017.

### Technical Progress:

The ground-mounted solar array is comprised of Minnesota made tenKsolar panels and inverters. Construction of the 50 kW solar array was started in mid-July and interconnected to the utility grid on October 4<sup>th</sup>, 2016.

TenKsolar announced it was entering bankruptcy in June of 2017 and would not honor its warranty after May 5<sup>th</sup>, 2017. The inverters are manufactured by a separate company, LEAD Solar, which continues to honor its warranty and offer replacement parts. Warranties on solar PV modules are performance based generally meaning modules will still produce 80% of their nameplate



**Figure 1. tenKsolar 50 kW Solar PV Array**

capacity after 25 years. Extra modules could be purchased now to replace poorly performing modules over time, but the WCROC has decided against this opting instead to replace any failing modules in the future with a different module or to just allow system performance to decrease. A few replacement inverters will be purchased if there are remaining grant funds since the inverter is a unique design and is more likely to adversely affect system performance in the event of a failure. While the inverter manufacturer is still in business, tenKsolar was its largest customer creating some uncertainty about its future ability to honor the inverter warranty.

Each wind turbine system consists of an 80 foot tall tower made by ARE Telecom, a 10 kW turbine made by Ventera, and an inverter to condition the generated electricity and feed it to the utility grid. The turbine located in a cow pasture (north tower site) also has a 4 kW solar array mounted to poles near its base.

On-site assembly of the wind turbine towers began in December of 2016 and both turbines were interconnected to the utility grid on June 6<sup>th</sup>, 2017. The towers have a tilt-down feature that allows the pole to be lowered with a portable hydraulic power pack and actuator. Figure 3 shows the south tower in the lowered configuration allowing the turbine to be attached without a lift or climbing the tower, and Figure 4 shows the tower in its final (upright) configuration. This feature will also be used for any turbine maintenance. The hydraulic power pack and actuator are both removed and stored indoors for safekeeping. Once the tower is raised a series of bolts are installed around a flange to secure the tower in the upright position.

The south turbine did not seem to be tracking well with the wind after the installation contractor left indicating the turbine was not level. There are a series of adjustable bolts that attach the turbine to the tower and allow the turbine to be leveled. Lowering the tower, adjusting the bolts, and then raising the tower to visually check for level is a time consuming and inaccurate process involving a lot of trial and error. An



**Figure 4. South 10 kW Wind Turbine Installed**



**Figure 2. North Wind Turbine with 4kW Pole-Mounted Solar Array**



**Figure 3. South Tower Folded Down for Turbine Installation**

80 foot man lift was rented so a level could be placed directly on the turbine mount while the bolts were adjusted to level. This proved to be a much more efficient process and the turbine was tracking the wind much better afterwards.

The supervisory control and data acquisition (SCADA) system for new thermal energy systems installed in the dairy parlor is complete. Additional refrigerant pressure sensors and an ultrasonic milk flow rate sensor were installed to better control the heat pump during milking. The intermittent nature of milking was causing the heat pump to fault due to insufficient heat being available

when lulls in milking occur. Monitoring milk flow and refrigerant pressures has remedied that problem.

There continues to be a problem of insufficient heat storage. Bids are being sought for an inexpensive way to reject heat from the storage tank into the unused portion of the dairy barn. Also, the large electric tankless water heater has developed a small leak that is being addressed. In the interim, the old gas water heater is being used to provide hot water for cleaning operations.

Life-cycle assessment (LCA, also known as life-cycle analysis or cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. A preliminary life cycle assessment model has been developed for the WCROC milking parlor. The LCA model is a tool that tracks inputs and outputs of the dairy system to look at how a change in inputs or processes will change the outputs and the downstream environmental impacts of the system. The model was designed as an exploratory LCA to look for major areas in the dairy system that are likely to increase environmental impacts, namely; global warming potential and fossil energy use. For global warming potential (GWP), carbon dioxide equivalents are tracked per unit of milk produced. Fossil energy use is tracked using individual types of fossil energy (natural gas, coal, crude oil), and as an overall fossil energy use standardized in mega Joules per unit of milk produced.

Fossil energy and greenhouse gas differences between the baseline dairy system and the energy enhanced system are being analyzed using renewable electricity production from the installed solar and wind energy systems. Future refinements of the model will allow quantification of the impacts of renewable energy and energy efficiency installations in the WCROC dairy parlor on fossil energy use and greenhouse gas emissions. More details are available in the preliminary LCA model included in the appendix.

A literature review was conducted assessing best management practices for integrating renewable energy generation on dairy farms. Many farms have installed renewable energy systems, but nothing analogous to the system level energy re-design incorporated into the WCROC dairy parlor was found. The literature review is included in the appendix.

A regional, public meeting was held at the WCROC facility in Morris, MN called the Midwest Farm Energy Conference (conference brochure included in appendix). The conference was held on June 13<sup>th</sup> and 14<sup>th</sup>, 2017, and included many presentations related to swine and dairy energy systems including one about this project which is included in the appendix. 75 people attended the conference.

**Additional Milestones:** Power production from solar and wind power systems is being monitored, and dairy thermal energy system control protocols are being developed in support of Milestone 5.

**Project Status:** The project has suffered delays in procurement and installation of the wind tower systems and turbine/inverter systems, as well as operational difficulties with dairy thermal energy equipment. Major equipment procurement and installation is now complete. The remaining time in the grant period will be devoted to data collection and analysis.

**Appendices:** LCA Model, Literature Review, MFEC Conference Brochure, MFEC Presentation: “Net-Zero Energy Dairy”.

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*Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund.*

## “Optimizing Renewable Electrical Energy Generation on Minnesota Dairy Farms”

LCA Report by Joel Tallaksen

Life cycle assessment work for this project is progressing with the modification of a previously developed LCA model to allow it to more easily model new pathways for analyzing renewable electricity impact on the dairy operation. The life cycle assessment model, described in more detail below, is a tool that tracks inputs and outputs from the dairy system to look at how a change in inputs or processes will change the outputs and the downstream environmental impacts of the system. Previously, the model was used to look at how incorporating more energy efficient equipment would affect environmental metrics of the dairy. The current work will incorporate renewable electricity into the model inputs and look at how different renewable and grid electricity mixes impact the dairy operation’s environmental footprint.

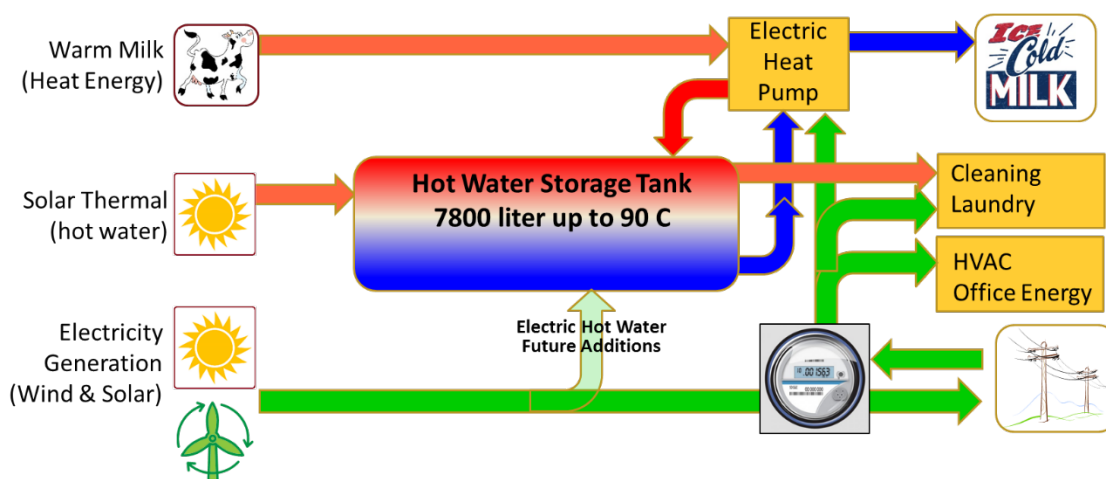


Figure 1. Schematic of Dairy system being model, with both previously studied energy efficiency equipment and currently modeled renewable energy inputs.

### Underlying Life Cycle Assessment Model.

The LCA model developed to study the dairy system was designed as an exploratory LCA, to look for major areas in the dairy system that were likely to increase environmental impacts. The model was designed to focus on two key environmental impacts; global warming potential and fossil energy resource depletion. For global warming potential (GWP), carbon dioxide equivalents are tracked per functional unit of milk produced. Fossil energy use (resource depletion) is tracked using individual types of fossil energy (natural gas, coal, crude oil), and as an overall fossil energy use standardized in megajoules.

The model is a process model that examines each step (process) in the system needed to produce fluid milk. Overall the dairy production system has two major cycles for the dairy system; replacement animal

production and milk harvesting operations. The model was designed as a 'cow centric' model, based growth stages (processes) of the cow and the inputs and outputs of each individual growth stages. This allows for the ability to change animal management strategy assumptions based on the questions being asked in various studies.

A number of different sources of data are used for this dairy LCA work. Priority is given to data generated at WCROC or data that was calculated based on WCROC operations. Energy audits conducted by WCROC researchers are another important source of information. But, some background data is used from databases or literature. The major Input for each stage includes an animal input from a previous stage of the LCA. Other inputs include grains, forages, natural gas, and of course, electricity. Typical output products for each stage are an animal that has progressed through the stage, loss of animals through mortality, birth of young animals, and the output products milk and meat.

