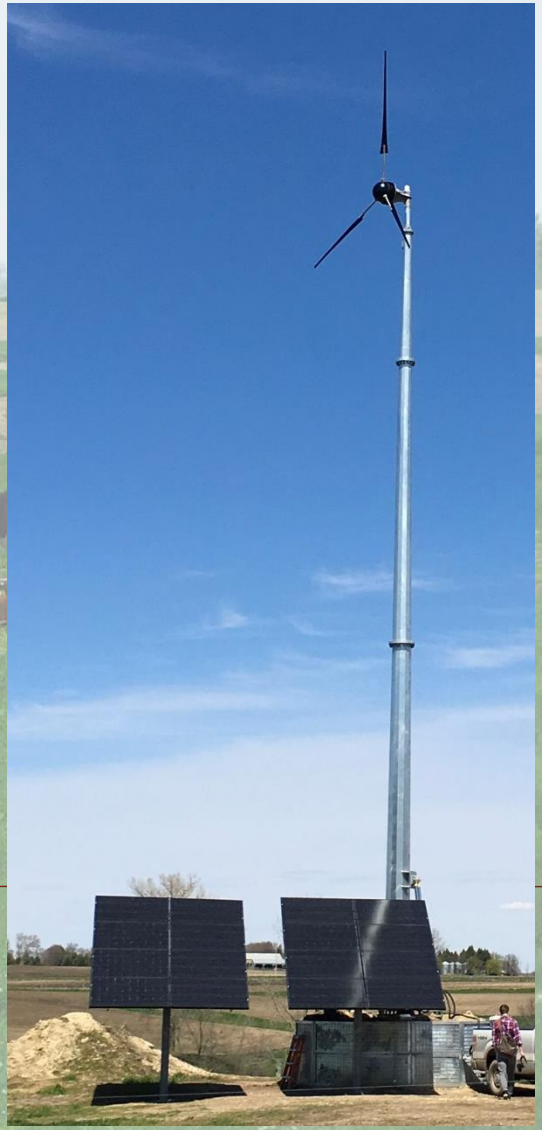
Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund.



