WCROC Farm Site in Morris

- 1 of 9 University research and outreach centers
- Part of the St. Paul campus, CFANs
- Swine, Dairy, crops, horticulture & Energy
Information to Share

‘Greening’ AG Energy

• Dairy barn energy monitoring
• New dairy ‘Net Zero’ energy systems
• Swine barn energy monitoring
• New swine energy systems
WCROC Existing Dairy

WCROC Dairy milks about 250 cows twice/day

• Typical of a medium sized Minnesota dairy farm
• Average 8500 lbs/day milk (990 gal/day)
  – 5500 lbs/day conventional (65%)
  – 3000 lbs/day organic (35%)
WCROC Existing Dairy
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
2015 August Electricity Usage
(310 kWh/day Total)

- Milk Cooling: 24%
- Ventilation: 21%
- Vacuum Pump: 10%
- Lights: 5%
- Washer/Dryer: 9%
- Heaters: 0%
- Office: 2%
- Pressure Washer: 2%
- Misc.: 27%

2015 Dairy Hot Water Usage
(~600 gal/day Total)

- Sanitizing Equipment: 46%
- Parlor Cleaning: 41%
- Washing Machine: 10%
- Bathroom: 3%
- Vacuum Pump: 10%
- Lights: 5%
- Washer/Dryer: 9%
- Heaters: 0%
- Office: 2%
- Pressure Washer: 2%
- Misc.: 27%
WCROC Existing Dairy

Milking is energy intensive

- We use ≈ 110,000 kWh/yr; $\Rightarrow$ 440 kWh/cow/yr
  - 3.5 kWh/cwt milk (~12 gal)
  - 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 ≈ 220,000 gal of hot H$_2$O /yr; $\Rightarrow$ 900 gal/cow/yr
  - 600 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 $>160^\circ$F to sanitize lines
“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 (5.6 kW)
VFD cost = $3,400
Savings = 38 kWh/day $3.80/day
Pay back = 2.5 years
‘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?

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
“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
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

Dairy Barn Heat Energy Balance

- Heat Sources
  - Milk
  - Solar

- Heat Loads
  - Hot Water
  - Barn Heat
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 Status

- 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
Swine Barn Energy Monitoring

Breed to Wean Barns

• Breed to wean barn #2
  – Sow unit is curtain sided
  – Farrowing rooms are tunnel vented

• Energy usage
  – Uses 54,000 kWh/month on ave.
  – About 2500 sows
  – 58,000 weaned pigs per year
  – 11.3 kWh per weaned pig

• Breed to wean barn #6
  – Sow unit is tunnel vented
  – Farrowing rooms are tunnel vented

• Energy usage
  – Uses 87,000 kWh/month on ave.
  – 3,300 sows
  – 76,000 weaned pigs per year
  – 11.9 kWh per weaned pig
Swine Barn Energy Monitoring

Breed to Wean (Barn 2)
Annual Electricity Loads
January 2015 to October 2015
Average use ≈ 54,000 kWh/month

- Heat Lamps: 46%
- Ventilation: 23%
- Misc.: 24%
- Food & Water: 2%
- Lights: 3%
- Cleaning: 1%
- Heat: 1%
- Office: 4%

Breed to Wean (Barn 6)
Annual Electricity Loads
December 2014 to November 2015
Average use ≈ 85,000 kWh/month

- Heat Lamps: 44%
- Ventilation: 13%
- Misc.: 30%
- Food & Water: 3%
- Lights: 4%
- Office: 4%
- Heat: 1%
- Cleaning: 1%
Swine Barn Energy Monitoring

Breed to Wean (Barn 2) Daily Electricity Usage January 2015- October 2015
Nurseries

• Nursery barn #3
  – Nursery rooms are tunnel vented
• Energy usage
  – Uses 3,600 kWh/month on ave.
  – 19,000 pigs per year
  – 2.3 kWh per weaned pig

• Nursery barn #7
  – Nursery rooms are tunnel vented
• Energy usage
  – Uses 12,000 kWh/month on ave.
  – 68,000 pigs per year
  – 2.4 kWh per weaned pig
Swine Barn Energy Monitoring

Nursery (Barn 3)
Annual Electricity Loads
April 2014 to July 2015
Average use ≈ 3,600 kWh/month

- Ventilation: 58%
- Feed System: 3%
- Misc: 28%
- Heat: 3%
- Pressure Washer: 2%
- Lights: 2%
- Office: 4%

Nursery (Barn 7)
Annual Electricity Loads
July 2015 to November 2015
Average use ≈ 12,000 kWh/month

- Ventilation: 49%
- Cleaning: 2%
- Misc: 30%
- Office: 9%
- Food & Water: 4%
- Heat: 3%
- Lights: 3%
Swine Barn Energy Monitoring

Nursery (Barn 7 Daily) Electricity Usage

Date

KWh/Day
0 50 100 150 200 250 300 350 400

- Manure System
- Feed System
- Lights
- Ventilation
- Well
- Pressure Washer
- Controllers (Heat)
- Office
Swine Barn Energy Monitoring

Finishing Barns

• Finish barn #5
  – Finish rooms are curtain sided

• Energy usage
  – Uses 800 kWh/month on ave.
  – 3,000 pigs per year
  – 3.3 kWh per weaned pig

• Finish barn #4
  – Finish rooms are tunnel vented

• Energy usage
  – Uses 7,400 kWh/month on ave.
  – 7,000 pigs per year
  – 12.7 kWh per weaned pig
Swine Barn Energy Monitoring

Finisher (Barn 5)
Annual Electricity Loads
December 2014 to November 2015
Average use ≈ 800 kWh/month

- Feed System: 14%
- Receptacles/Curtain: 1%
- Lights/Heat: 3%
- PW: 2%
- Misc: 4%
- Ventilation: 76%

Finisher (Barn 4)
Annual Electricity Loads
December 2014 to November 2015
Average use ≈ 7,400 kWh/month

- Feed System: 3%
- Well: 8%
- Lights: 1%
- PW: 0%
- Heat: 0%
- Misc: 32%
- Office Heat: 3%
- Ventilation: 53%
Swine Barn Energy Monitoring

Barn 4 Daily Electricity Usage

-kWh/day

Date


Feed System Well Lights Pressure Washer Heat Ventilation
Swine Barn Energy Systems

Morris Example (finishing barn roof)

- Use PVwatts to predict performance (easy)
  - Predicted annual production = 35,480 kWh
  - Cost = $86,000 ($3.20/Watt)

Over 25 years

- 9.7¢/kWh (no incentives)
- 6.8¢/kWh (fed tax credit)
- 1.6¢/kWh (FTC & MiM)

Might have maintenance costs with inverters
Key Points

• Biggest electricity load in Breed to Wean barns is heat lamps
• Biggest electricity load in Nursery & Finish barns is ventilation
• Barn roofs may provide adequate area to get to ‘Net Zero’ with solar PV
  – Solar PV is very economical with MiM incentive
• Energy monitoring can uncover saving opportunities
  – Generator block heaters and space heaters
Questions?

Stay tuned for progress

• http://wcroc.cfans.umn.edu/research-programs/renewable-energy

Funding Sources:

• IREE, Institute on Renewable Energy & the Environment (U of M, now IonE)
• RDF, Xcel Energy Renewable Development Fund (Xcel ratepayers)
• LCCMR, Legislative Citizen’s Commission on MN Resources (lottery money)