The major direct use of energy in the dairy system is in the milking harvesting operations. This includes collection of milk from the animal, cooling of the milk, and cleaning of the facilities. Other activities are needed to support this work, including building heating/cooling, employee shower and cleaning space, and office equipment. In the previous study, enhancements were made to the WCROC dairy to add renewable hot water, heat exchanger technology, and more energy efficient equipment to the process (figure 1).

As part of the current LCA efforts for the dairy system, the fossil energy and greenhouse gas differences between the baseline dairy system and the energy enhanced system are being analyzed using renewable electricity production. The comparison primarily use the conventional dairy (organic not included) and renew energy production data, plus previous potential energy savings. Based on Initial findings for energy reduction from the conservation measures, it is likely that renewable electricity will fill in most of the energy needed for the dairy facility. With the energy production and consumption data available for the new renewable energy production systems, the model is being updated to directly look at electricity based environmental impacts.

# **Best Management Practices for Integrating Renewable Energy Generation on Dairy Farms**

**August 2017**

## **1 Literature Review**

### **1.1 *Energy Intensity in Livestock Operations- Modeling of Dairy Farming Systems in Germany* –Simone Kraatz (2012)**

In reducing energy use on a dairy farm, it is important to understand the total energy inputs per amount of milk produced. The goals of this study were to determine energy intensity on dairy farms throughout the entire farming process that is needed to produce milk, as well as to determine how energy intensity changes when using different feeds, housing, and technologies in the milking process.

As the human population of the planet steadily increases toward 9.5 billion people by 2050, high quality food that requires the least possible quantity of resources and energy input is in high demand. To accommodate this increase in demand (80% increase in dairy products demand by 2050 (Steinfeld et.al., 2006)), it is important to study the energy intensity aspects of dairy farming including feed supply and diet composition, machines and technical facilities, livestock operations, and the milking process regarding these factors in dairy production.

#### **I. Methodology**

In this study, it was important to define characteristics of dairy farms in order to apply the information that was gathered to particular dairy farms and make detailed comparisons. For example, all heifers must be raised at the farm in order to maintain herd size, the energy needed for production is related to the unit of milk produced, the milk is corrected for an energy content of 3.5% protein and 4.0% fat (standard), and an average milk yield is defined as 8000 kg ECM cow<sup>-1</sup> year<sup>-1</sup>. Additionally, the number of head at the farm affect the energy intensity calculations with respect to livestock buildings, storage facilities, machines and equipment, technology, and the rate of replacement of the herd.

#### **II. Feed Supply and Diet Composition**

In supplying feed for dairy production, it was found in this study that the least energy intensive way to feed the cows was by full time summer pasture grazing. The next most energy intensive option was half-time summer pasture grazing, followed by the most energy intensive option which was free-stall barn indoor feeding and raising. Free-stall barn indoor feeding and raising is the most energy intensive and therefore the least efficient option for amount of energy per kilogram of milk produced due to the fact that it includes the energy intensive process of tillage, seeding, fertilization, plant protection, harvest, transportation, and conservation (S. Kraatz, 2012).



### III. Machines and Technical Facilities

This section included some aspects that were not significant in increasing efficiency of dairy productions, however it was found that whole-year confinement in a free-stall barn was the most energy intensive way to raise dairy cows compared to half-time summer grazing or full-time summer grazing. Additionally, including pasture feeding in the diet of young cattle reduces energy inputs for machines by 46%. Barns and other facilities on dairy operations made from different materials yield different energy intensities. For example, the use of plastic in buildings and milking machines is 20 times more efficient than steel materials.

### IV. Milking Process

The main energy input in the milking process is in the form of electricity used to power machines and cooling apparatuses. For example, direct energy inputs of automatic milking systems are 25% higher than those of conventional milking systems. By using direct cooling systems, electricity consumption is decreased by 15-20% compared to indirect cooling systems. Additionally, by using stainless steel materials instead of plastic materials, the indirect energy input is increased by 155%. Also, higher tank capacities for cool milk storage is more efficient than tanks with smaller tank capacities. 16% of the energy intensity of milk production comes from the milking process itself, which makes for a large area of the milk production process where efficiencies can be increased and energy usage decreased.

#### 1.2 Dairy Energy Prediction (DEP) Model: A Tool for Predicting Energy Use and Related Emissions and Costs in Dairy Farms –Maria Caria, et.al. (2017)

This paper describes that it is important to consider fossil fuel use and high energy prices when powering dairy farms, and how nonrenewable energy sources result in pollution, greenhouse gas emissions, and an overall increase in the carbon footprint of the dairy industry. The goals of this study were to estimate how much diesel fuel and electricity is used on dairy farms and to assess inefficiencies in energy consumption, CO<sub>2</sub> emissions, and energy costs on dairy farms.

Data collected from 285 conventional dairy farms in southern Italy were used in this study to develop a model for a Dairy Energy Prediction (DEP) tool. By using characteristics from each dairy farm, the DEP and Energy Utilization Indices (EUIs) are able to predict diesel fuel use, electricity consumption, carbon dioxide emissions, and the costs of energy purchases so that farmers can evaluate the energy performance of their farms.

#### I. Materials and Methods

For this study, data was collected from 285 conventional dairy farms, 55% of which were barn confinement farms, and the average size of the farms were 127 cows per farm. Each of these



farms on average produced 495 tons of milk per year. The average amount of diesel used was 13,120 kg yr<sup>-1</sup> and the average amount of electricity consumed was 16,250 kWh yr<sup>-1</sup>. Detailed energy audits for each farm were conducted, as well as a Life Cycle Analysis (LCA) for each farm.

II. Diesel Model

The results of the diesel research were that as the size of the farm increased in terms of dairy head and hectares, the amount of diesel fuel consumption increased.

III. Electricity Model

The results of the electricity research were that as the size of the farm increased in terms of dairy head and size of barns, the electricity consumption increased.

IV. Dairy Energy Prediction Tool

The DEP uses the farm characteristics (total number of head, total number of lactating cows, hectares of cultivated area, and feeding strategy) and characteristics of the irrigation system to predict an estimation of diesel and electricity requirements per year, emissions of carbon dioxide (MJ and percent contribution), and the annual energy cost for diesel and electricity. The DEP can also calculate more specific carbon dioxide emission factors in terms of diesel emissions and electricity emissions, avoided emissions due to production of renewable energy, and the price related to the purchase of energy (euro per unit of diesel and electricity). This tool also predicts the Farm Emission Class Indicator, classifying the emission intensity according to kilograms of carbon dioxide emitted per 100 kilograms of milk produced.

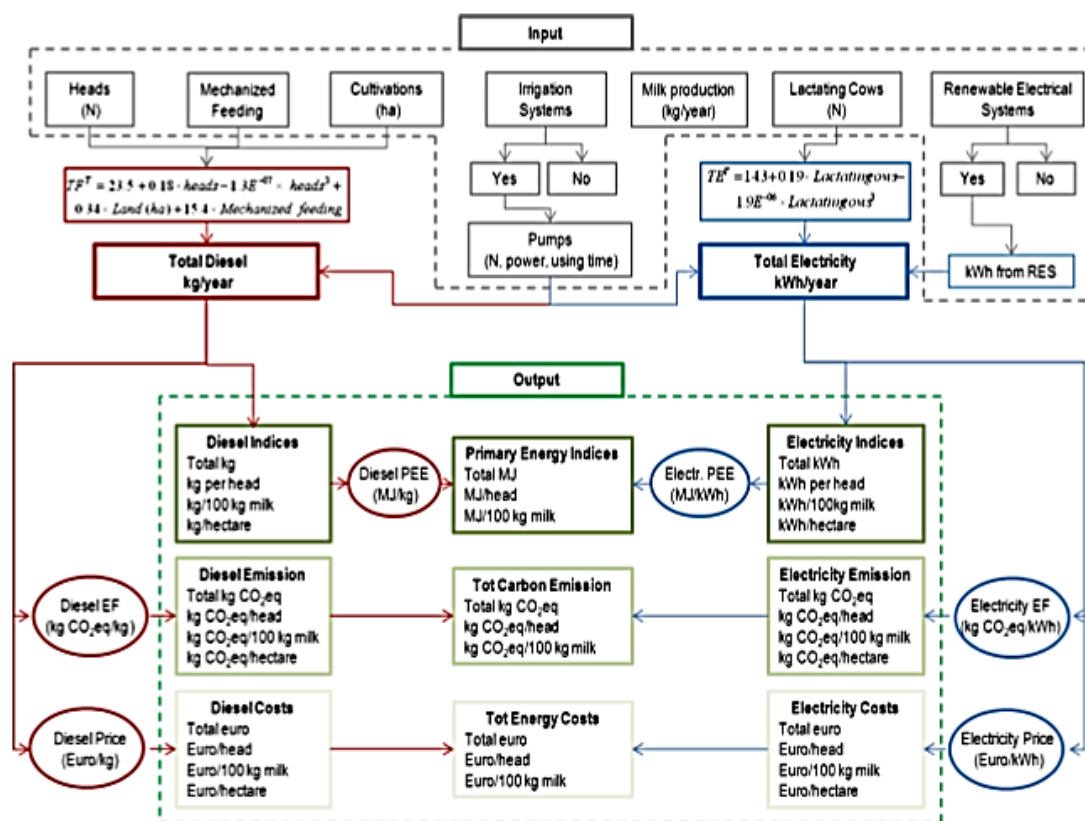


Figure 1: Flowchart of inputs (grey) and outputs (green) of the DEP tool. Diesel fuel is shown in red, electricity consumption is shown in blue. Red and blue circles are parameters used to assess diesel and electricity indices

### 1.3 Evaluation of Energy Efficiency and Renewable Energy Generation Opportunities for Small Scale Dairy farms: A Case Study in Prince Edward Island, Canada -Carrie Houston, et.al. (2013)

This paper highlights steps in reducing energy-related operational costs with powering a dairy farm by reducing total energy consumption, increasing energy efficiency, and using renewable energy systems on the farm to produce inexpensive, on-site clean energy. It is also explained in this paper how it is important to conduct an energy audit to assess energy use on the farm and where there might be opportunities to increase energy efficiency.