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

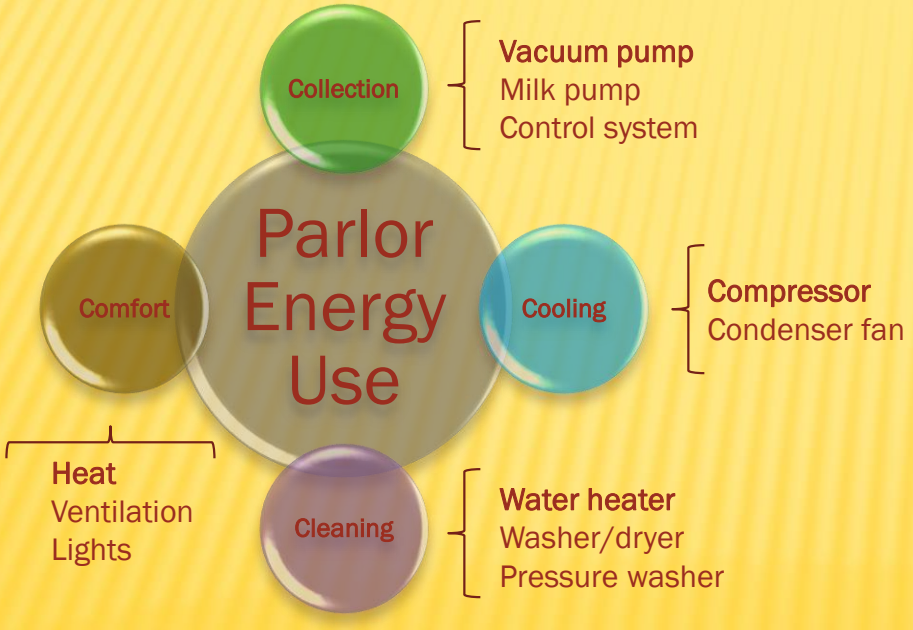
STEP 3: Convert Thermal Loads

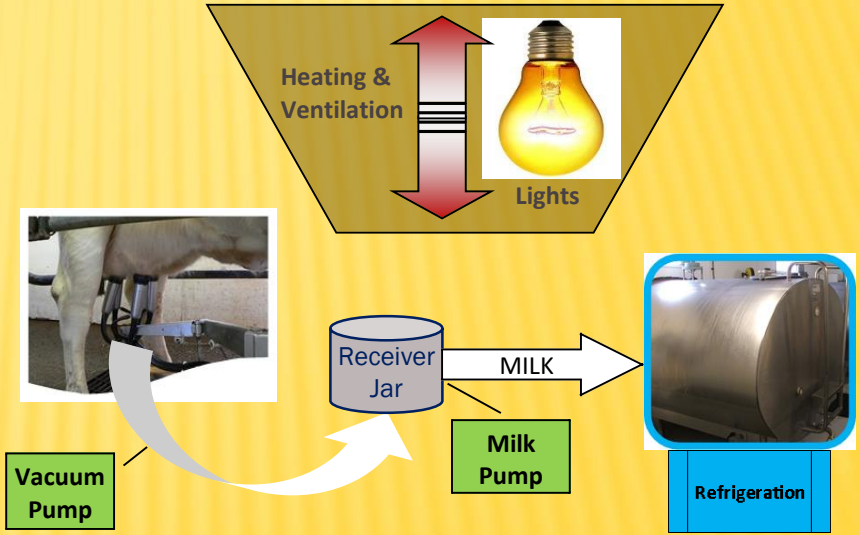
STEP 2: Energy Efficiency

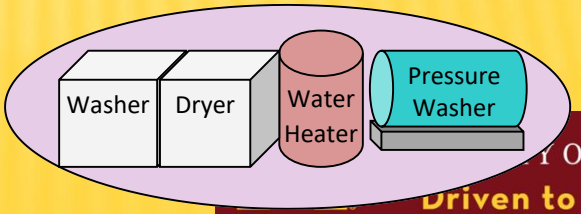
STEP 1: Understand Energy Usage

STEP 1: UNDERSTAND ENERGY USAGE

- Milking cows is energy and water intensive



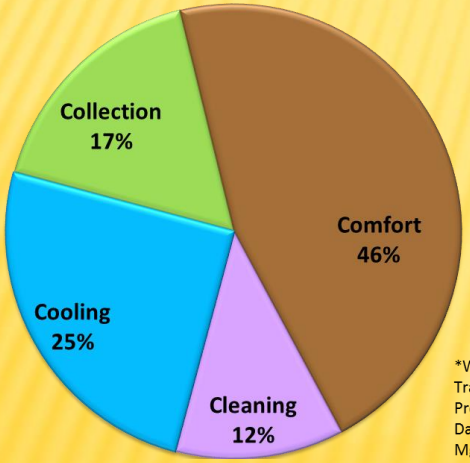




STEP 1: UNDERSTAND ENERGY USAGE

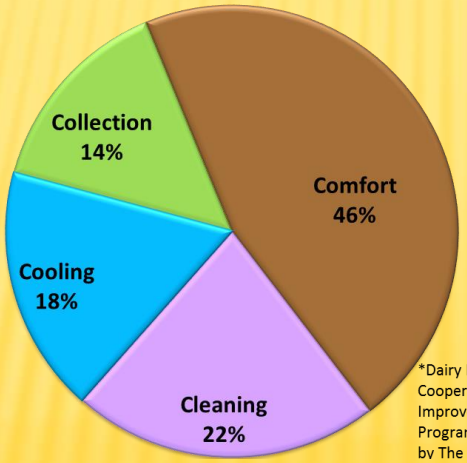
- Where is energy used? The 4 C's:

Wisconsin Dairy Energy Use* (2005)



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

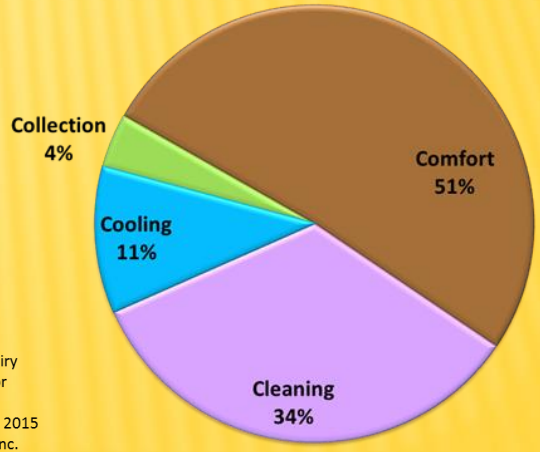
30 Farms from HCCC Dairy Energy Use* (2015)



