Using Renewable Energy in Dairy Production

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WCROC Dairy Herds

- **Organic herd**
  - 130 cows
  - 40 lbs milk, 4.4% fat, 3.5% protein, 265 SCC
  - Milk price: $36.94 /cwt.

- **Conventional herd**
  - 140 cows
  - 55 lbs milk, 4.2% fat, 3.4% protein, 236 SCC
  - Milk price: $19.44/cwt.

- **Dairy breeds**
  - Holstein, Jersey, Montbéliarde, Viking Red, Normande, 1964 Holstein
WCROC Existing Dairy

- WCROC Dairy milks about 200 cows twice/day
  - Typical of a medium sized Minnesota dairy farm
  - Average 12,000 lbs/day milk
    - 7,500 lbs/day conventional
    - 4,500 lbs/day organic
Milking is energy intensive

- We use \( \approx 110,000 \text{ kWh/yr} \); \( \Rightarrow 440 \text{ kWh/cow/yr} \)
  - 3.5 kWh/cwt milk (~12 gal)
  - 300 kWh/day \( \Rightarrow \$30/\text{day} \)
- We use \( \approx 4500 \text{ therms/yr} \) of nat. gas; \( \Rightarrow 21 \text{ therms/cow/yr} \)
  - 14 therms per day for furnace and water heater \( \Rightarrow \$11/\text{day} \)
- We use \( \approx 220,000 \text{ gal of hot } H_2O /\text{yr} \); \( \Rightarrow 900 \text{ gal/cow/yr} \)
  - 600 gallons of hot \( H_2O \)/day \( \Rightarrow 2.5 \text{ gpd hot } H_2O (6 \text{ gpd total})/\text{cow} \)
  - Does NOT include drinking water
  - Hot water heated to >160°F to sanitize lines
Dairy Energy Monitoring

- Data logger collects and stores data
  - Monitors every 10 seconds, calculates average and stores data every 10 minutes
    - 11 water temp and flow sensors
    - 4 air temp sensors
    - 20 electric current sensors
  - 2.4 million data points per year
WCROC Dairy Status

2200 gal thermal storage tank designed & built
Dairy project objectives

• Conduct baseline energy audits of dairy facilities

• Develop and evaluate energy-optimized system for conventional and alternative production systems

• Conduct life cycle assessment in dairy production systems
'Systems' Approach to Net Zero
Look at entire process to assess resources & loads

- **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?
Planned Dairy Energy Systems

Milk Parlor

Milking Process

Vacuum Pump

Receiver

Milk Pump

Refrigeration

Bulk Tank

40°F

Support Processes

Clean Parlor

Electric Pressure Washer

Dryer

Washing Machine

Tankless Water Heater

Thermal Storage Tank

Clean Lines

Bathroom

Heat Pump

Cold Water

Solar Heat

Electricity

Heat

Lights Ventilation Office

Furnace Ventilation

MILK @ 100°F

MILK @ 40°F
Scroll vs. Reciprocating compressor

Scroll compressor bulk tank

Reciprocating compressor bulk tank
Scroll vs. Reciprocating compressor

Sep 2013 Dairy Electricity Usage

- Conv. Compressor
- Org. Compressor
- Conv. Milk
- Org. Milk

Recip. Comp. = 1.08 kWh/cwt

Scroll Comp. = 0.73 kWh/cwt

32%
VFD vacuum pump

Vacuum motor = 7.5 hp (5.6 kW)
VFD cost = $3,400
Savings = 38 kWh/day $3.80/day
Pay back = 2.5 years
Daily dairy hot water usage

Sep 22, 2013 Daily Dairy Hot Water Usage

Flow rate (gpm)

Time

- Wash sink
- Pressure washer
- Tank wash
- Wash machine

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Monthly dairy water usage
Yearly dairy water usage

2015 Dairy Average Water Usage

Gallons/Day

All Water
Total Hot
Press. Washer
Sink H
Washer H
Tank Wash H

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
November 2014 dairy electricity usage

- Total Meas.
- Furnace
- Conv. Comp.
- Org. Comp.
- Vac. Pump
- Press. Washer
- Dryer
- Utility Fan
Yearly dairy electricity usage
Yearly dairy electricity usage
2015 Dairy Parlor Total Energy Usage
Gas & Electric ≈ 2900 MJ/day (800 kWh/day)

- Parlor heat*: 43%
- Water Heating*: 21%
- Milk Cooling: 10%
- Ventilation: 6%
- Heaters: 2%
- Washer/Dryer: 3%
- Misc.: 8%
- Vacuum Pump: 3%
- Lights: 2%
- Office: 1%
- Pressure Washer: 1%

*Natural Gas Loads
2016 Dairy Parlor Total Energy Usage
Gas & Electric ≈ 2200 MJ/day (620 kWh/day)

- Parlor heat*: 23%
- Water Heating*: 27%
- Misc.: 7%
- Milk Cooling: 13%
- Vacuum Pump: 4%
- Lights: 4%
- Ventilation: 7%
- Heaters: 8%
- Washer/Dryer: 5%
- Office: 1%
- Pressure Washer: 1%
2015 Dairy Electricity Usage
(290 kWh/day Total)

