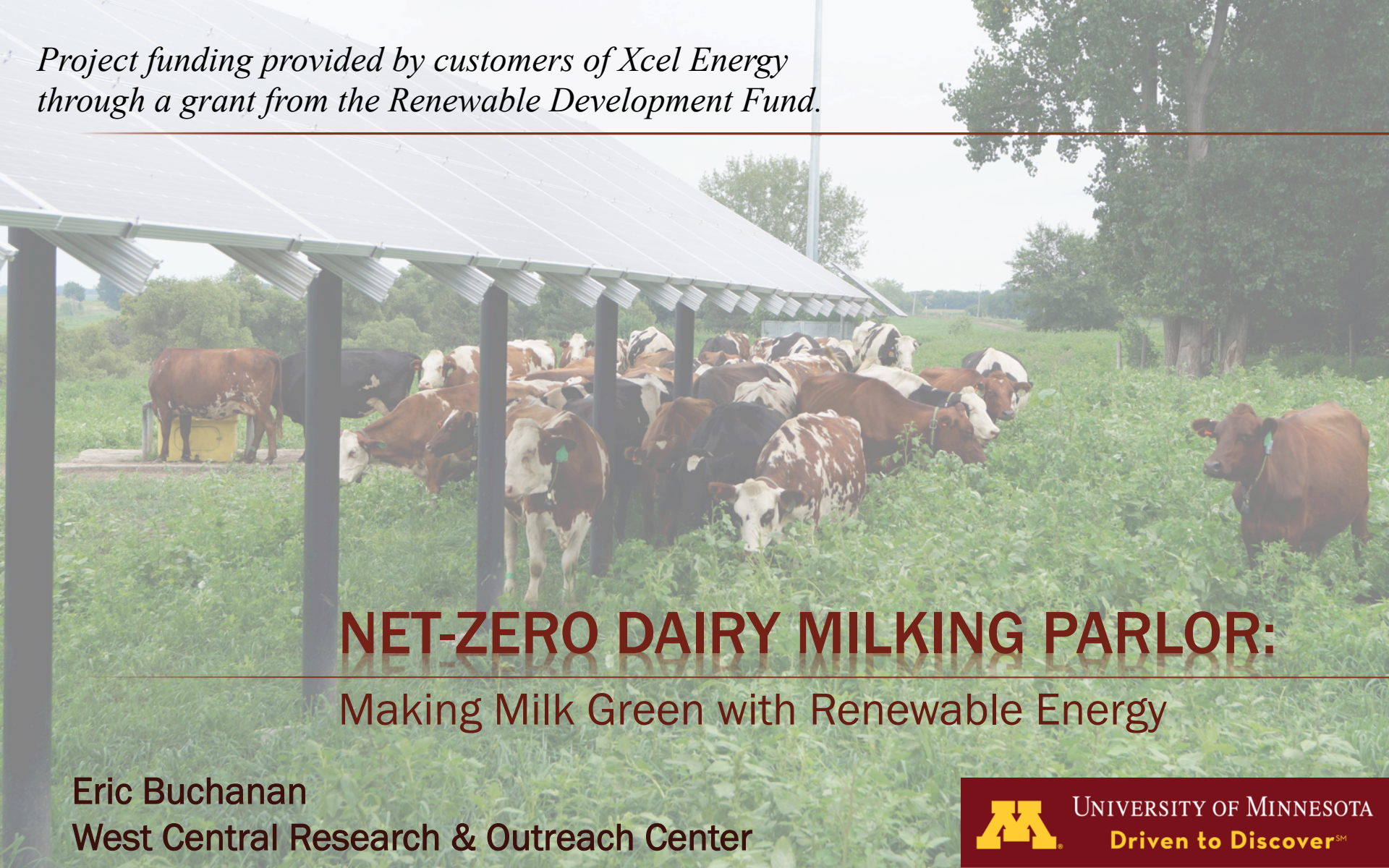
Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund.



NET-ZERO DAIRY MILKING PARLOR:

Making Milk Green with Renewable Energy

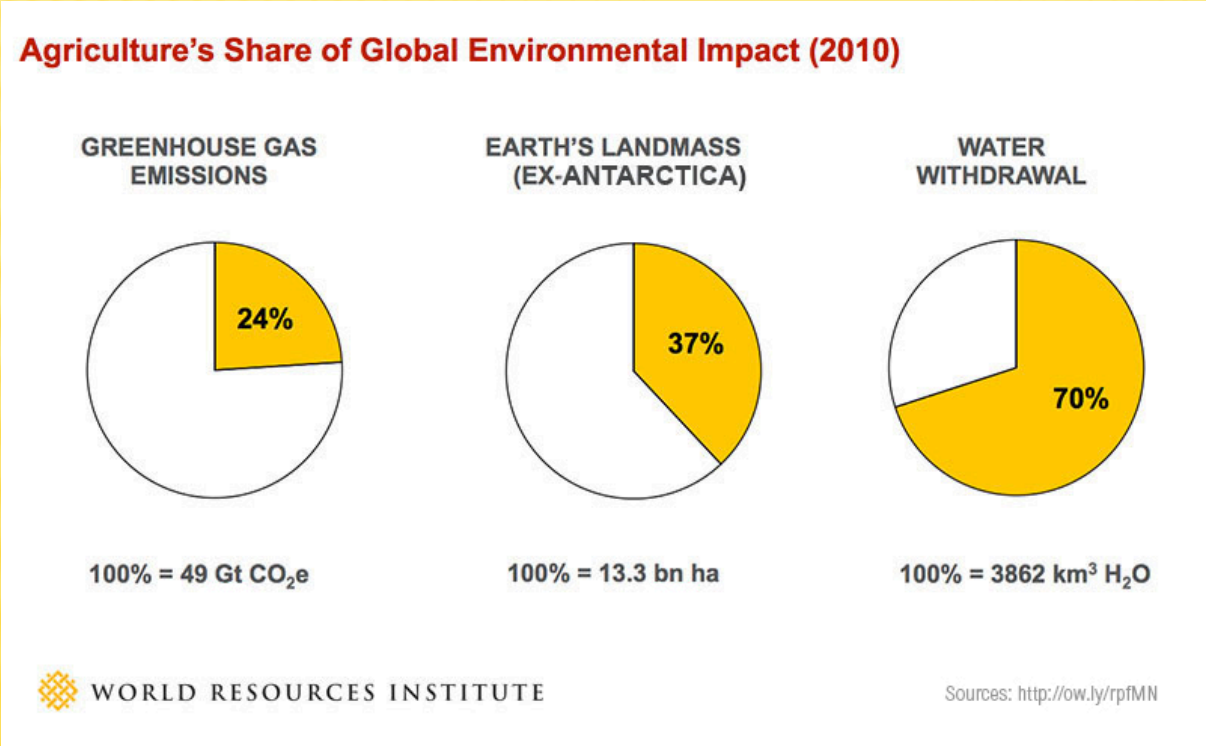
Eric Buchanan
West Central Research & Outreach Center

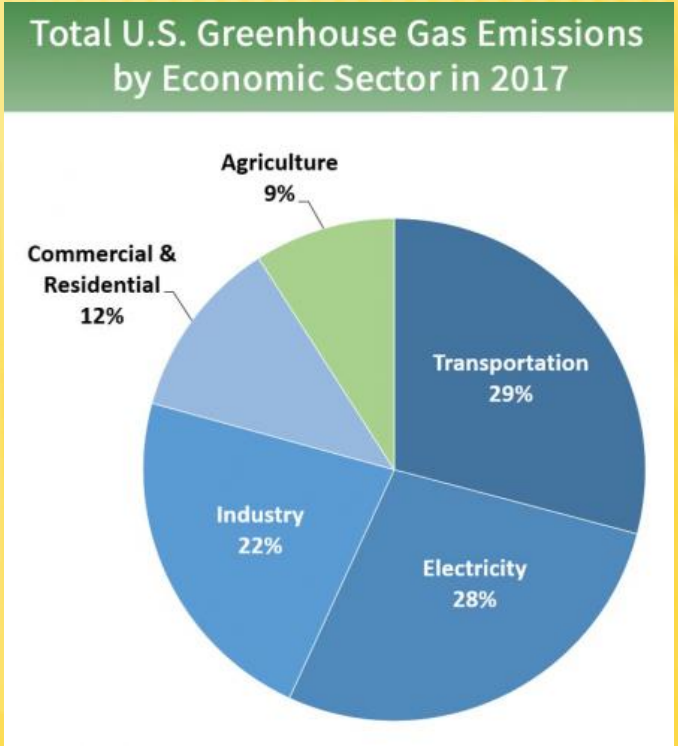
University of Minnesota
Driven to Discover℠

