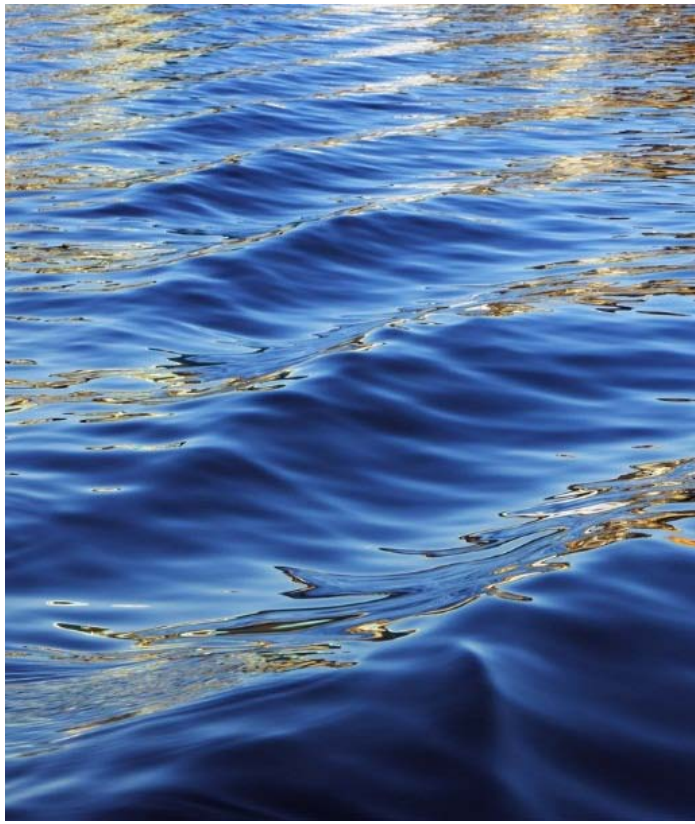
Capturing Waste Heat from Biogas-Powered Generators for Conductive Cooling on NYS Dairy Farms

Joseph Usack and Kristy Perano, Cornell University



Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy Conference (EMEP)
November 6-7th, 2013: Albany, New York

OUTLINE

- Project Team
- The Problem to be Addressed
- Project Overview
- PART I: Capturing Waste Heat from Biogas-Powered Generators
- PART II: Conductively Cooling Dairy Cows with Waste Heat
- Future Plans