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

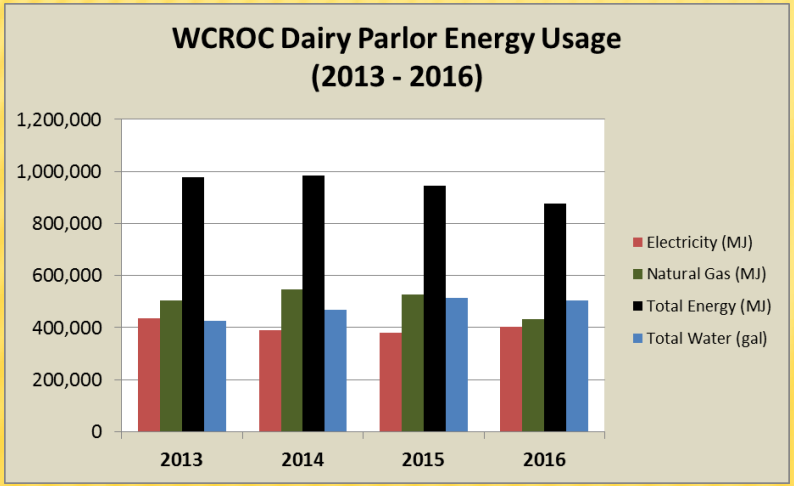
WCROC Dairy Parlor Total Energy Use

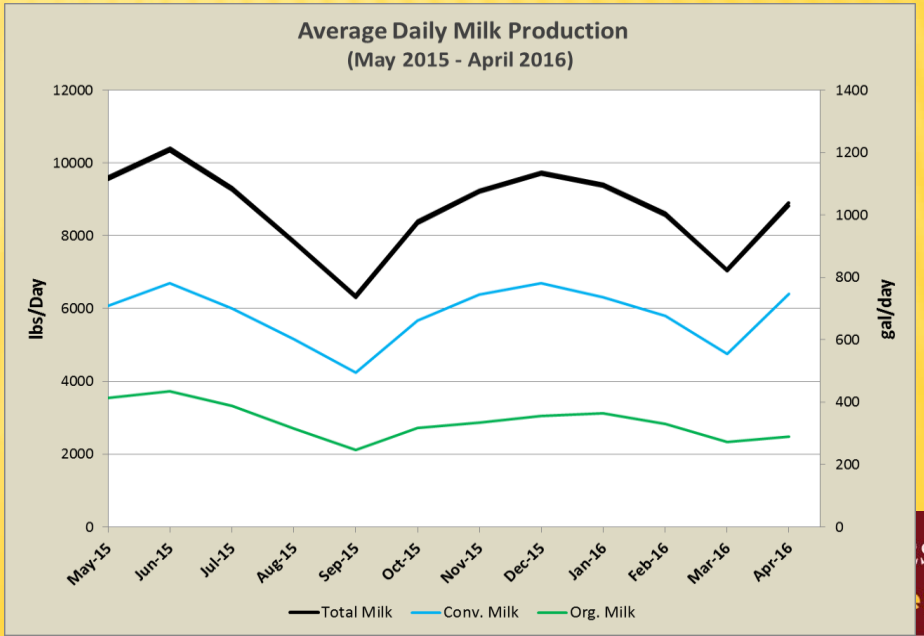
Gas & Electric ≈ 2650 MJ/day (740 kWh/day)



STEP 1: UNDERSTAND ENERGY USAGE

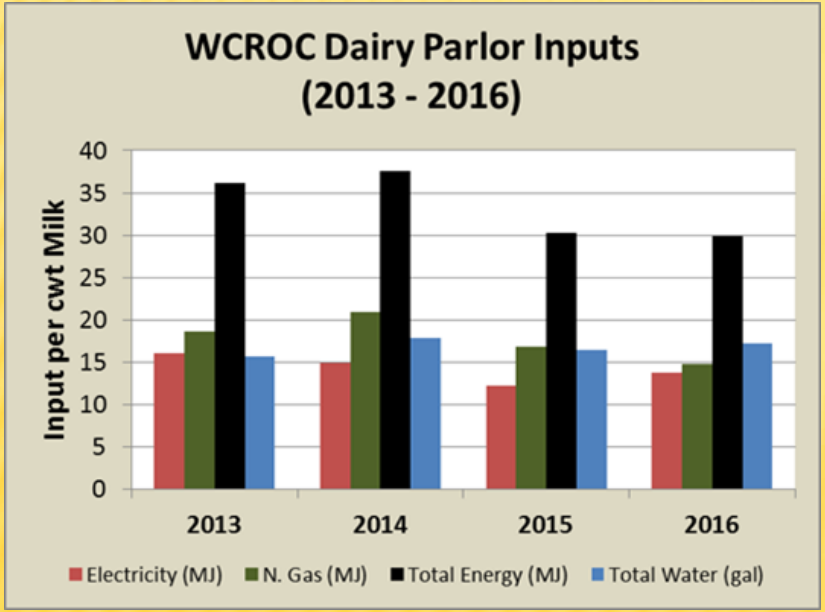
- Current project focuses on the WCROC Milking Parlor
  - Extensive energy monitoring began in late 2013
    - 20 individual electric load sensors, 11 water flow & temp sensors