Similar to operations at the West Central Research and Outreach Center (WCROC), many of the steps toward reducing energy needs on dairy farms lead to an idea of net zero energy production by wisely using resources on the farm to power the production of dairy. This includes taking advantage energy efficiency opportunities and investing in small to medium scale renewable energy systems to provide most of the energy the farm needs on-site.

#### I. Methodology

In this study, a detailed energy audit was completed in order to quantify the energy consumption with the long term goal of identifying opportunities to increase efficiency, decrease energy

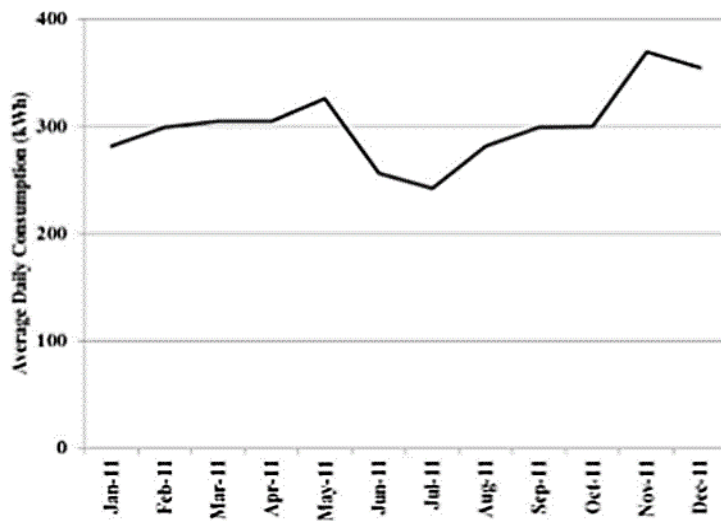


Figure 2: Average daily electricity consumption based on historical billing analysis

consumption, and decrease costs. The energy audit consisted of three phases: Phase I, an audit of historical data to focus on past consumption trends of the facility, Phase II, the screening survey, which investigates the current operation of the facility, assigning ratings of equipment and estimated hours of operation, and Phase III, the detailed investigation and analysis, which further investigates and analyzes key areas explored in Phase II. The audit included energy consumption of livestock keeping, farm house use, waste management, milking, milk cooling and storage, and cleaning and disinfection.

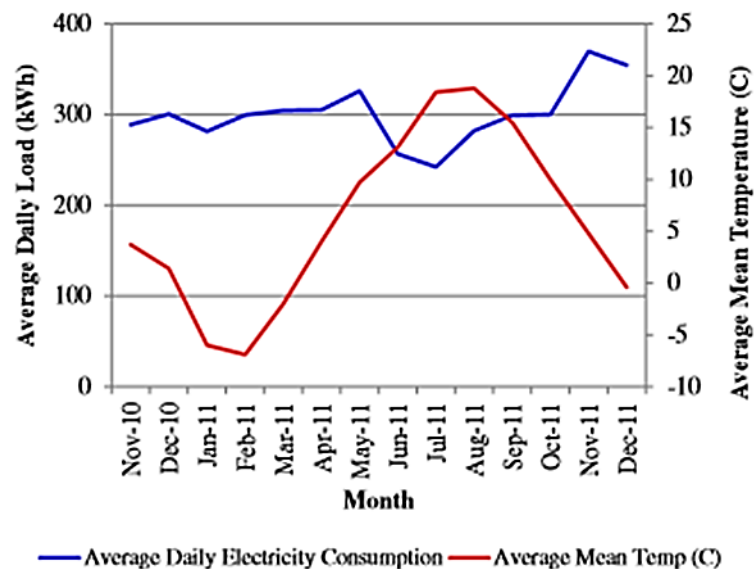


Figure 3: Average daily load and mean temperature trend

## II. Results and Analysis

From Phase I, it was found that electricity and propane are the two primary energy sources consumed on the farm. The percentage of total energy consumption is 89% electricity and 11% propane. The sanitation of the milking facility requires hot water heated by the

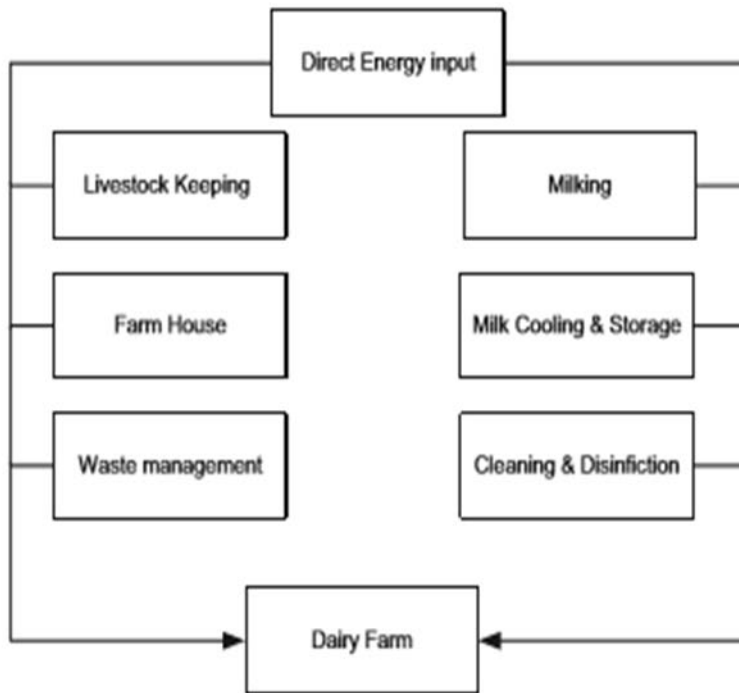


Figure 4: System boundary and direct energy inflow for the case study farm

propane source every 48 hours after the milk tank becomes full and is picked up by the milk purchaser. Seasonally, an increase in energy consumption occurs in winter months, and a decrease in energy consumption in the summer months, related to longer days in the summer and less lighting requirements, and shorter days in the winter requiring more lighting. Additionally, in the summer the cows move outside permanently, and there is no need for ventilation in the barn, as there is in the winter months when the barn gets too warm with all the cows inside. From Phase II, it was found that the

operation requires energy for milking two times per day at 12 hour intervals. After each milking, a one-hour sanitation cycle is required with hot water. These are key energy consumption processes in milk production. From Phase II, lighting, refrigeration, and ventilation were found to be the three most energy intensive processes in the dairy operation. In Phase III, an analysis of the lighting was done to see where opportunities existed to reduce energy use. It was determined that there was a need to transition from using incandescent light bulbs to T8 lights, which would result in a 68% savings in annual electricity costs and the payback period would be only one year. It was also suggested to investigate LED lightbulb, which are 31% more efficient than the T8 lighting. Regarding refrigeration, it was found that a maintenance program for condensers and fans would be best suited to reduce energy needs in this area. Regular cleaning and maintenance would improve energy efficiency. Finally, in regards to ventilation, an automatic fan system was just recently installed in the barn, and the suggestion from the energy audit was to further investigate how to seasonally reduce energy consumption in this area.

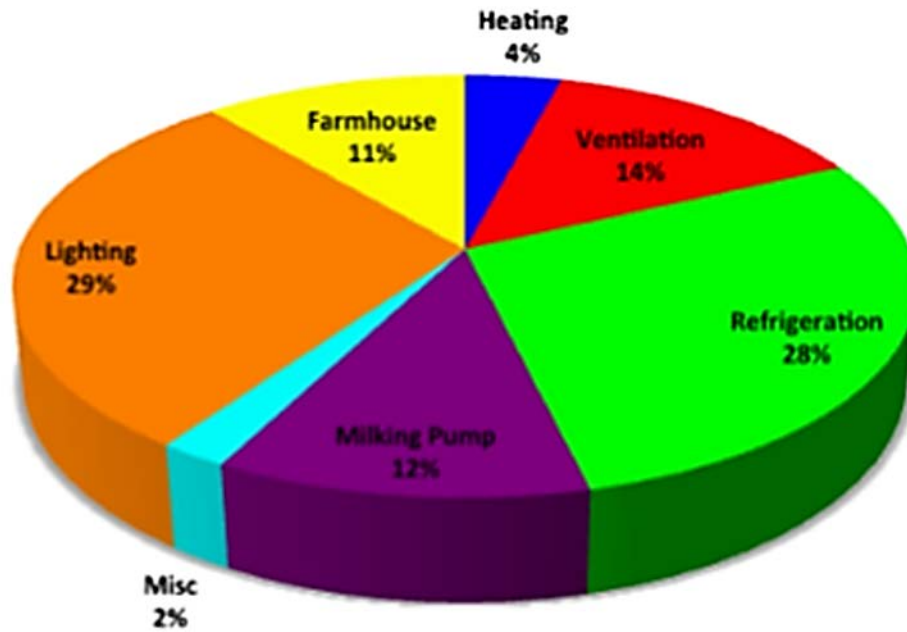


Figure 5: Phase II audit- electrical consumption breakdown by sector

### III. Feasibility Study of Renewable Energy

Implementation of renewable energy systems are funded at 50% up to \$50,000 per farm from the Renewable Energy Initiative in Canada. In addition, energy audits are funded at 75% up to \$1500. In many cases, for small farms in Canada, a 25 kW wind turbine is suggested as a source of renewable energy on the farm. In one year, a 25 kW turbine produced 96 MWh of electricity, powering 82% of the electricity needs on the farm. This particular system had a payback period of 11.3 years.