Project Team

Heat/Mass Transfer in Biological Systems

Bioenergy and Integrated Energy Systems

Dairy Sustainability -- Outreach

Dairy Cattle Nutrition and Management

Co-PI: Kifle Gebremedhin

PI: Lars Angenent

Co-PI: Curt Gooch

Controlled Environment Agriculture

Advisor: Prof. Tom Overton

Sustainable Energy Systems – Renewable Energy

Advisor: Prof. Norm Scott

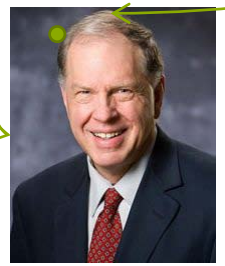
Kristy

Joe

Advisor: Dr. Tim Shelford

Croll Prof. of Sustainable Energy Systems – Director of Cornell Energy Institute

Advisor: Prof. Jeff Tester

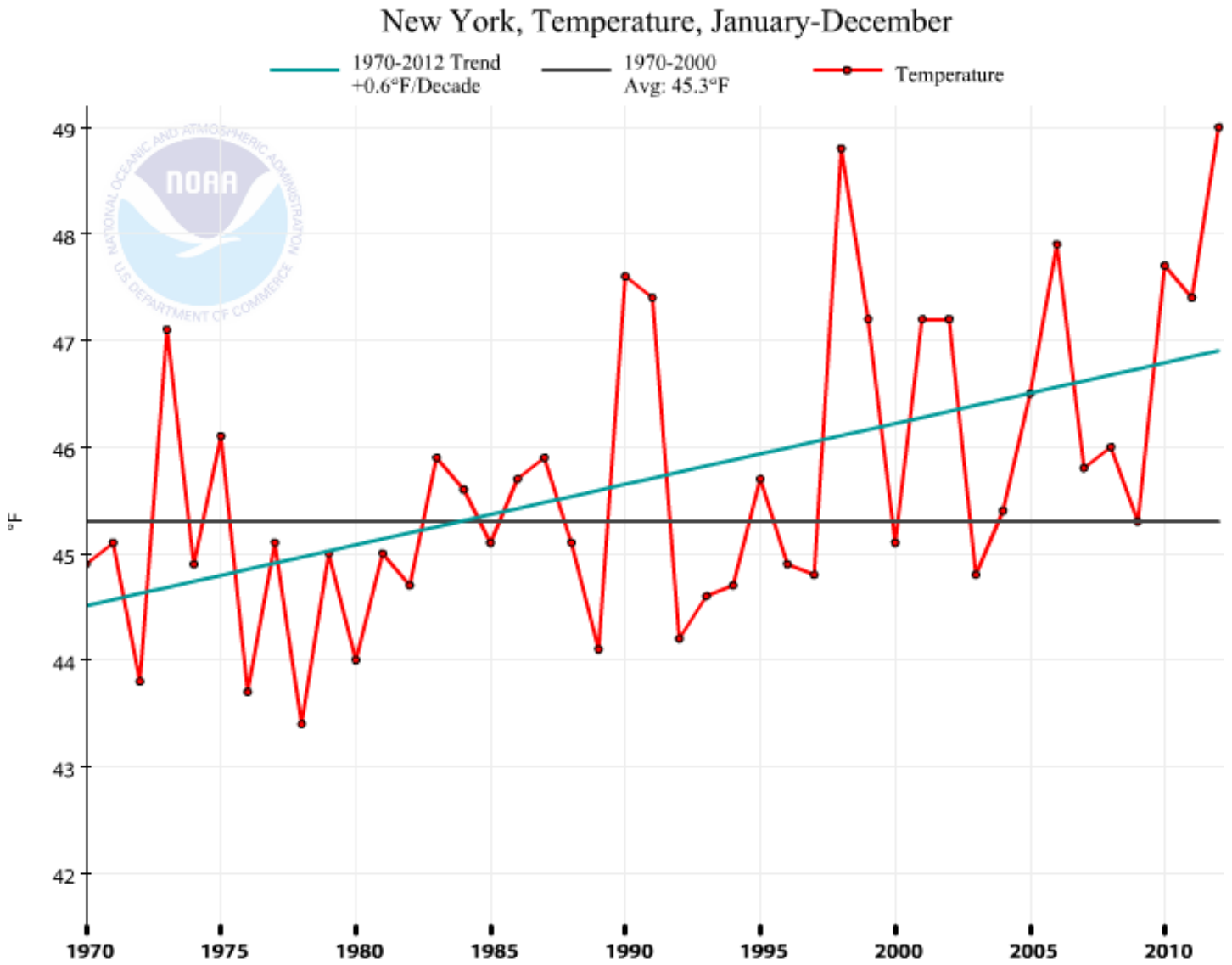


Collaborator: Rejman Family Farm

Collaborator: Shelmidine Family Farm

Heat Stress in New York State

- Dairy is a major industry in New York State
- $25 million/yr. cost of heat stress