- Milk Cooling: 27%
- Ventilation: 16%
- Lights: 7%
- Vacuum Pump: 9%
- Heaters: 7%
- Washer/Dryer: 9%
- Pressure Washer: 2%
- Office: 2%
- Misc.: 21%
2016 Dairy Electricity Usage
(300 kWh/day Total)

- Milk Cooling: 26%
- Heaters: 16%
- Ventilation: 15%
- Washer/Dryer: 9%
- Vacuum Pump: 9%
- Lights: 8%
- Misc.: 15%
- Pressure Washer: 1%
- Office: 1%
2015 Dairy Hot Water Usage
(~600 gal/day Total)

- Parlor Cleaning: 41%
- Sanitizing Equipment: 46%
- Bathroom Cleaning: 3%
- Washing Machine: 10%
2016 Dairy Hot Water Usage
(~510 gal/day Total)

- Sanitizing Equipment: 57%
- Parlor Cleaning: 27%
- Washing Machine: 12%
- Bathroom: 4%
Sanitizing Equipment 59%
Washing Machine 12%
Parlor Cleaning 25%
Bathroom 4%

2016 January Hot Water Usage
(~520 gal/day Total)

Sanitizing Equipment 68%
Washing Machine 15%
Parlor Cleaning 12%
Bathroom 5%

2016 July Hot Water Usage
(~420 gal/day Total)
2015 Parlor Electricity & Milk Production

Milk Production (lbs/day)

Average Daily Energy (kWh/day)

Milk Production

Total Electricity

January
February
March
April
May
June
July
August
September
October
November
December

University of Minnesota | Extension
## 2015 Dairy Production

<table>
<thead>
<tr>
<th>Milk Production</th>
<th>Cows</th>
<th>Total (lbs)</th>
<th>Total (gal)</th>
<th>Average (lbs/day)</th>
<th>Average (gal/day)</th>
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</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>115</td>
<td>2,008,029</td>
<td>232,411</td>
<td>5501</td>
<td>637</td>
</tr>
<tr>
<td>Organic</td>
<td>104</td>
<td>1,113,654</td>
<td>128,895</td>
<td>3051</td>
<td>353</td>
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<tr>
<td>Total</td>
<td>219</td>
<td>3,121,683</td>
<td>361,306</td>
<td>8553</td>
<td>990</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Usage</th>
<th>Total</th>
<th>Average/cow/day</th>
<th>Average/gal milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas (MJ)</td>
<td>526,134</td>
<td>6.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Electricity (kWh)</td>
<td>105,654</td>
<td>1.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Total Water (gal)</td>
<td>519,710</td>
<td>6.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Electricity usage January/May 2015

2015 Electricity Usage (JAN) (310 kWh/day Total)
- Milk Refriger. 27%
- Vacuum Pump 7%
- Heaters 24%
- Pressure Washer 2%
- Washer/Dryer 8%
- Lights 11%
- Ventilation 6%
- Misc. 12%
- Office 3%

1.44 kWh/cow
.58 kWh/lb fat and protein (Org)
.42 kWh/lb fat and protein (Conv)

2015 Electricity Usage (MAY) (280 kWh/day Total)
- Milk Refriger. 31%
- Vacuum Pump 6%
- Pressure Washer 2%
- Washer/Dryer 10%
- Ventilation 16%
- Lights 7%
- Office 5%
- Misc. 23%

1.05 kWh/cow
.52 kWh/lb fat and protein (Org)
.35 kWh/lb fat and protein (Conv)
Water usage January/May 2015

2015 January Hot Water Usage
(349 gal/day Total)

- Milk Lines: 48%
- Milk Tanks: 18%
- Washing Machine: 17%
- Parlor: 12%
- Bathroom: 5%

2015 May Hot Water Usage
(362 gal/day Total)

- Milk Lines: 44%
- Milk Tanks: 20%
- Washing Machine: 17%
- Parlor: 13%
- Bathroom: 6%

1.62 gal/cow

1.05 gal/cow
WCROC Milking Parlor Electricity Usage

Average Daily Usage (kWh)

- 2013
- 2014
- 2015
- 2016
Dairy Production LCA Boundaries

Joel Tallaksen, 2016
Figure 2. Greenhouse Gas Emissions

GHG Emissions (CO₂ Eq. per kg Milk)

- Conventional Milk Production System
- Organic Milk Production System

- Animal husbandry
- Milk harvesting

Heins and Tallaksen, 2016
Figure 3. Fossil Energy Footprint

- **Conventional** Milk Production System:
  - Animal husbandry: 0.113
  - Hot water for cleaning: 0.199
  - Misc. electricity: 0.247
  - NG facility heating: 0.171

- **Organic** Milk Production System:
  - Animal husbandry: 0.192
  - Hot water for cleaning: 0.339
  - Misc. electricity: 0.42
  - NG facility heating: 0.29

Heins and Tallaksen, 2016
“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

– 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
Future Dairy Energy Research

- We will evaluate the shade potential of solar systems for pastured-cattle
- Monitor energy and water usage on Minnesota dairies
- Field test electric vehicles for pasture dairy use
- Install Smart Level II charging station with Tesla batteries at the WCROC

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Generation, Storage, and Utilization of Solar Energy

Preliminary funding approved by LCCMR for July 1, 2017
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