#### 1.4 Energy Demand on Dairy Farms in Ireland –J. Upton, et.al. (2013)

This paper addresses how to reduce electricity consumption on Irish dairy farms and lower peak electricity costs as prices continue to rise, in attempt to discourage electricity use during peak times. Additionally, in order to reduce the costs of running a small- to medium-sized dairy farm, energy use must be shifted to off-peak energy consumption times. Reducing energy consumption in general is also necessary, so in this study a Life Cycle Assessment (LCA) was completed to identify key electricity consumption sources on the dairy farm.

Similar to the LCA completed at WCROC, this study aimed to identify areas where energy consumption could be reduced to decrease the operating costs of running a small- to medium-sized dairy farm. It was mentioned in this paper that there needs to be more research done on a region-to-region basis in order to best illustrate models that can be adapted by farmers to reduce energy-related operational costs, as well as reduce energy consumption per kilogram of milk produced on the farm. This is what WCROC is aiming towards with net zero dairy production research and modeling.

## I. Materials and Methods

For this study, 22 Irish dairy farms were selected to serve as study farms. In 2011, all data on financial information, size of herd and general farm size. Manual recording and wireless transfer systems were used to collect data for the LCA. Electricity consumption was monitored using a wireless monitoring system from Italy. Energy analyzers, EM24 DIN and Digi Connect Wireless Wan cellular routers collected data on electricity consumption. Power soft

logging and the recoding software from Italy collected cumulative energy use every 15 minutes for each electricity consumption process behind the farm gate. For this study, the farm gate was defined as every process prior to shipping and transportation of the finished milk product, including all feed and fertilizer, electricity, gas and propane, and other resources. The LCA was completed according to the International Organization for Standardization by quantifying total energy use on each farm. There were four main stages of the LCA, including goal and scope, inventory analysis, impact assessment, and an interpretation of results were completed. For the goal and scope stage, the main function is expressed quantitatively in terms of a system, in this case the amount of milk produced. Kilograms of energy corrected milk, kilograms of fat-

and protein-corrected milk, and kilograms of milk solids were examined, along with liters of milk and kilograms of milk in general. For the inventory analysis stage, energy conversion factors were determined, specifically the amount of energy related to the production and transport of each unit of milk. The unit of energy used was the megajoule. To begin calculating the amount of energy that goes into producing each unit of milk, the feed composition was examined by calculating the energy content per ton of feed, the liquid fuel use, hours worked in the field for each operation (plowing, manure spreading, and fertilizer spreading), seeds used for reseeding grassland, as well as herbicides and minerals and their production. Raw data was processed in the impact assessment stage, where total energy use from cradle to farm gate of milk production was calculated. This leads to the results stage.

## II. Results: Energy Analysis

It was found in this study that the main consuming areas of the total milk production electricity load were milk cooling (31%), water heating (23%), milking (20%), pumping water (5%), and

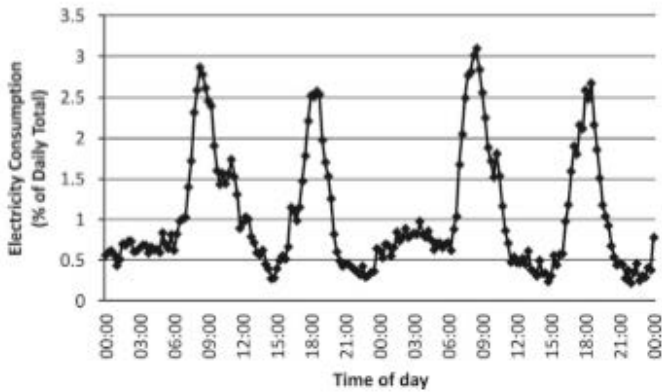


Figure 6: Average percentage of daily electricity consumption for 22 commercial farms in Ireland from June 14 to 15, 2011; data points are at 15-minute intervals

lighting (3%). A miscellaneous category of additional electrical loads such as winter housing systems, air compressors, and backing gates accounted for 18% of the total electrical energy consumption in the milk production process. It was found overall that the total amount of energy used per kilogram of milk was 2.42 MJ/kg of milk, 2.37 MJ/kg of ECM, and 2.36 MJ/kg of FPCM. Regarding electricity peaks, large peaks of energy consumption were a result of morning and evening milkings, between 0700 to 1200 hours and again from 1630 to 1930 hours.

### III. Options for Reducing Electricity Consumption and Electricity Costs

Following these results, it was concluded that, as a result of high peak demand at similar times on each farm, smart metering of electricity usage and improving efficiency on the farm would help to lower these peak times, resulting in a decrease in electricity-related operational cost on each farm. Milk cooling, being the highest source of electrical energy consumption in the milk production process (31%), is a good example of a place where electrical usage could be monitored and more efficient technologies could be implemented. For example, by implementing a heat exchanger for milk cooling, energy use would be reduced and therefore cost associated with milk cooling would decrease. This would also provide an opportunity to shift loads to off-peak rates, reducing day and night farm energy costs. Another way to reduce energy costs by increasing efficiency is to install a variable frequency drive for fans and pumps, or to use solar thermal water-heating systems to heat water for sanitation use in the milking parlor rather than using a natural gas heater.

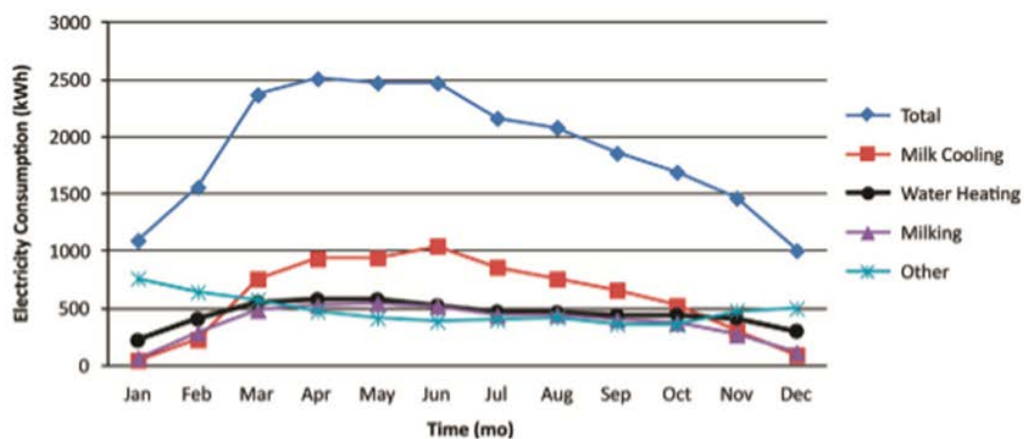


Figure 7: Monthly electrical energy consumption (kWh) for 22 farms over 12 months for all major energy-consuming processes.



# 2017 MIDWEST FARM ENERGY CONFERENCE

## TUESDAY, JUNE 13TH

**U of MN West Central Research and Outreach Center, Morris**

**Registration 12:00 PM**

**Afternoon Sessions 1:00 PM**  
*Emphasis on renewable energy initiatives for Midwest dairies*

- Energy Consumption in MN Dairies
- Creating a Net-Zero Energy Dairy
- Life Cycle Assessment
- Utilizing Wastewater for Sustainable Production
- Tour of WCROC Dairy

**Networking & Social Hour 5:30 PM**

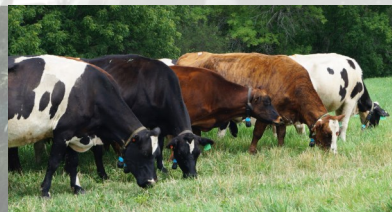
**Dinner and Keynote Speakers 6:30 PM**  
(Meal provided)

Keynote Speakers:

*Dean Brian Buhr, College of Food, Agriculture, and Natural Resource Sciences, U of MN*

*President Barry Dunn, South Dakota State University*

*Mark Greenwood, Sr. Vice President, Relationship Management at AgStar Financial Services*



## WEDNESDAY, JUNE 14TH

**Breakfast and Welcome 7:30 AM**

**Morning Sessions 8:00 AM**  
*Emphasis on renewable energy initiatives for swine production*

- Why Producers Should Care About Swine Energy Systems
- Energy Conservation in Livestock Production
- Reducing Fossil Fuel Use in Swine Production
- Energy Consumption Across Six MN Commercial Facilities
- Financing, Economics, and Case Studies

**Lunch 12:00 PM**

Tour of Swine Energy Systems

**Conference Wrap-Up 2:30 PM**

*Funding for swine and dairy renewable energy projects at the U of MN WCROC provided by:*

Minnesota Environment & Natural Resources Trust Fund (through LCCMR)

U of MN Agricultural Rapid Response Fund

Xcel Renewable Development Fund

Initiative for Renewable Energy & the Environment (IREE)



## Conference Pricing

**Full Conference Rate \$80.00**

*Includes all conference sessions, tours, handouts, and keynote dinner. Student pricing available.*

**Register before April 1, 2017 for the early bird full conference rate of \$60**  
*Hurry! The first 20 registrants will be entered for a door prize!*

**Single Day Rate \$50.00**

*Select which day you plan to attend. Includes sessions, tours, handouts, and meals for selected day.*

**Keynote Dinner only (June 13) \$15.00**

*Join us for social hour, networking, dinner, and keynote speakers at 5:30 pm on June 13th.*

## Registration Information

**Register Online**

<http://z.umn.edu/mfec2017>

Access the above link for conference details including hotel accommodations, agenda, and presenters.