STEP 1: UNDERSTAND ENERGY USAGE

- Looking at energy per unit of production

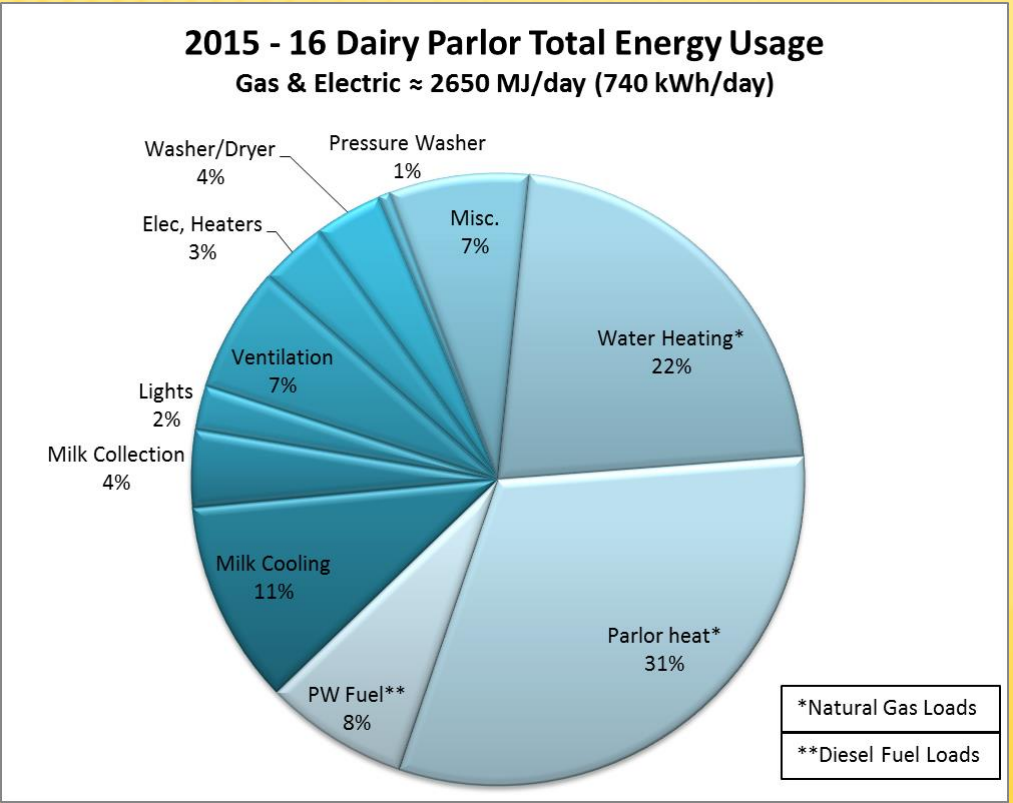


WCROC Milking Parlor Energy Usage				
	2013 - 2016			
Energy Usage	Annual Ave.	Ave./cow	Ave./cwt milk	$/cwt milk
Natural Gas (therm)	4,767	23.6	0.2	$ 0.12
Electricity (kWh)	111,708	553.0	3.9	$ 0.39
Total Energy (MJ)	936,314	4635	32.9	**$ 0.52**
Total Water (gal)	478,362	2368	16.8	--

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)



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

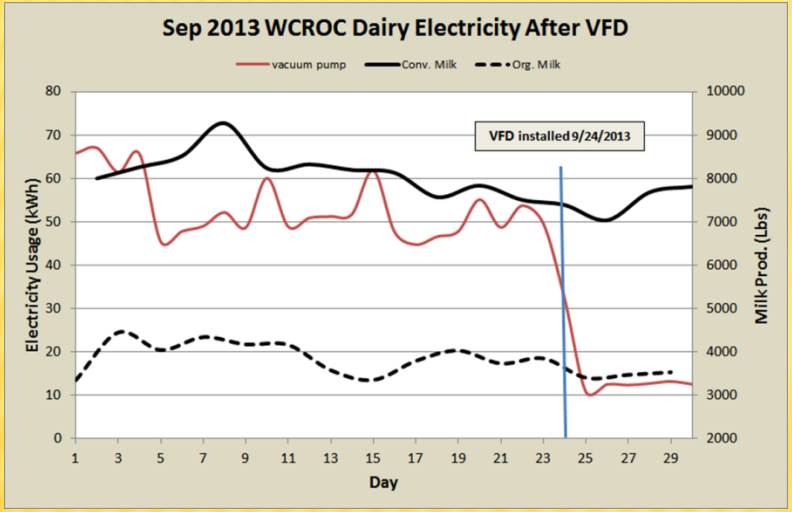
Parlor heating is the largest single load followed by water heating.