Drawbacks to Current Practices

- Energy use

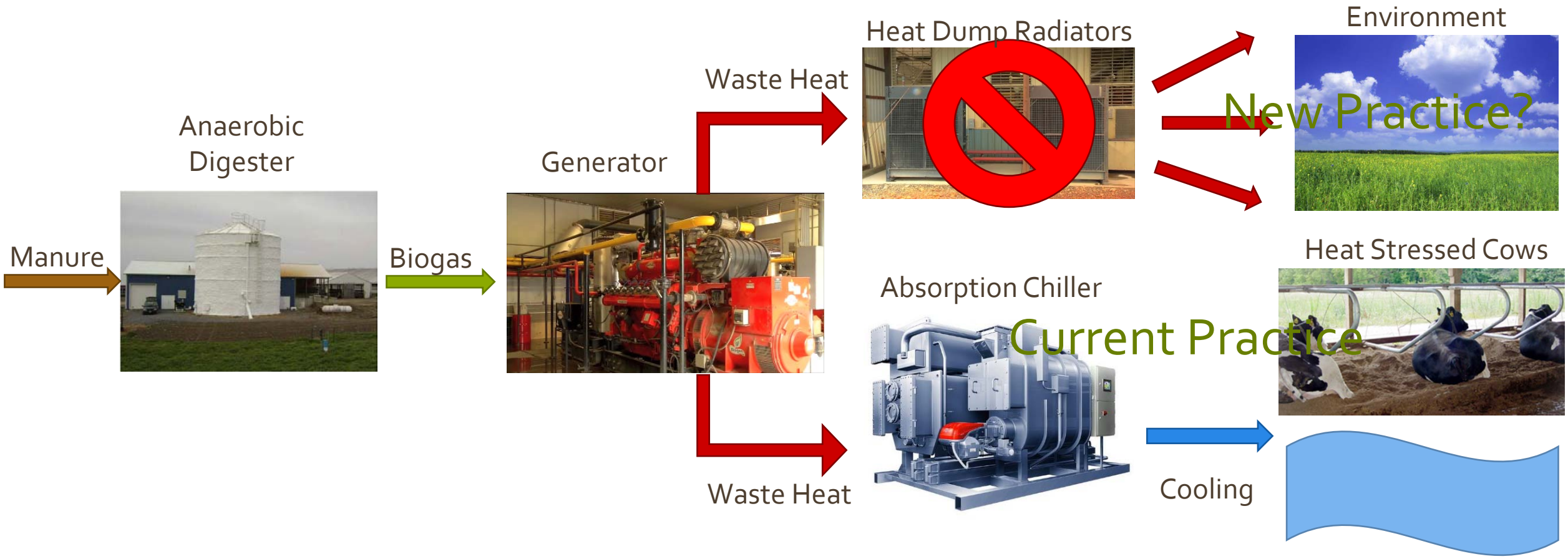
Picture retrieved October 27th, 2013 with permission from
http://www.powellbuttevet.com

Drawbacks to Current Practices

- Environmental effects
- Sanitation

Picture retrieved October 27th, 2013 with permission from http://www.ecorpco.com/images/Products/CattleMisting.jpg

The Basic Idea—Project Overview