**Questions? Contact Esther at 320-589-1711**







- Tour the WCROC swine facilities to see our solar photovoltaic systems, and novel sow cooling system.



- Learn practical information for agricultural producers regarding energy technologies for Midwest farms.



- Tour the WCROC dairy facilities which feature energy optimized systems for producing milk.
- Opportunities to network with energy experts and professionals.

### Conference Location Information

**West Central Research and Outreach Center**  
46352 State Hwy 329, Morris, MN  
320-589-1711

**Directions to the WCROC**  
[wcroc.cfans.umn.edu/about-us/location-map](http://wcroc.cfans.umn.edu/about-us/location-map)

**Questions?**  
Contact Esther Jordan at [ejordan@umn.edu](mailto:ejordan@umn.edu)

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## 2017 Midwest Farm Energy Conference



**June 13th - 14th  
2017**

Conference details at: <http://z.umn.edu/mfec2017>



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WEST CENTRAL RESEARCH & OUTREACH CENTER

*Project funding provided by customers of Xcel Energy  
through a grant from the Renewable Development Fund.*

Optimizing Energy Production and Use for a

# NET-ZERO ENERGY DAIRY

Eric Buchanan MFEC 2017





# NET-ZERO: What is it?

## How do we get there?

STEP 4: Renewable Energy

STEP 3: Convert Thermal Loads

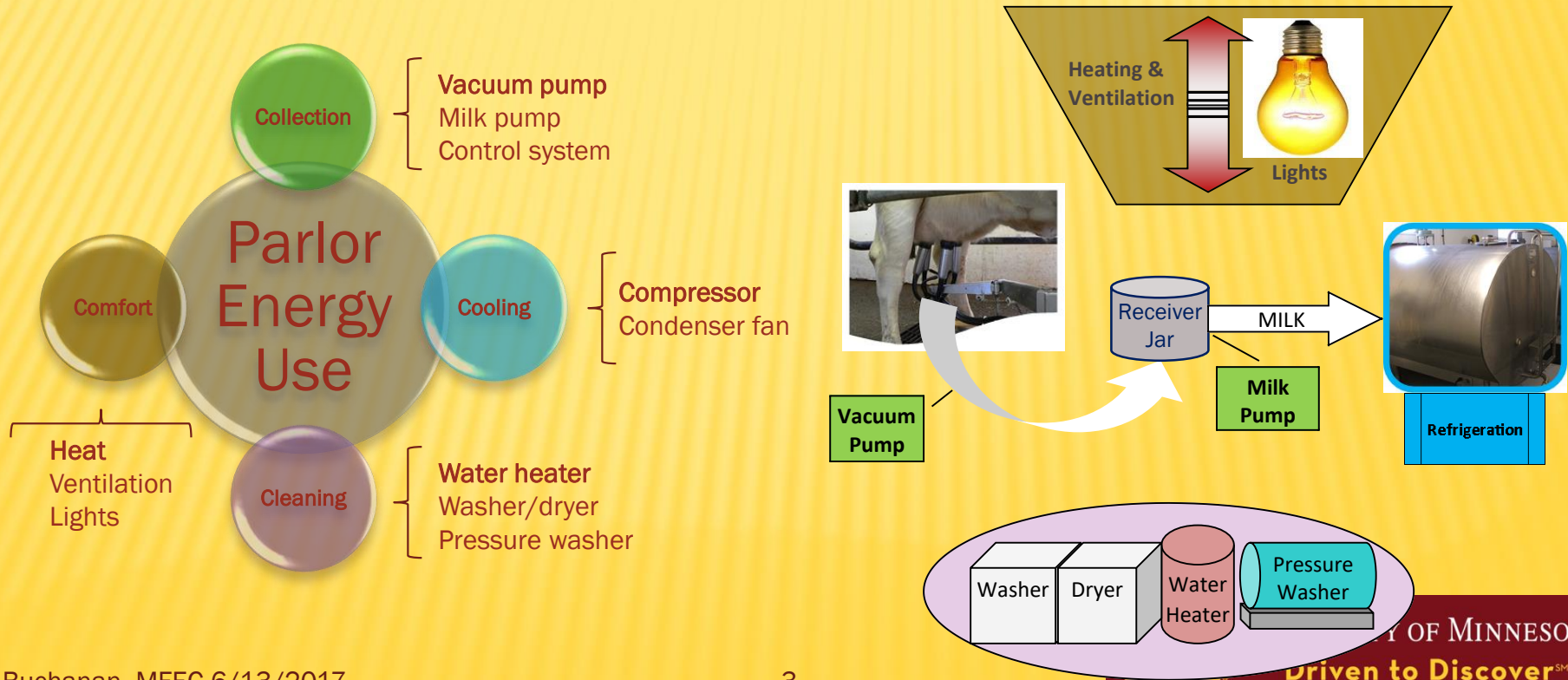
STEP 2: Energy Efficiency

STEP 1: Understand Energy Usage



# STEP 1: UNDERSTAND ENERGY USAGE

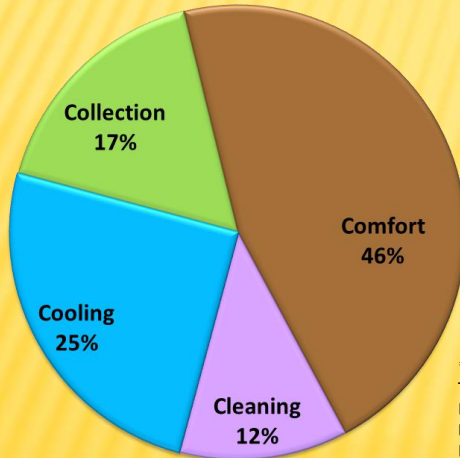
- ❖ Milking cows is energy and water intensive



# STEP 1: UNDERSTAND ENERGY USAGE

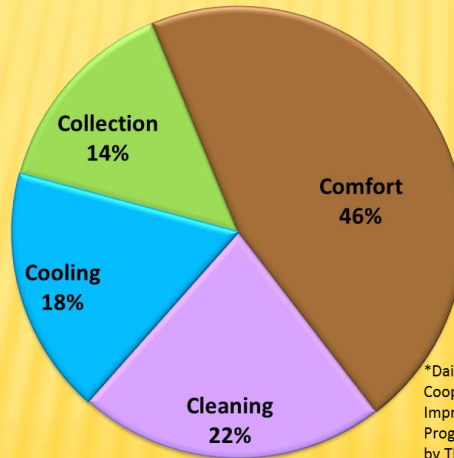
## ❖ Where is energy used? The 4 C's:

Wisconsin Dairy Energy Use\* (2005)



\*Wisc. Dept. of Ag,  
Trade & Consumer  
Protection, 2006,  
Dairy Farm Energy  
Mgmt Handbook

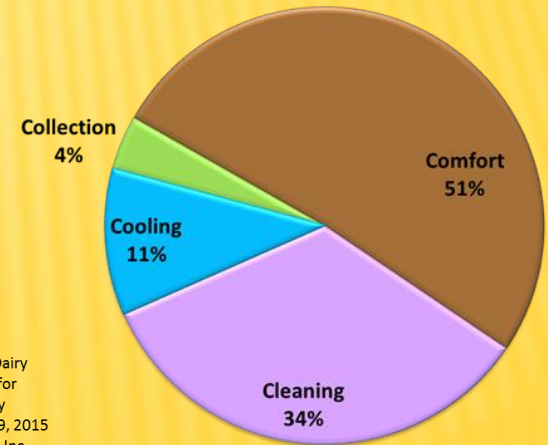
30 Farms from HCCC Dairy Energy Use\* (2015)



\*Dairy Energy Efficiency: Dairy  
Cooperative Partnerships for  
Improved Energy Efficiency  
Program Adoption, May 29, 2015  
by The Minnesota Project, Inc.

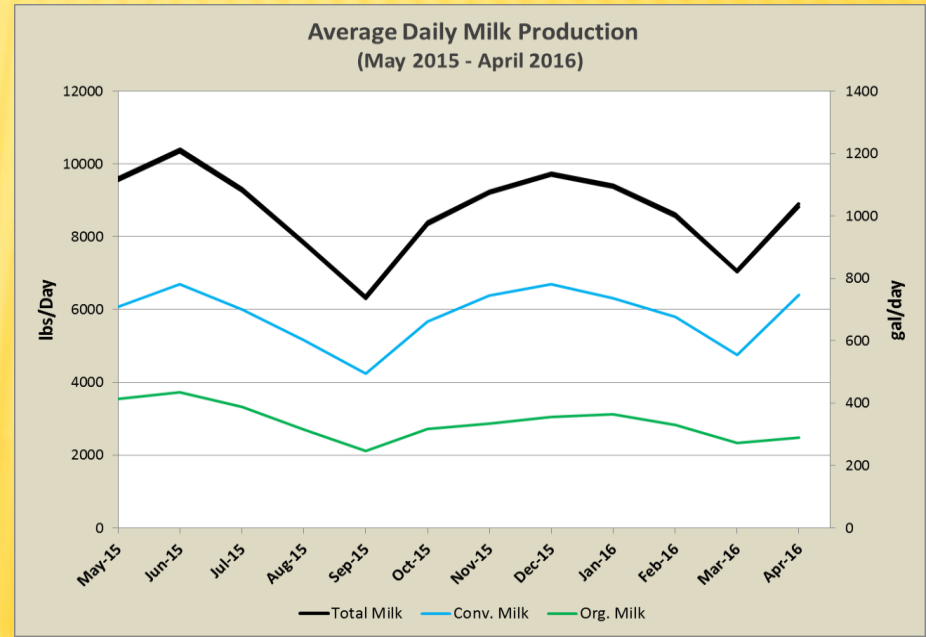
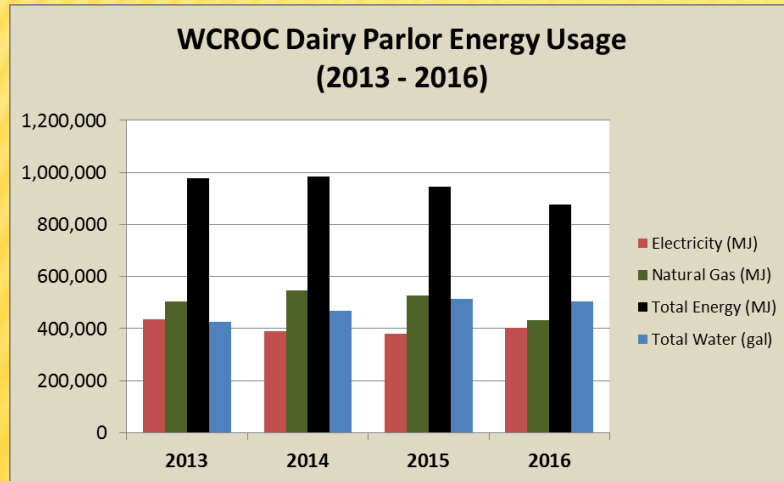
WCROC Dairy Parlor Total Energy Use