STEP 2: ENERGY EFFICIENCY

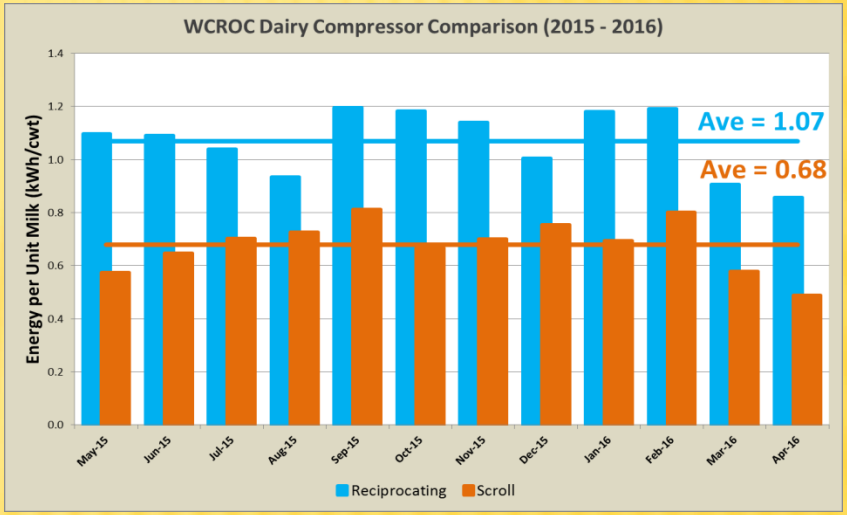
- Reducing energy usage is an important step that will reduce the size of any needed renewable energy (RE) system
  - There is no unit of energy cheaper than one you don't use!
  - Energy efficiency upgrades often pay back in under 10 years
    - MN project HCCC average payback estimates:
      - LED 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