Part I: Capturing Waste Heat from Biogas Generators

Large Scale:

- Sunny Side Farms, Scipio Center, NY
  - ~2700 cows
  - 1000 kW Generator Capacity

Small Scale:

- Sheland Farms, Adams, NY
  - ~600 cows
  - 125 kW Generator Capacity

CHP Engine at Sheland Farms

Digester at Sunny Side Farms

Digester at Sheland Farms

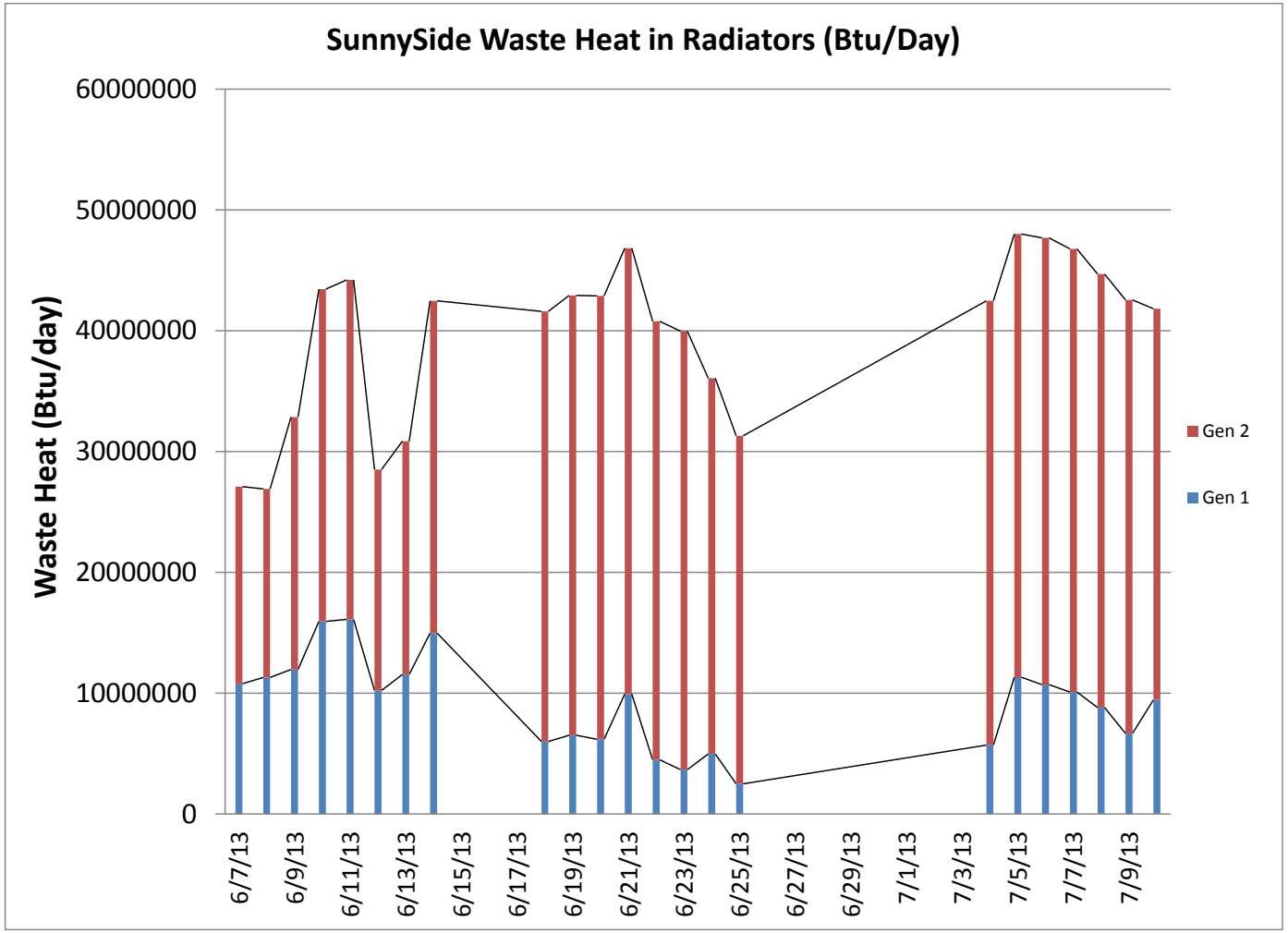
Part I: Capturing Waste Heat from Biogas Generators — Questions