QUESTIONS TO ANSWER

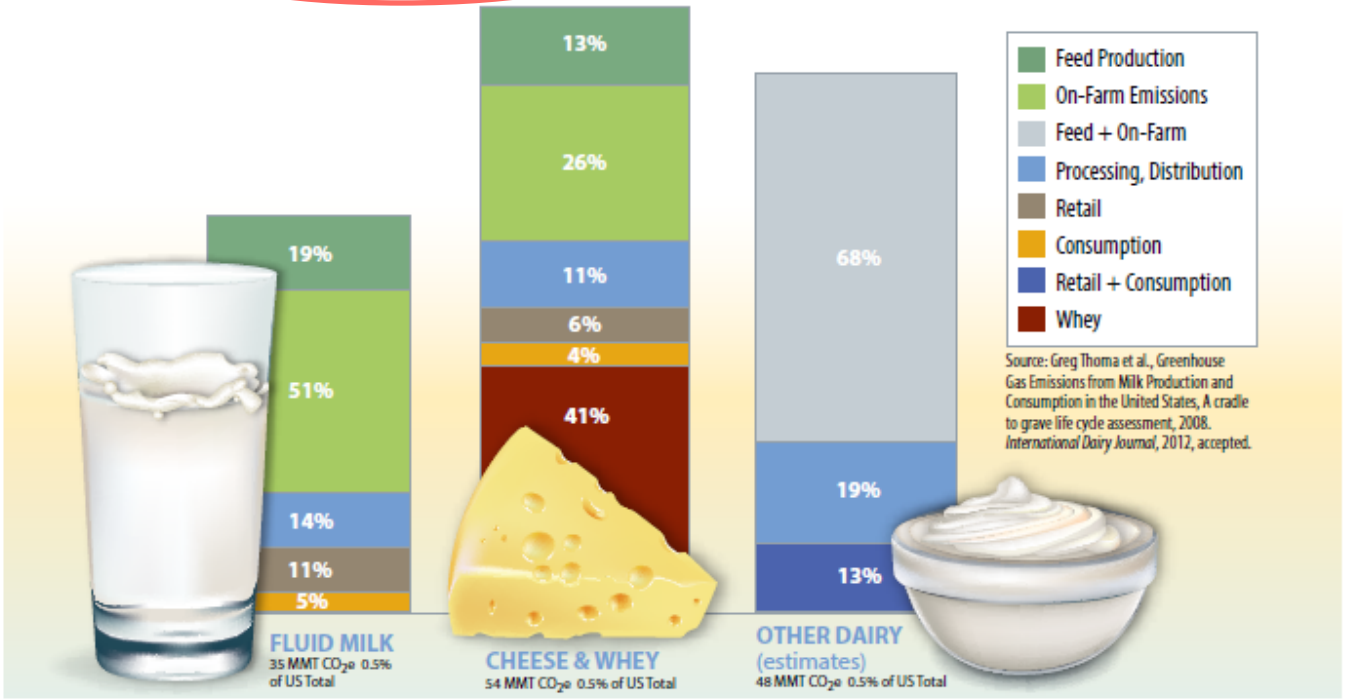
- How does agriculture contribute to climate change?
- What is the contribution from dairy?
- How is energy used in milk production?
  - How much energy is used?
- What does a Net-Zero dairy look like?
  - Solutions may apply to other industries

AGRICULTURE & CLIMATE CHANGE





DAIRY & CLIMATE CHANGE



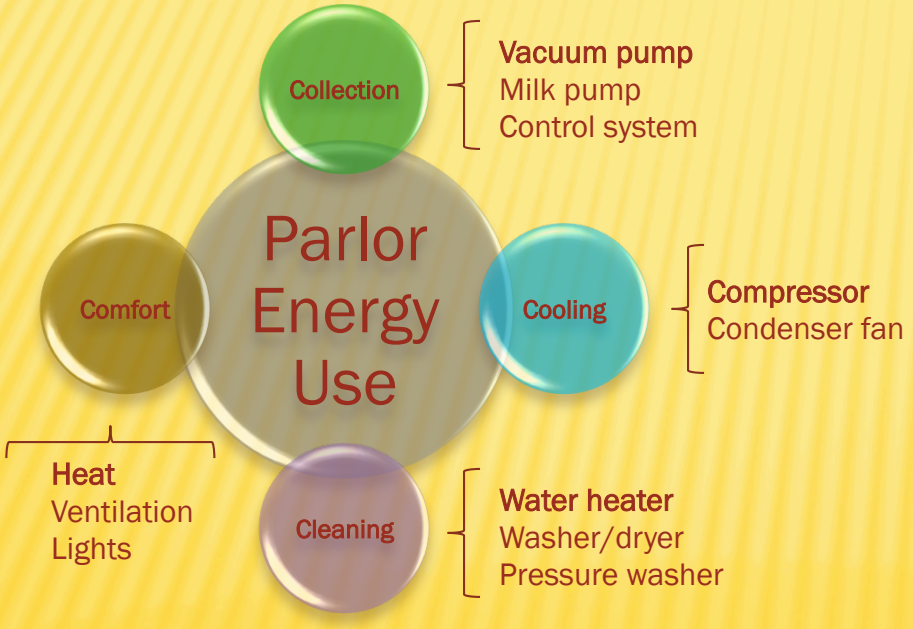
Thoma [e] et al. (2012). *Comprehensive Life Cycle Assessment for Cheese and Whey Products* - Final Report.