Gas & Electric  $\approx$  2650 MJ/day (740 kWh/day)



# STEP 1: UNDERSTAND ENERGY USAGE

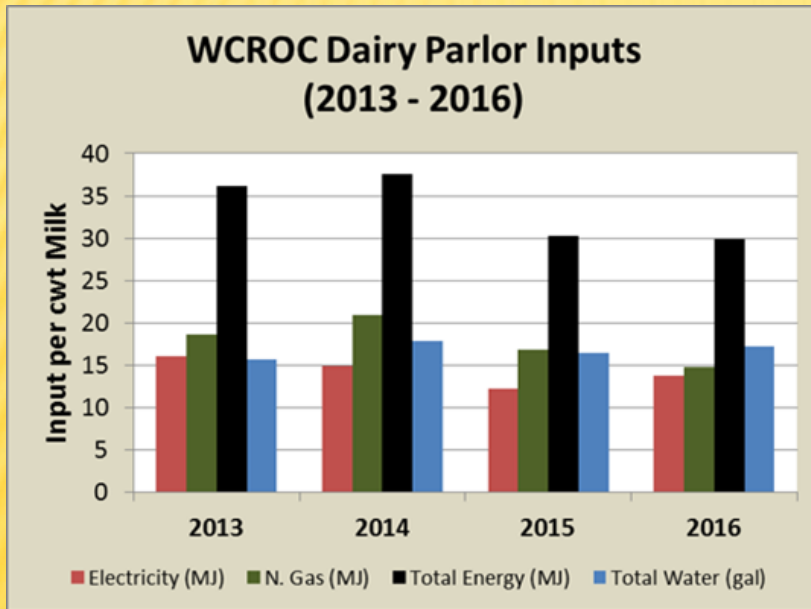
- ❖ Current project focuses on the WCROC Milking Parlor
- ❖ Extensive energy monitoring began in late 2013
  - ❖ 20 individual electric load sensors, 11 water flow & temp sensors





# STEP 1: UNDERSTAND ENERGY USAGE

## ❖ Looking at energy per unit of production



WCROC Milking Parlor Energy Usage				
Energy Usage	2013 - 2016			
	Annual Ave.	Ave./cow	Ave./cwt milk	\$/cwt milk
Natural Gas (therm)	4,767	23.6	0.2	\$ 0.12
Electricity (kWh)	111,708	553.0	3.9	\$ 0.39
Total Energy (MJ)	936,314	4635	32.9	\$ 0.52
Total Water (gal)	478,362	2368	16.8	--

Energy costs per cwt of milk are not large, but total annual energy costs are about \$14,700

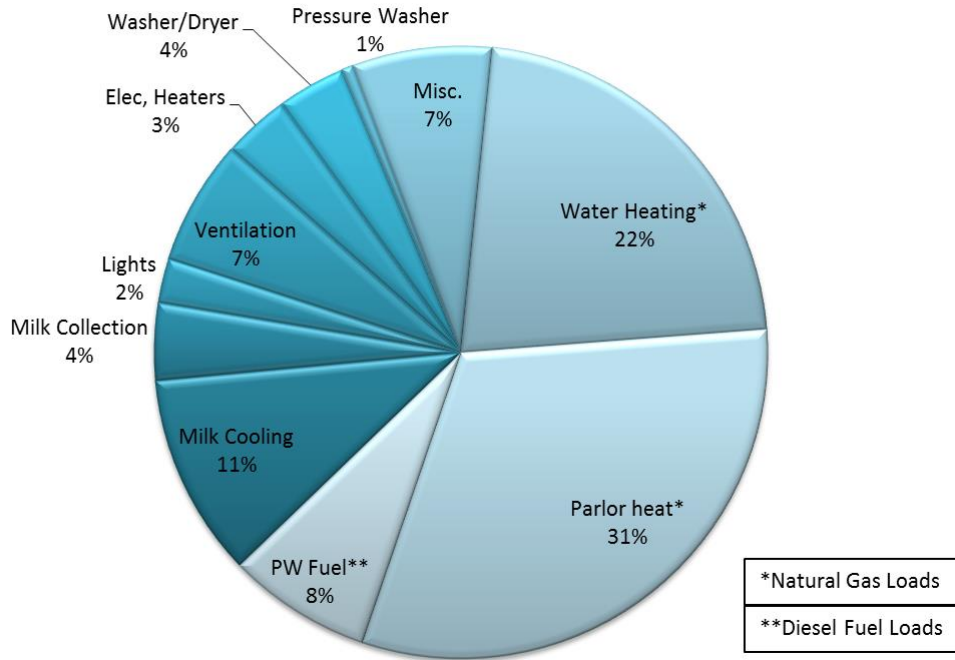


# STEP 1: UNDERSTAND ENERGY USAGE

## ❖ A deeper dive: parlor total energy usage (natural gas & electricity)

### 2015 - 16 Dairy Parlor Total Energy Usage

Gas & Electric  $\approx$  2650 MJ/day (740 kWh/day)



70% more total energy is consumed in the winter compared to summer due to parlor heating.

Parlor heating is the largest single load followed by water heating.



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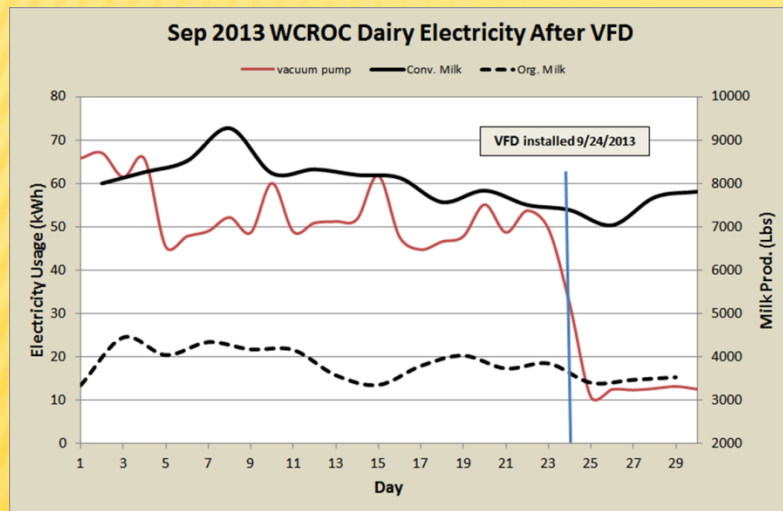
# STEP 2: ENERGY EFFICIENCY

- ❖ Reducing energy usage is an important step that will reduce the size of any needed renewable energy (RE) system
- ❖ There is no unit of energy cheaper than one you don't use!
- ❖ Energy efficiency upgrades often pay back in under 10 years
  - ❖ MN project HCCC average payback estimates:
    - ❖ LED lights – 3.3 yrs, Electric water heaters – 6.2 yrs
    - ❖ VFD's – 6 to 14 yrs, RHR – 7.8 yrs, Plate Cooler – 9.5 yrs
- ❖ A smaller RE system enhances payback times

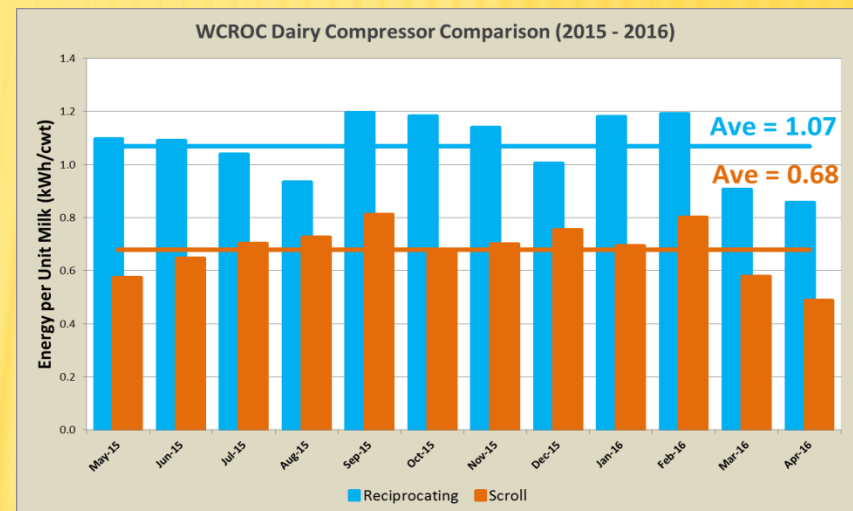


# STEP 2: ENERGY EFFICIENCY

## ❖ Lessons learned from WCROC energy monitoring



Vacuum motor = 10 hp (7.5 kW), Cost = \$3,400  
 Savings = 38 kWh/day (\$3.80/day)  
 Pay back = 2.5 years  
 VFD failed after 3 years and was replaced  
 Cost = \$5600, Pay Back in 4 years