- How Much Waste Heat is Available?
- How Efficient is an Absorption Chiller using CHP-DG Waste Heat?
- Is this Technology Worth it Economically? Environmentally?

Radiators to dispose of waste heat

Part I: Quantifying Waste Heat Available

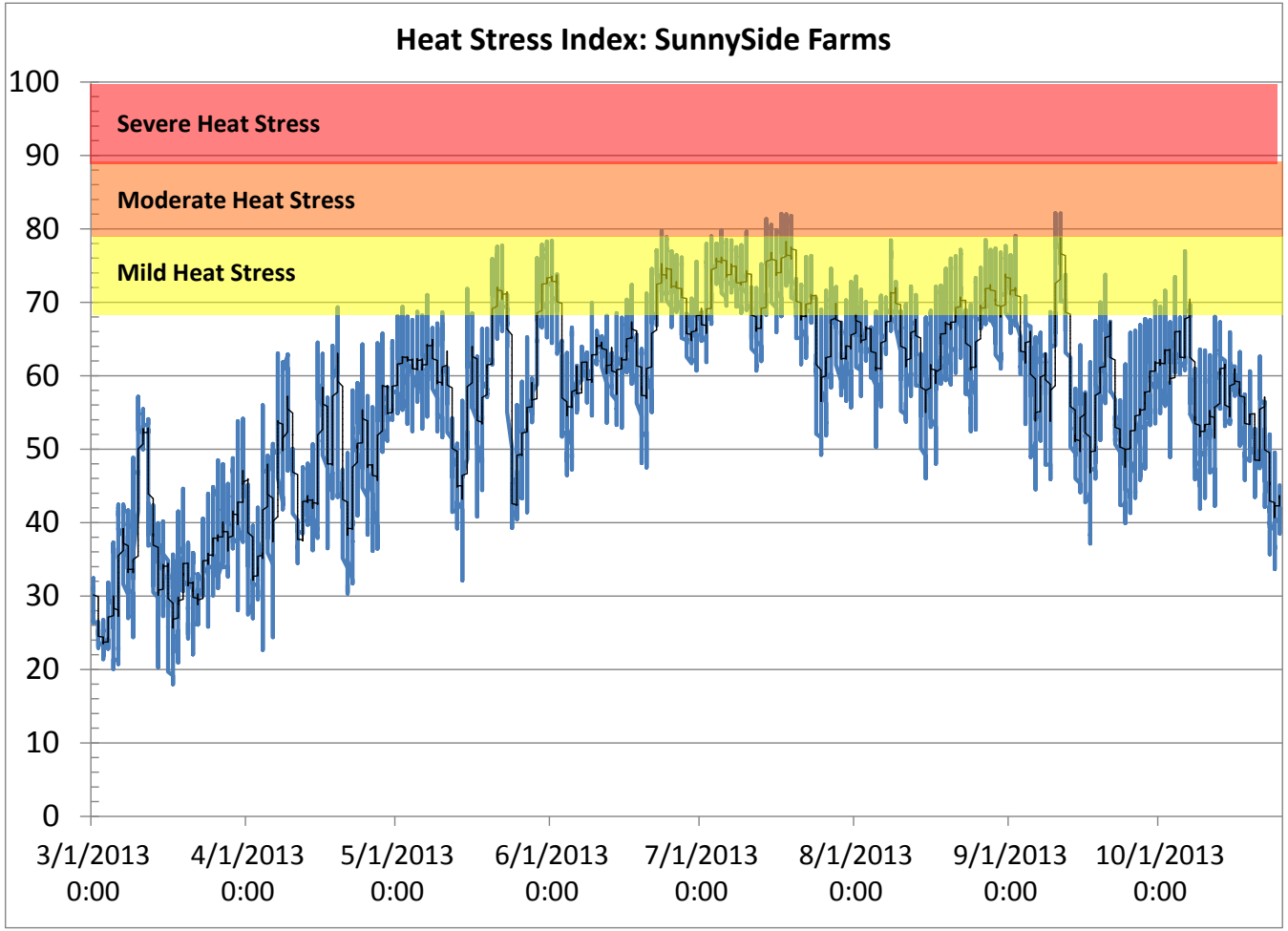
Sunny Side Farms: Preliminary Results



- Approx. 35 MBtus/Day during the Summer
- Additional heat available in the exhaust recuperator.

Integration of Waste Heat with Conductive Cooling

To what extent is heat stress occurring?



Matlab model showing 800+ hours of heat stress in summer 2013 at Sunny Side Farms

Part II: Conductively Cooling Dairy Cows with Waste Heat – Heat Stress Effects

Heat Stress is Costly!