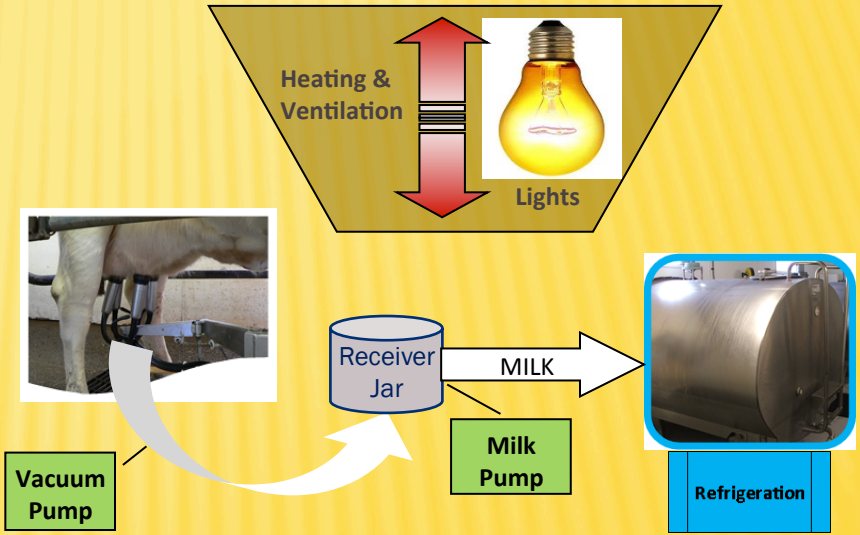
DAIRY & CLIMATE CHANGE

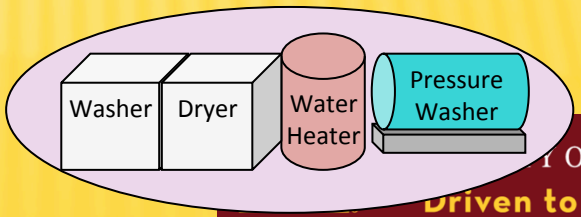
- There are about 270 million dairy cows in the world (WWF)
- There are about 9 million dairy cows in the US (USDA)
  - Each cow produces about 10,600 kg of milk per year (23,400 lbs)
  - 7.6 kg (16.7 lbs) of CO_{2e} per gallon of milk
  - 1 US human ~15.8 MT CO_{2e}/yr, 1 US dairy cow ~21.3 MT CO_{2e}/yr
- Just over 40,000 dairy farms in the US
- The average dairy farmer controls the CO_{2e} of 315 people
- The decisions a single farmer makes can have a large impact!!

HOW IS ENERGY USED ON DAIRY FARMS?

- Milking cows is energy and water intensive







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

HOW MUCH ENERGY IS USED?

- WCROC “Greening” of AG strategic plan
  - Started farm wide projects to monitor energy usage
    - Dairy milking parlor
    - 5 swine barns
    - Farm vehicles & trucks
    - Fieldwork tractors

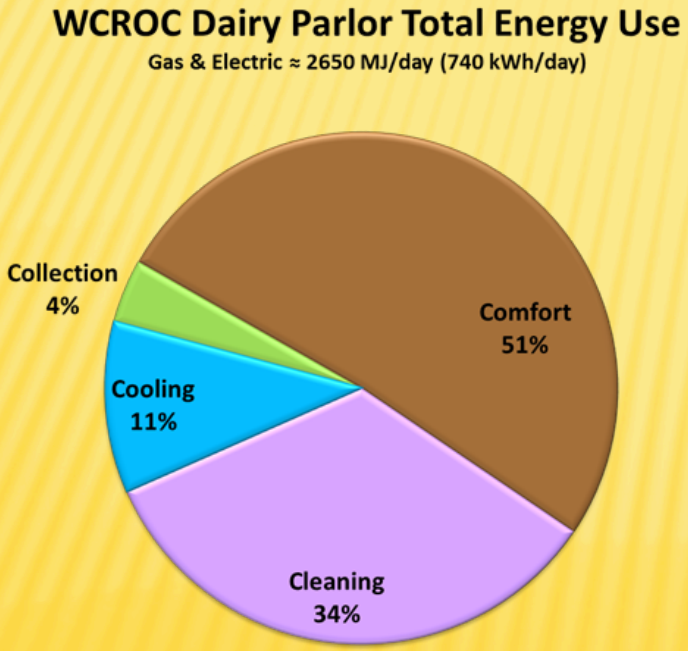
Over 30 individual electric loads
11 water flow and temperature sensors
4 air temperature sensors

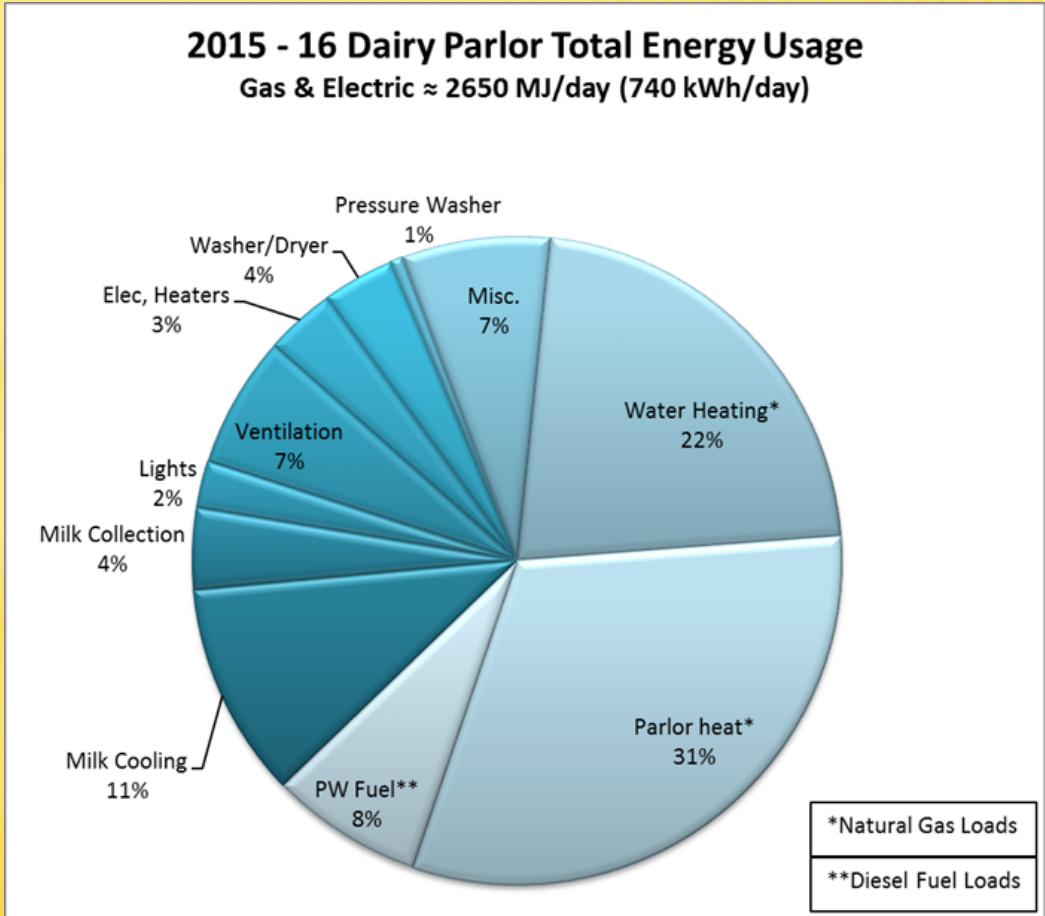
10 second measurements averaged and stored every 10 minutes ~ 3 million data points per year