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

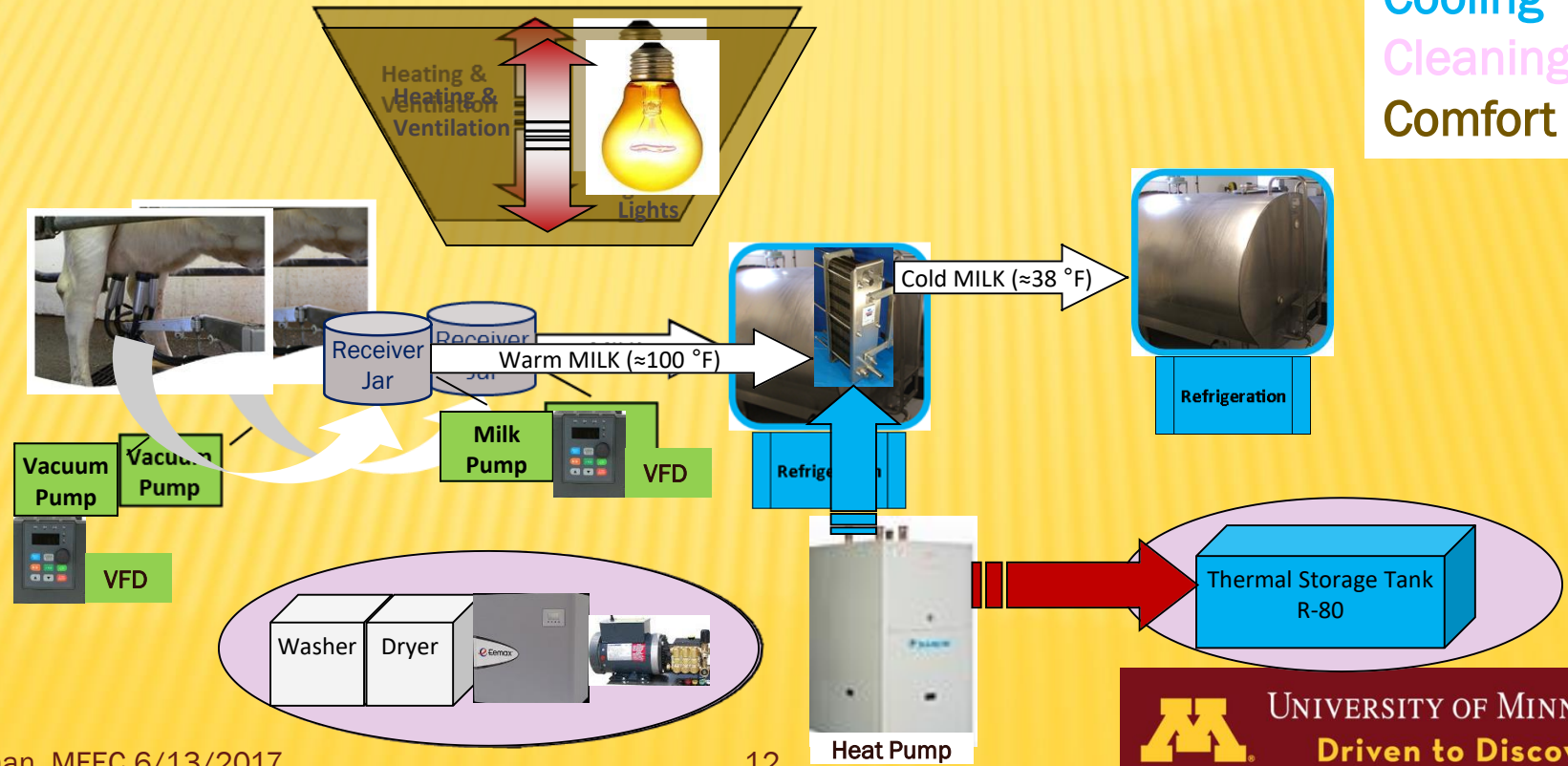
WCROC dairy energy optimization goals

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



STEP3: THERMAL LOAD CONVERSION

Energy optimized milking process

Storage Tank

Water Heaters

Solar Drain Back Tank

Heat Pump

VFD's

Pressure Washer

Heat Exchanger

Control Panel

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