Scroll comp.= 5 hp (3.7 kW), Cost = \$3,080  
 Savings = 8898 kWh/yr (\$890/yr)  
 Pay back = 3.5 years



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# STEP 3: THERMAL LOAD CONVERSION

- ❖ Only required if a Net-Zero operation is desired
  - ❖ It is difficult to replace burned fuels with RE
    - ❖ In MN, solar thermal systems can not replace 100% of thermal loads
- ❖ Electric appliances are typically more efficient than their gas fueled counterparts (95% versus 65%)
  - ❖ Efficiency alone results in large energy savings
  - ❖ But may NOT lead to cost savings if fuel prices are low



# STEP3: THERMAL LOAD CONVERSION

## WCROC dairy energy optimization goals

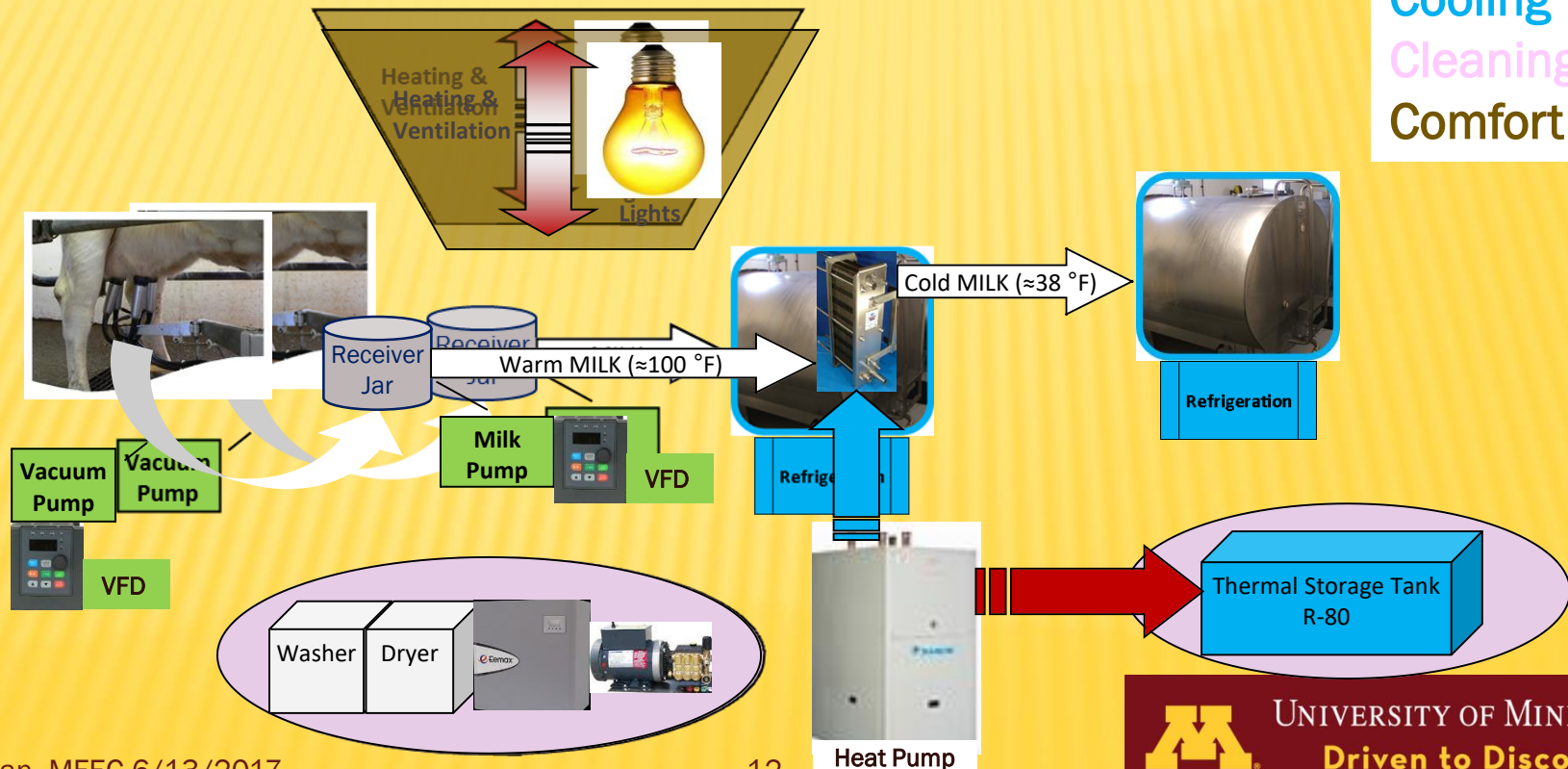
1. **Collect thermal energy from milk as a resource**  
Stored in large, well insulated water tank
2. **Use stored heat to preheat cleaning water**  
Including pressure water
3. **Replace gas water heater & PW with electric models**  
Eventually do the same for the furnace
4. **Add solar thermal energy**



# STEP3: THERMAL LOAD CONVERSION

## Energy optimized milking process – 4 C's

Collection  
Cooling  
Cleaning  
Comfort



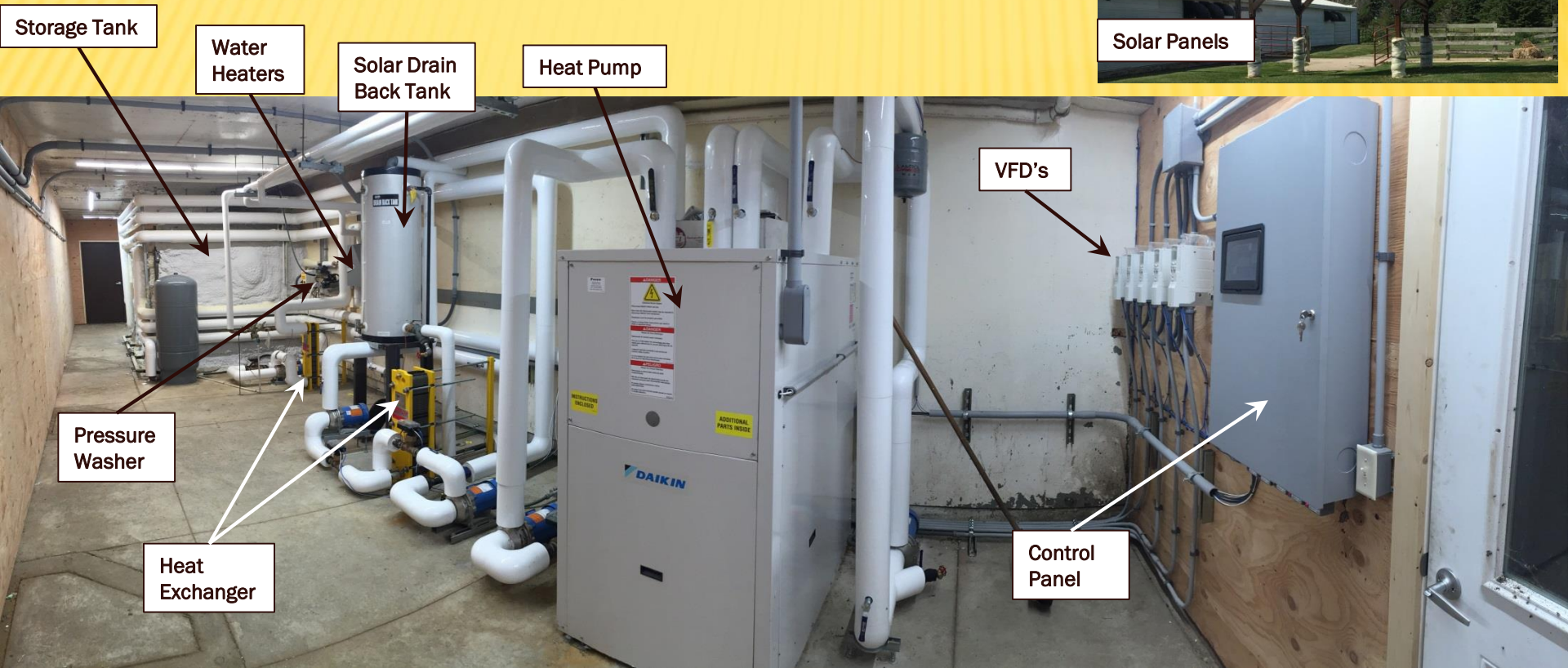
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# STEP3: THERMAL LOAD CONVERSION

## Energy optimized milking process



# STEP3: THERMAL LOAD CONVERSION

- ❖ **WCROC lessons learned:**
  - ❖ Tankless water heaters can supply dairy hot water loads, but only if well water is pre-heated
  - ❖ Storage tank size must be sufficient to cool milk
    - ❖ Manure lagoon or fan coil unit could be a good thermal buffer
  - ❖ Heat pump controls need to be customized to deal with fluctuating milk flow
  - ❖ Solar thermal heating is probably not needed if milk heat is fully harvested



