RENEWABLE & EFFICIENT ENERGY SYSTEMS FOR MIDWEST DAIRIES

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WCROC Existing Dairy

WCROC Dairy milks about 200 cows twice/day

- Typical of a medium sized Minnesota dairy farm
- Average 8300 lbs/day milk
  - 5100 lbs/day conventional
  - 3200 lbs/day organic
WCROC Existing Dairy

Milking is energy intensive

- We use ≈ 100,000 kWh/yr; \( \Rightarrow \) 500 kWh/cow/yr
  - 3.6 kWh/cwt milk
  - 300 kWh/day \( \Rightarrow \) $30/day
- We use ≈ 4500 therms/yr of nat. gas ; \( \Rightarrow \) 21 therms/cow/yr
  - 14 therms per day for furnace and water heater \( \Rightarrow \) $11/day
- We use ≈ 200,000 gal of hot H\(_2\)O /yr; \( \Rightarrow \) 900 gal/cow/yr
  - 560 gallons of hot H\(_2\)O/day \( \Rightarrow \) 2.5 gpd hot H\(_2\)O (6 gpd total)/cow
  - Does NOT include drinking water
  - Hot water heated to >160°F to sanitize lines
WCROC Dairy Energy Pie

2015 Electricity Usage (MAY)
(280 kWh/day Total)

- Milk Refrigeration: 31%
- Misc.: 23%
- Office: 5%
- Lights: 7%
- Ventilation: 16%
- Washer/Dryer: 10%
- Vacuum Pump: 6%
- Pressure Washer: 2%

2015 Hot Water Usage
(560 gal/day Total)

- Pressure Washer: 36%
- Milk Lines: 30%
- Milk Tanks: 11%
- Washing Machine: 11%
- Parlor: 9%
- Bathroom: 3%
Current Dairy Energy Systems

Milk Parlor

Milking Process

Vacuum Pump

Receiver

Milk Pump

Refrigeration

Bulk Tank 40°F

Support Processes

Clean Parlor

Pressure Washer

Dryer

Washing Machine

Water Heater

Bathroom

Clean Lines

Electricity

Heat

Diesel

GAS

Electricity

Furnace Ventilation

Lights Ventilation Office

Electricity

Electricity

Electricity

Electricity

Electricity

Heat
“Greening” Dairy Energy Usage

Energy efficiency options

- Refrigeration Heat Recovery (RHR)
  - Uses heat from milk refrigeration system to pre-heat hot water

- Variable Frequency Drives (VFD)
  - Matches a motor’s speed to actual demand

- Plate Cooler
  - Pre-cools milk coming from cows with well water and heat exchanger

- More efficient lighting, fans, etc.
WCROC VFD Case Study

Vacuum motor = 7.5 hp
VFD cost = $3,400
Savings = 38 kWh/day
  $3.80/day
Pay back = 2.5 years
“Greening” Dairy Energy Usage

Renewable energy options

• Solar Thermal collectors to pre-heat water
• Solar PV panels for electricity
• Small wind turbine for electricity
• Large, insulated tank for thermal energy storage
  – Heat pump to convert extra electricity into hot water (COP =2.5 in MN)
• Innovative control system
  – Manages sources and delivery
**‘Systems’ Approach to Net Zero**

Look at entire process to assess resources & loads

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**Loads:**
- Milk harvest
- Milk cooling
- Water heating
- Cleaning
  - Parlor
  - Rags
  - Milk lines
- Ventilation (cooling)
- Lights
- Parlor heat
- Misc. electric loads

**Resources:**
- Heat in milk
- Heat in parlor
- Heat in lagoon
- Heat in Earth
- Sunlight
- Wind
- Storage?

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Heat Pump
‘Systems’ Approach to Net Zero

• Make electric loads as efficient as possible or practical
  – VFD drives, LED lights, scroll compressors, etc.
  – Watch for waste and quick fixes that become permanent

• Convert all thermal loads to electricity
  – Heat pumps

• Add renewable energy systems, and storage, to meet demand
Energy Balance

Comparing available heat sources with loads

1000 lbs of milk requires 50 kBtu (14.5 kWh) of energy to be removed to cool it from 100°F to 40°F
Energy Balance

Comparing available heat sources with loads

Thermal storage could store summer excess heat for winter use
Energy Balance

Comparing available heat sources with loads

With lagoon heat

Taking heat from the lagoon provides the needed thermal energy in winter
Energy Balance

Comparing available heat sources with loads

Without solar

Taking heat from the lagoon may make solar thermal collectors unnecessary.
WCROC Dairy Future

• Heat pump/thermal storage system engineered by AKF Group in Mpls.
  – 20 ton water to water heat pump
  – 12 solar thermal collectors (4’x10’ Solar Skies)
  – 2200 gal thermal water storage tank w/heat exchangers
  – Custom, configurable control system and data logging

• 50 kW solar PV and 20 kW wind system planned
  – Awaiting PUC approval of Xcel RDF grant

• Lagoon thermal loop and barn HVAC will be addressed in future grant proposals
WCROC Dairy Status

- 12 solar thermal collectors, 2 tankless electric water heaters, elec. pressure washer, plate cooler have been purchased
- 2200 gal thermal storage tank designed & built
Key Points

• Cooling milk provides a **resource**
• Thermal storage can balance thermal systems
  – Need sufficient volume and insulation
• Heat pumps have many advantages
  – Make low grade heat useful
  – Efficient way to electrify thermal loads
  – Can be used to harvest energy from a manure lagoon and store electricity as heat
• VFD’s provide a quick payback
• Energy monitoring can uncover saving opportunities
Questions?

Stay tuned for progress

• [http://wcroc.cfans.umn.edu/research-programs/renewable-energy](http://wcroc.cfans.umn.edu/research-programs/renewable-energy)

Resources:

  – Solar PV production model

  – Great info about RE, efficiency & installers

• [http://www.dsireusa.org/](http://www.dsireusa.org/)
  – Info about all state energy incentives

• [http://www.mnproject.org/index.html](http://www.mnproject.org/index.html)
  – Info about sustainable energy use and food production