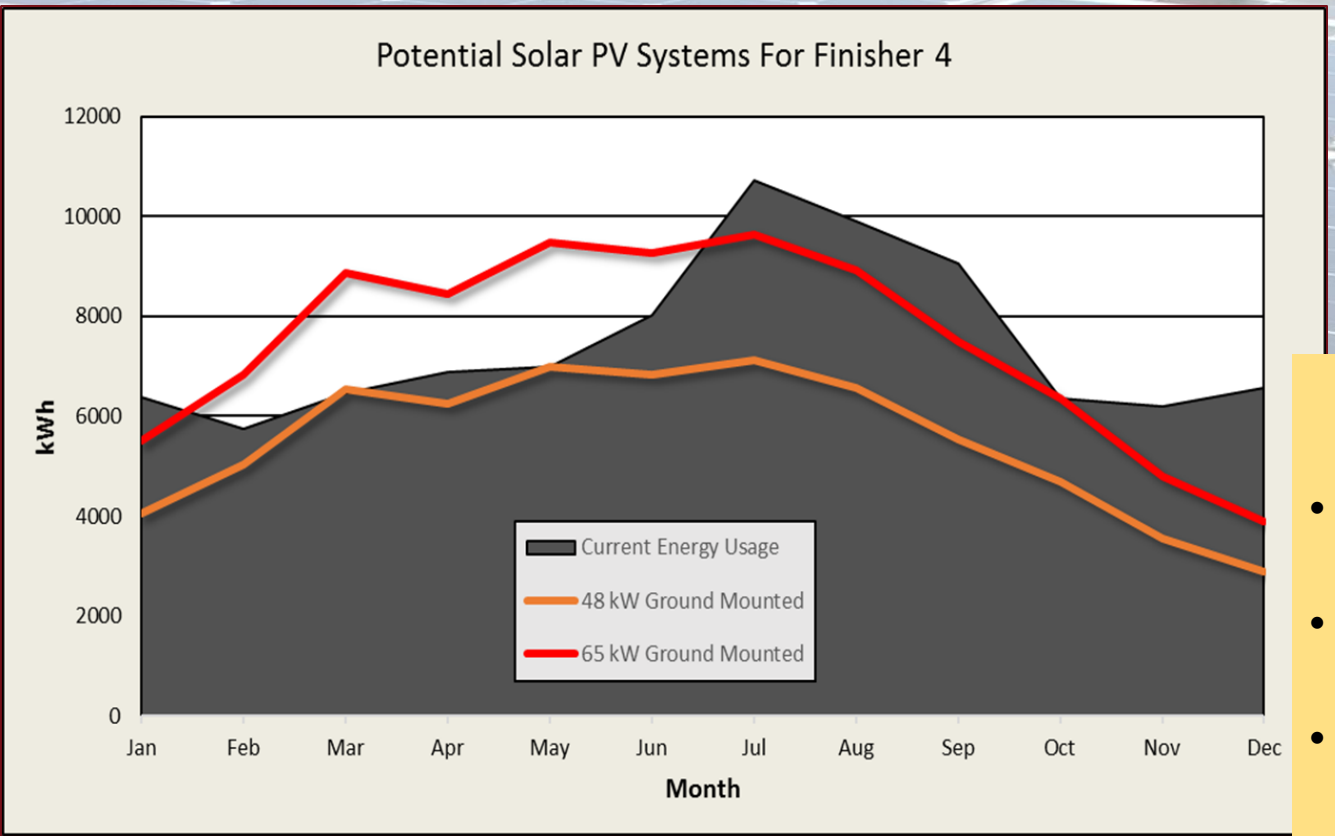
- After energy consuming processes have been optimized and thermal loads have been converted to electricity, a RE system can be sized to generate the total annual energy load.
  - This results in a Net-Zero operation
- RE systems generally have high up front costs and longer pay back times than efficiency 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 (≈3¢/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)