# STEP 4: RENEWABLE ENERGY SYSTEMS

- ❖ After energy consuming processes have been optimized and thermal loads have been converted to electricity, a RE system can be sized to generate the total annual energy load.
  - ❖ This results in a Net-Zero operation
- ❖ RE systems generally have high up front costs and longer pay back times than efficiency upgrades
  - ❖ Depends on incentives (FTC, MiM, REAP grant, etc.)
  - ❖ Solar PV and small scale wind (<100 kW) are probably the most economical options and certainly the simplest





# STEP 4: RENEWABLE ENERGY SYSTEMS

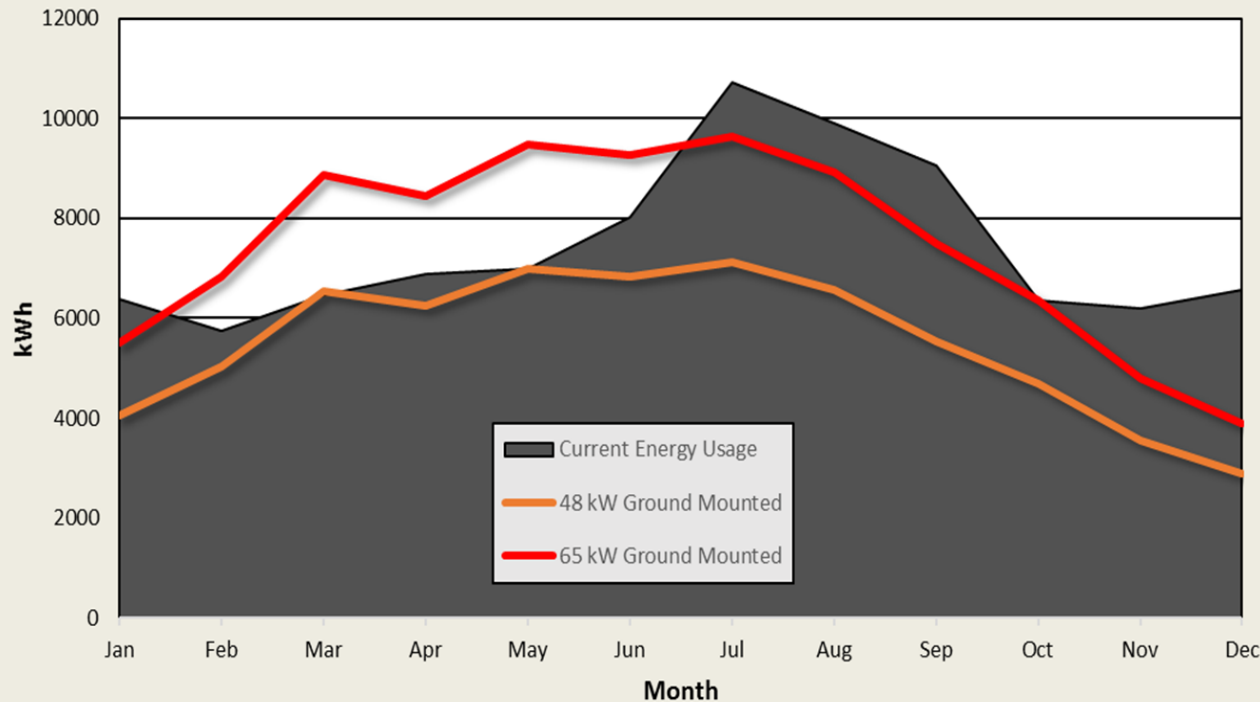
- ❖ **How does it work?**
  - ❖ **A grid-tie system is probably best choice for most farms.**
    - ❖ Batteries are expensive and require maintenance
  - ❖ **Net Metering in MN for systems <40 kW**
    - ❖ Full retail credit for unused electricity
      - ❖ Otherwise, avoided cost rate ( $\approx 3\text{¢/kWh}$ )
    - ❖ A larger system may still be economical
      - ❖ Need to carefully size system and match use to generation so energy is used “behind the meter”



# Commercial Finish Barn Solar PV Study

- 65 kW system for “Net Zero”, but 48 kW is optimal
- 48 kW cost = \$134,400 (\$2.80/Watt in 2016)

Potential Solar PV Systems For Finisher 4

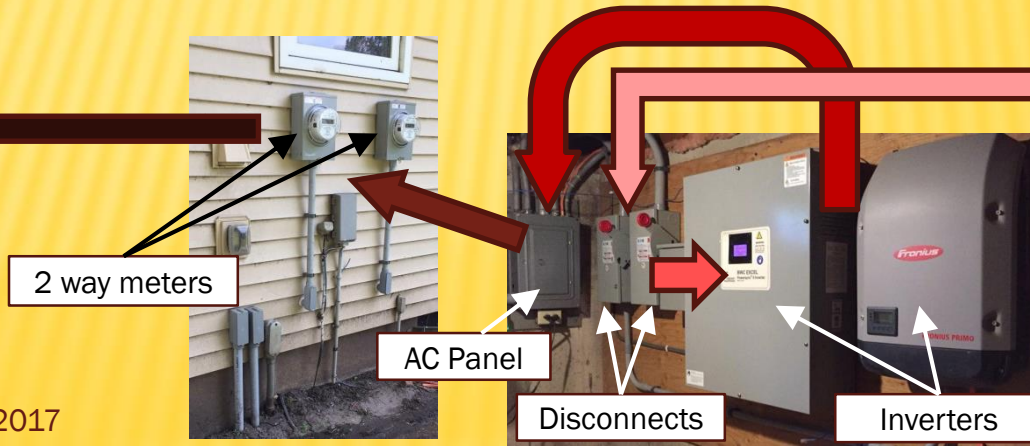


## Over 25 years

- 7.2¢/kWh (no incentives)  
18 year payback
- 5.0¢/kWh (fed tax credit)  
13 year payback
- 3.2¢/kWh (FTC & REAP)  
8 year payback

# STEP 4: RENEWABLE ENERGY SYSTEMS

- **Grid-tie system components:**
  - DC electricity (solar) and wild AC (wind) have a disconnect switch near the installation site
  - Electricity travels to a disconnect inside bldg.
  - Then to power inverters to be converted to AC
  - Then to AC panel
  - On to the utility meters
  - Finally to the utility electric grid





# STEP 4: RENEWABLE ENERGY SYSTEMS

- ❖ **WCROC lessons learned:**
  - ❖ **There are interconnection costs (talk to your utility early!)**
    - ❖ \$100 to \$250 application fee, \$200 to \$600 for a 2 way meter
    - ❖ Interconnecting directly to a transformer incurs linemen charges
    - ❖ There may be stand-by demand charges
  - ❖ **3 phase installations can be problematic**
    - ❖ Mixed phase inverters may not operate properly with a single phase failure
    - ❖ Solution is a phase monitoring relay



3 mixed phase wind inverters



Our experience so far

# WCROC RENEWABLE ENERGY SYSTEMS

You are  
Here

North Turbine  
(10kW) &  
Solar PV (4kW)

Milking  
Parlor

Farrowing  
Barn

Finishing  
Barn

Solar  
Thermal  
Panels

Solar PV  
(50kW)

South Turbine  
(10kW)

Solar PV  
(27kW)

Solar PV  
(20kW)



## GROUND MOUNTED SOLAR

### PRO's

- generally simpler
- Allows mounting angle choice
- Probably less expensive
- Easy access for snow removal

### Con's

- Takes up valuable space
- In path of debris (mowing/blowing)
- Ground cover/landscaping/fencing

## ROOF MOUNTED SOLAR

### PRO's

- Out of sight
- Panels are close to the load
- Less chance of damage/vandalism

### Con's

- May require engineering study
- May require roof enhancements
- Need to remove panels to re-roof



# WCROC RENEWABLE ENERGY SYSTEMS

❖ Solar and snow: 2 days after storm



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# WCROC RENEWABLE ENERGY SYSTEMS

- ❖ **Small scale wind:**
  - ❖ Small wind industry is not as mature as solar
    - ❖ Pricing, service, warranties, etc. are all less stable than with solar
  - ❖ **Performance is highly dependent on local wind speed & site**
    - ❖ Bottom of rotor should be 30' above anything within 300'
  - ❖ **Good tower height  $\approx$  100' (30 meters). Guyed or tilt-down**
    - ❖ Guyed towers are less expensive, but take up more space
      - ❖ Guy radius is  $\frac{1}{2}$  to  $\frac{3}{4}$  of tower height
    - ❖ Tilt-down towers make maintenance easier
  - ❖ **Small turbines can be louder than utility scale turbines**



# WCROC RENEWABLE ENERGY SYSTEMS

## General guidelines:

- ✓ **Use NABCEP certified contractors**
  - ✓ Find someone who has experience with what you want to do
  - ✓ A good contractor can help you apply for incentives and permits
- ✓ **Talk to the utility company early on**
  - ✓ Understand costs, interconnection requirements, and timeline
  - ✓ Inverters must have UL 1741 listing
- ✓ **Check local and county ordinances for set back req.'s, etc.**





# QUESTIONS?

## Resources:

- <http://www.cleanenergyresourceteams.org>

CERT's is a great educational site and a portal to almost any RE information

- <https://wcroc.cfans.umn.edu/energy-dairy>

The WCROC site hosts a renewable energy guidebook, dairy energy guidebook & decision tool, as well as information relating to our ag energy projects

- <http://www.dsireusa.org/> The definitive web site for all energy incentives
- <http://pvwatts.nrel.gov/> Free Solar PV prediction tool
- <http://smallwindcertification.org/home/> Independent certification for wind turbines