  - Monitored energy use on 6 commercial swine barns and 4 commercial dairy farms

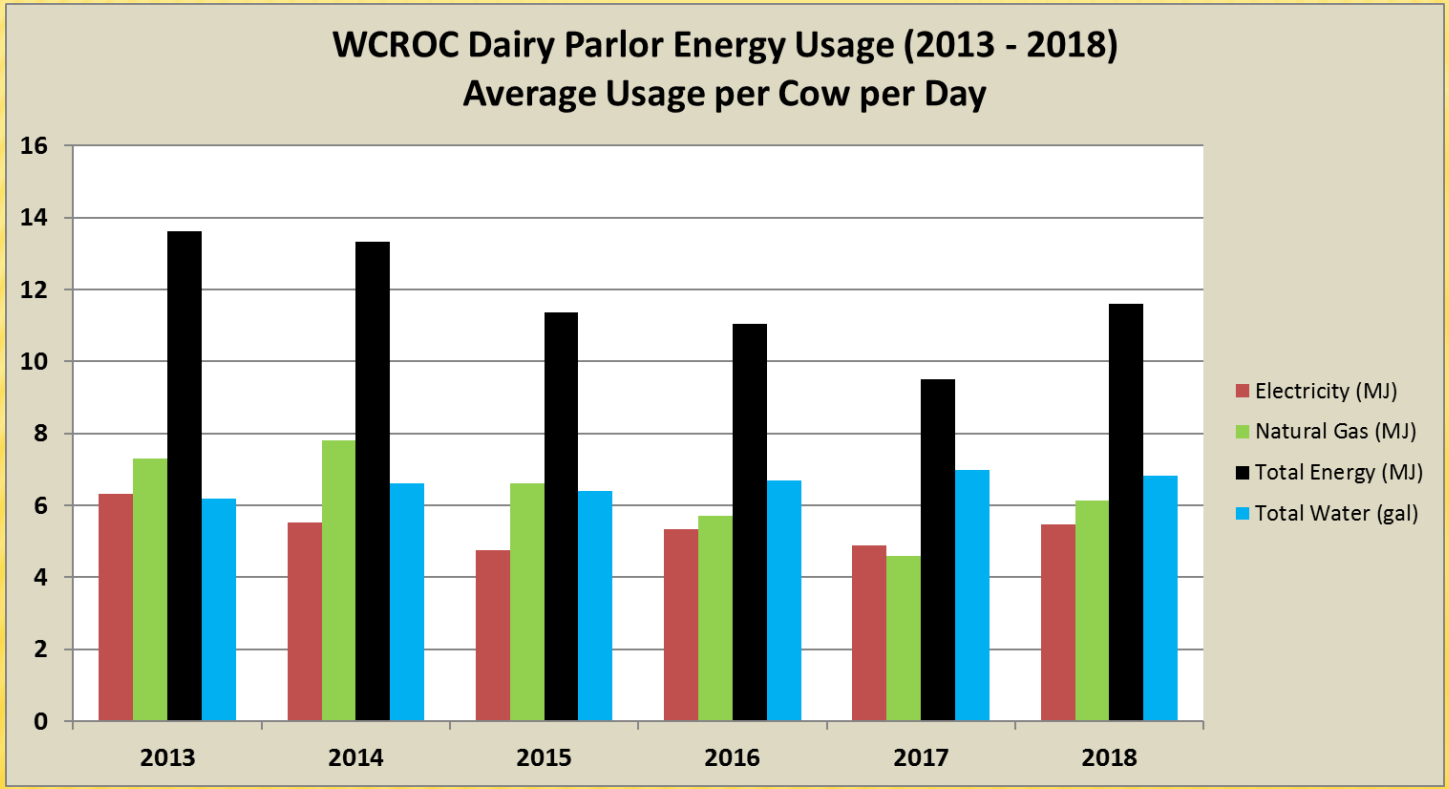
STEP 1: UNDERSTANDING ENERGY USAGE

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





STEP 1: UNDERSTANDING ENERGY USAGE



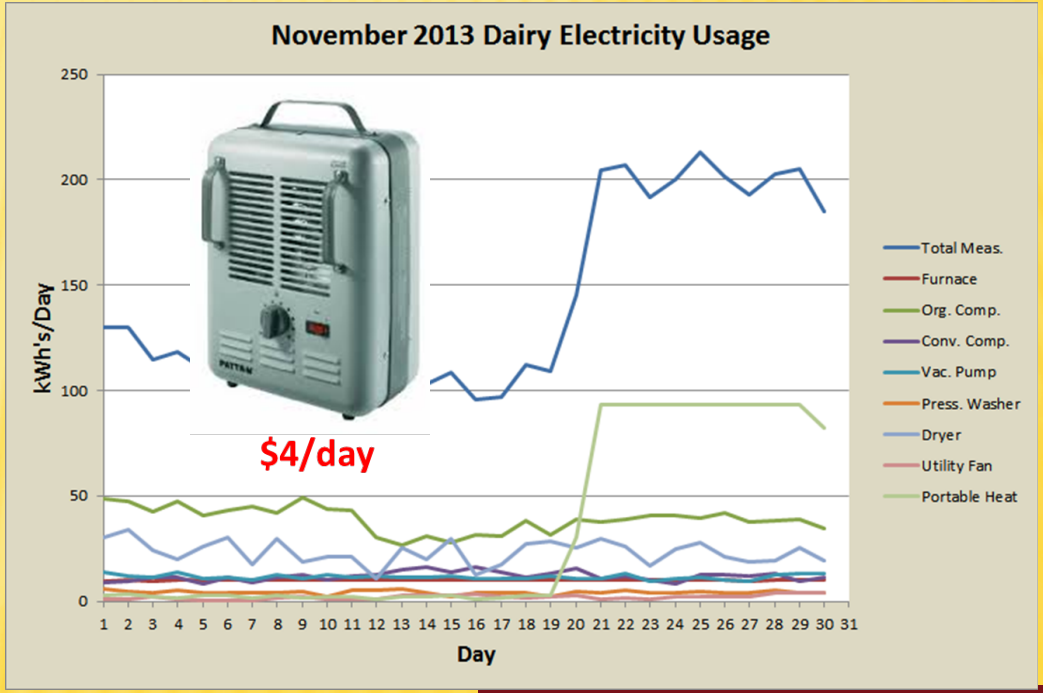
Energy Usage* per gallon of Milk	
Natural Gas (MJ)	1.2
Electricity (kWh)	0.3
Total Energy (MJ)	2.3
Total Water (gal)	1.2

* Energy usage is for milk harvesting only

Milking 234 cows twice per day

STEP 2: ENERGY EFFICIENCY

- Lessons learned from WCROC energy monitoring
  - "Milk house heaters" are a common site on farms in winter
  - Similar usage for back-up generator heaters
- Could be a big potential for solar/ battery back-up power