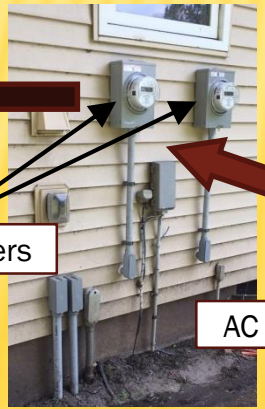


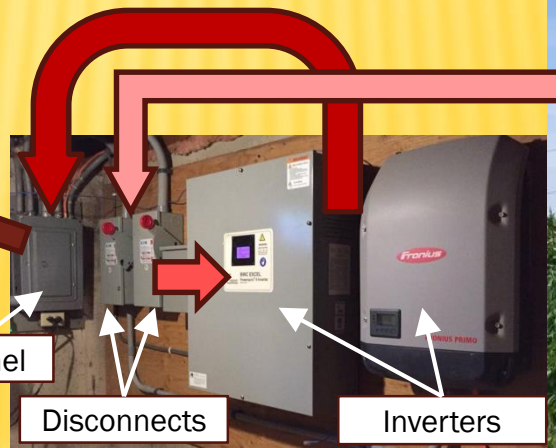
Over 25 years

- 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





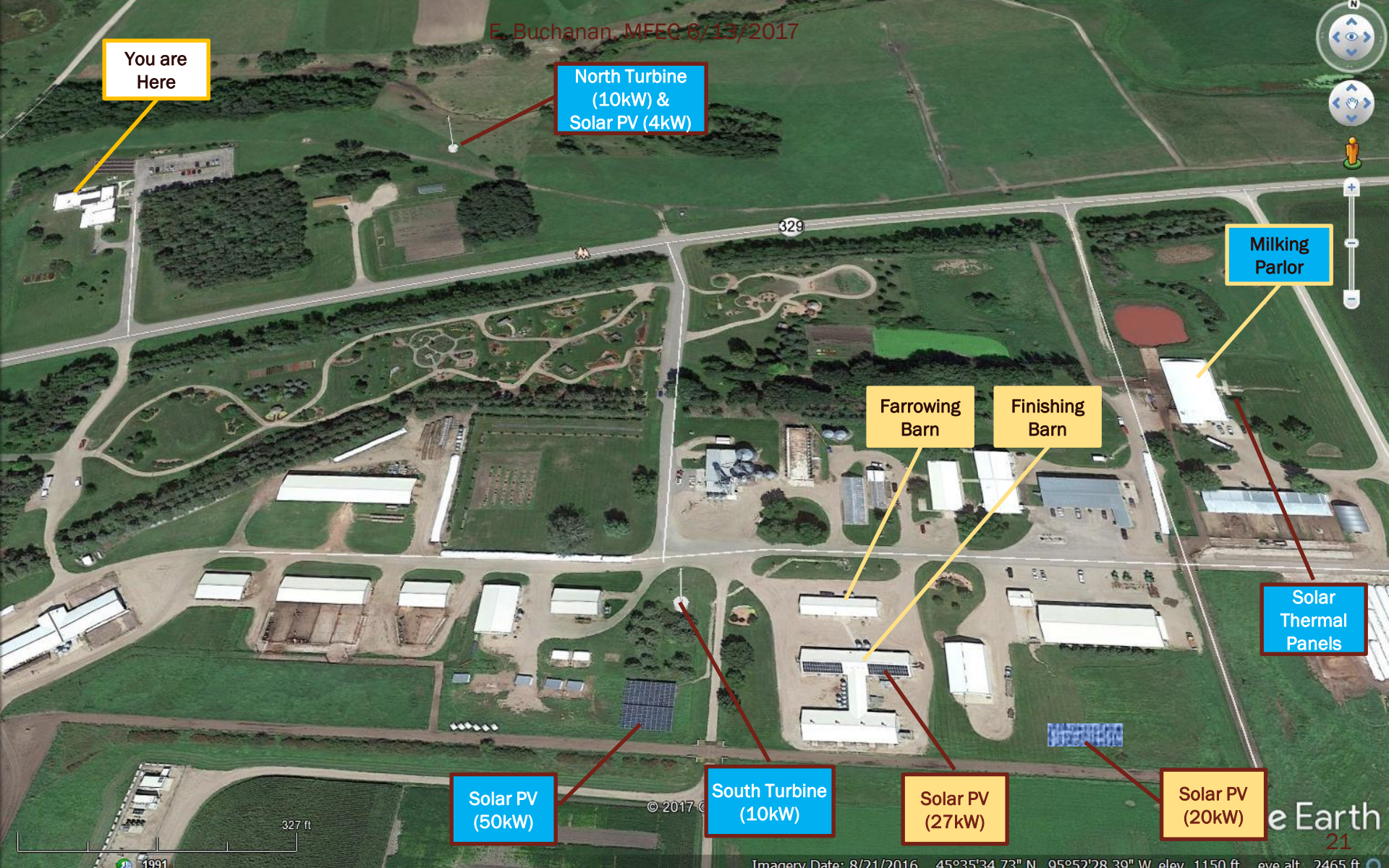
STEP 4: RENEWABLE ENERGY SYSTEMS

- 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


E. Buchanan, MFEC 6/13/2017
You are Here
North Turbine (10kW) & Solar PV (4kW)
329
Milking Parlor
Farrowing Barn
Finishing Barn
Solar Thermal Panels
Solar PV (50kW)
South Turbine (10kW)
Solar PV (27kW)
Solar PV (20kW)
327 ft
1991
© 2017
e Earth
Imagery Date: 8/21/2016 45°35'34.73" N 95°52'28.39" W elev 1150 ft eye alt 2465 ft

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

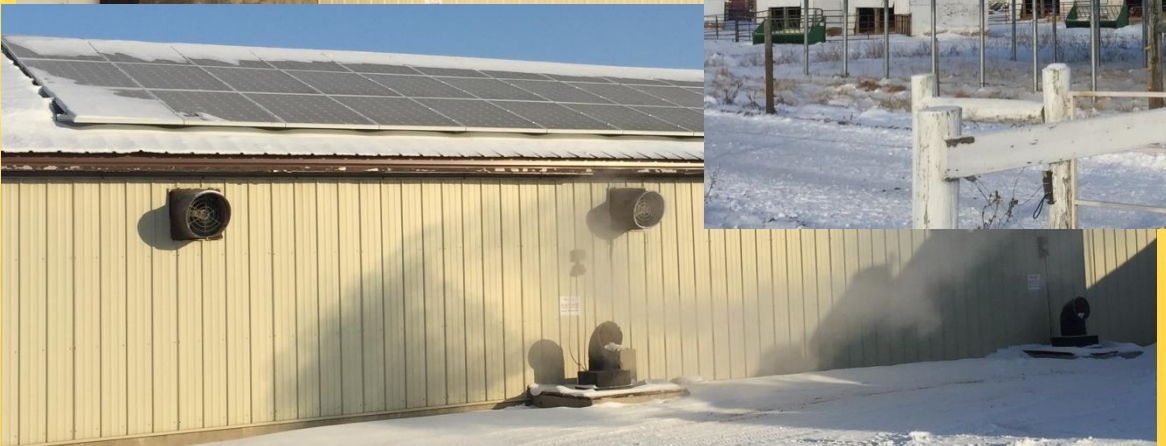
Con's

- 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



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 ≈ 100’ (30 meters). Guyed or tilt-down
    - Guyed towers are less expensive, but take up more space
      - Guy radius is ½ to ¾ 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