STEP3: THERMAL LOAD CONVERSION

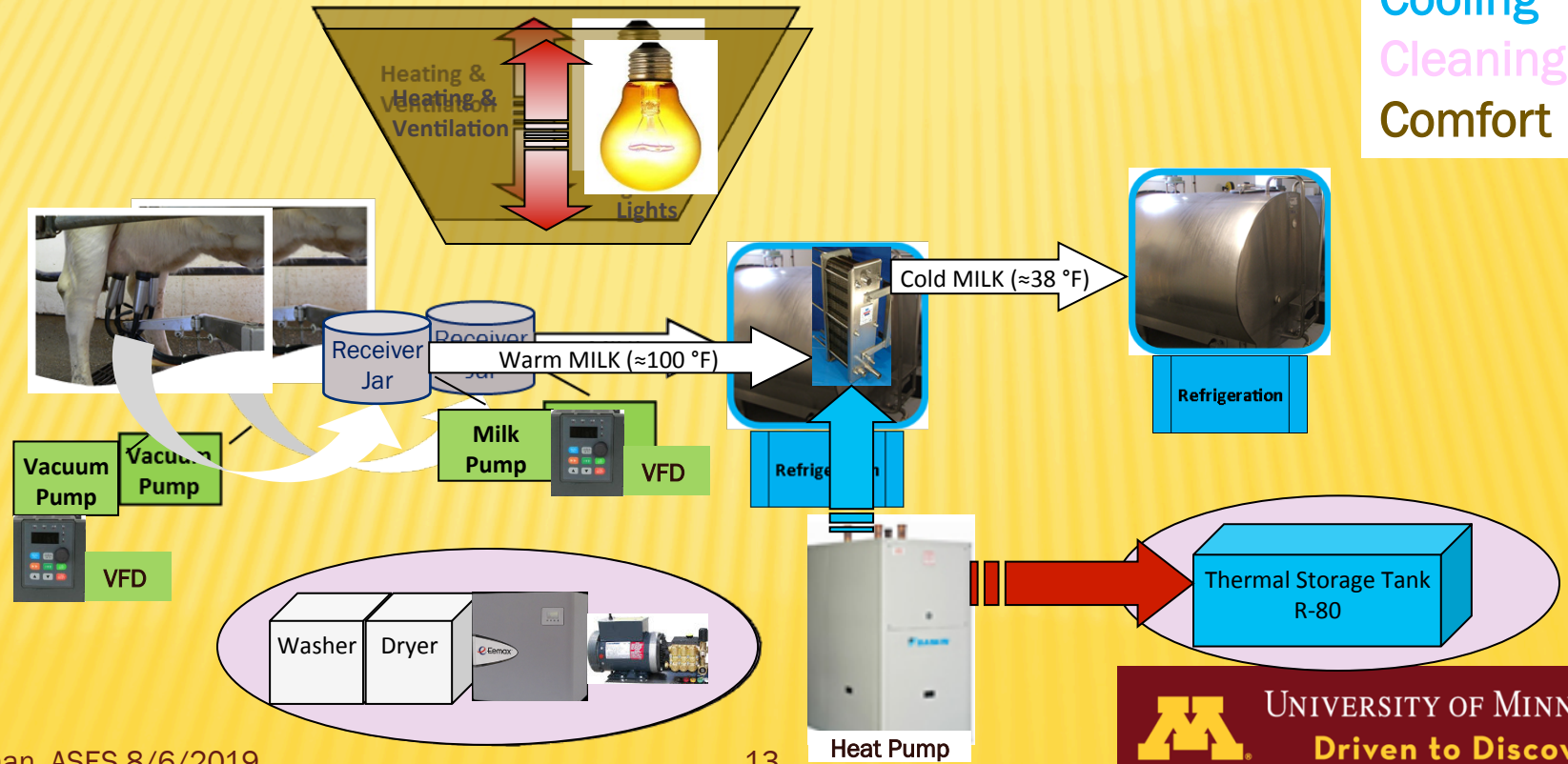
WCROC dairy energy optimization goals

1. Collect thermal energy from milk as a resource (heat pump)
   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

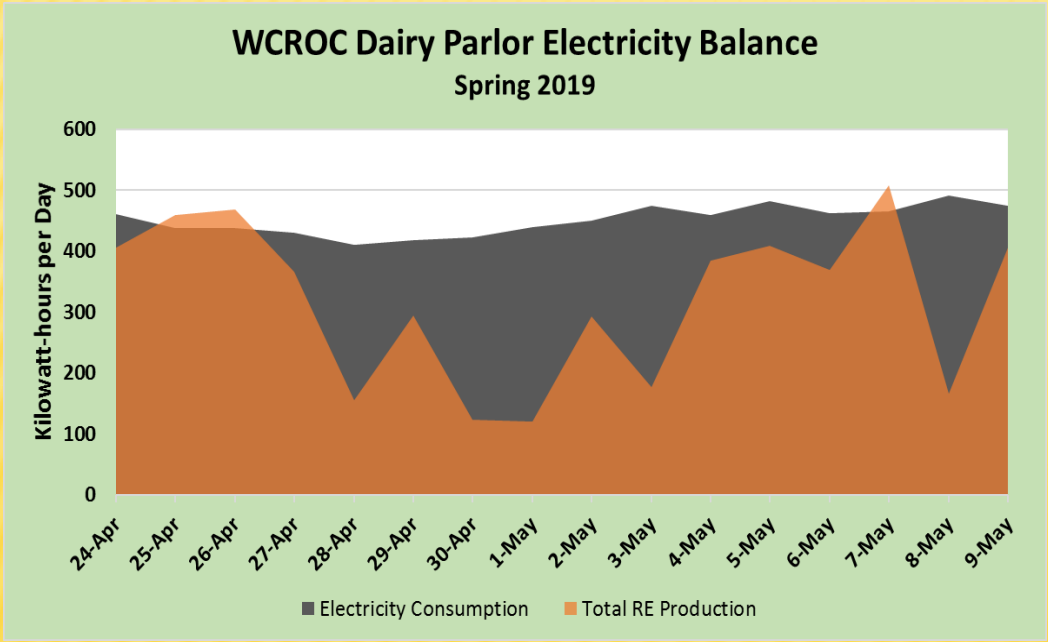
Control Panel

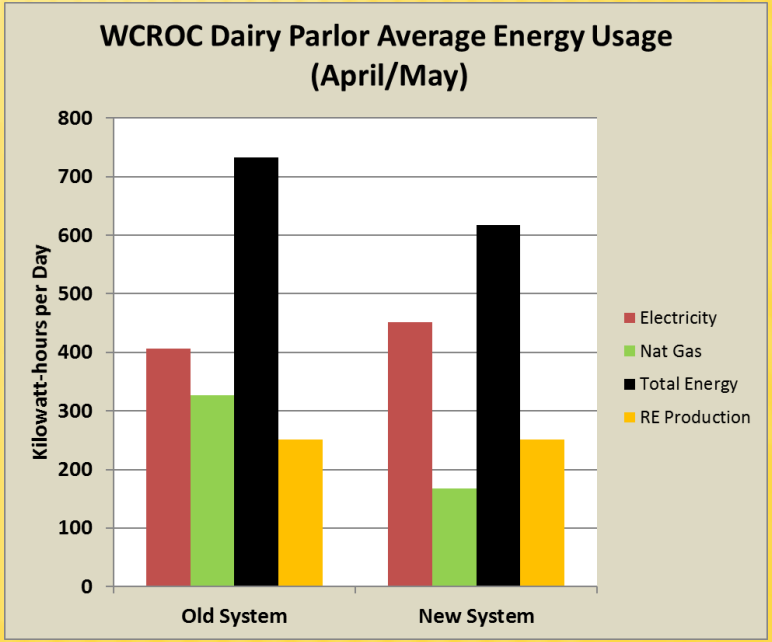
STEP 4: RENEWABLE ENERGY SYSTEMS

- WCROC dairy installed the following systems:
  - 50 kW solar PV array (ground mounted)
  - 30 kW solar PV array (in cow pasture)
  - Two 10 kW wind turbines (70', tilt-down towers)
  - 4 kW pole mounted solar PV array (in cow pasture)

NET-ZERO DAIRY PARLOR?

- Net-Zero analysis for 2 weeks of Spring, 2019





- We still have some work to do

SO WHAT DOES IT ALL MEAN?

- Commercial AG needs to be a part of the solution
- Farm sites present practical difficulties
  - Need low hassle solutions (heaters, back-up generation, etc.)

- Pairing heat sources with heat loads via heat pumps can reduce energy use and eliminate thermal fuels
- Hot water tanks can work well storing renewable electricity where there is a consistent hot water load
  - Hotels, fitness centers, laundromats, etc.
  - Much more efficient than battery storage

THANK YOU

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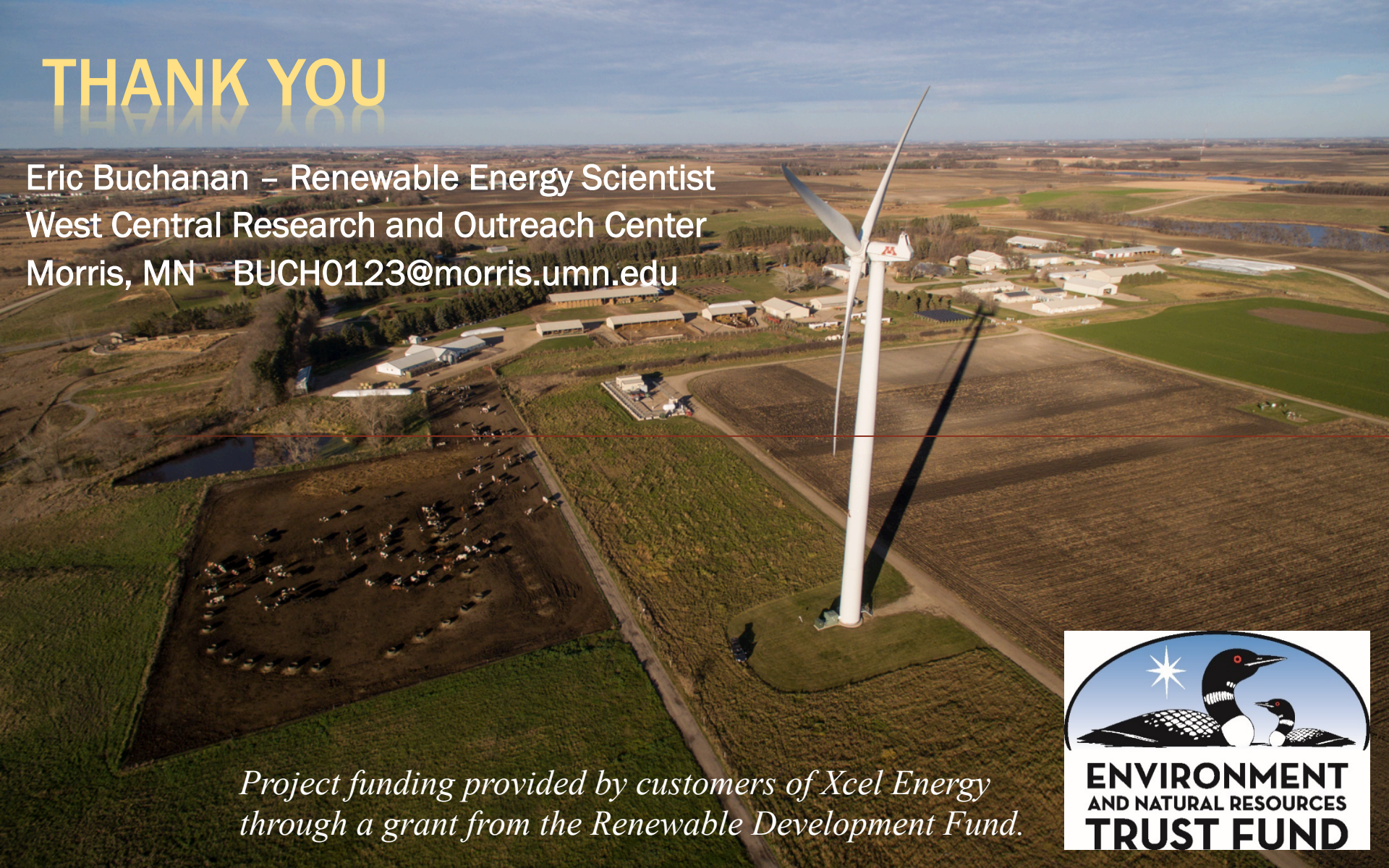

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