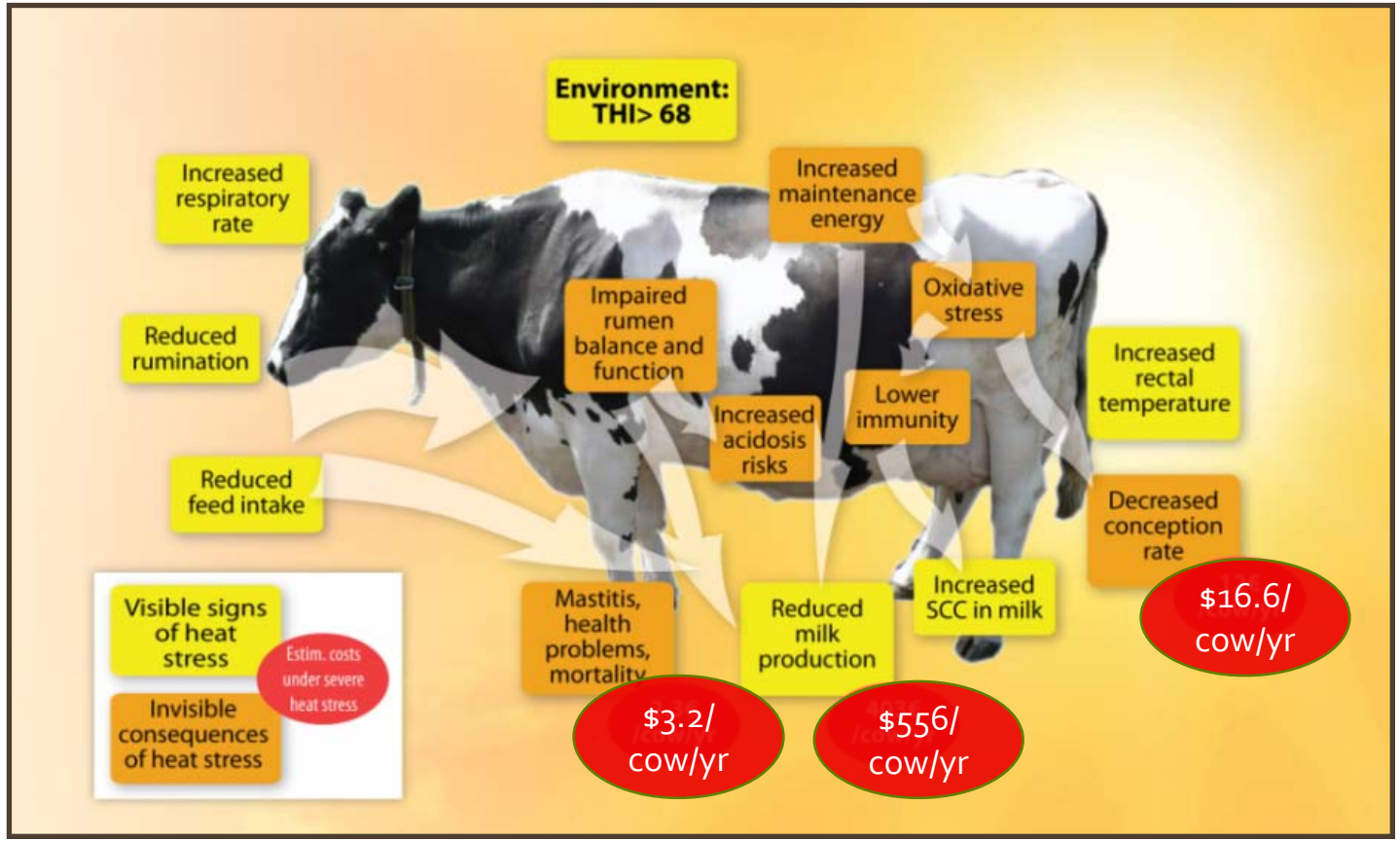


Image from www.lallemandanimalnutrition.com

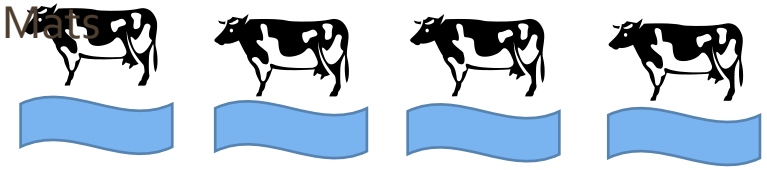
Part II: Conductive Cooling – Experimental Design

- 42 days (six weeks)
- 8 cows (4 experimental and 4 control)
  - Four had waterbeds that were cooled and four were not cooled
- Cows were kept in stalls on waterbeds during the daytime but put in individual pens at night
- Temperature of the stall room and waterbeds were controlled experimentally

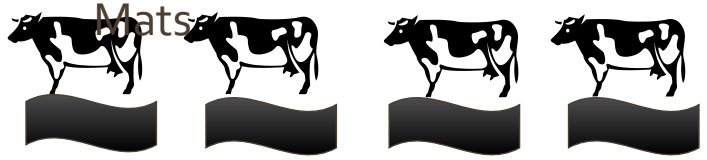
Cows resting on chilled beds

Temperature Controlled Room

Experimental Group—Conductive Cooling Mats



Control Group—Normal Mats



Chilled water reservoir

Part II: Conductive Cooling – Experimental Design

- 1st week: Baseline data with minimal heat stress and no conductive cooling.
- 2nd to 5th week: Four different combinations of heat stress levels and cooling levels
- 6th week: Repeated higher stress/higher cooling treatment but switched experimental and control cows.

	Higher Cooling (water temp 40 °F)	**Lower Cooling (water temp 50 °F)**
Higher Heat Stress	3rd week and 6th week	2nd week
Lower Heat Stress	4th week	5th week

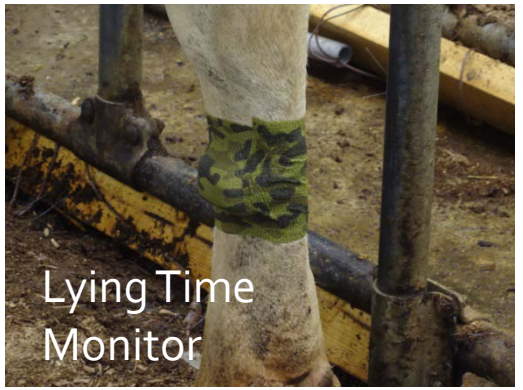
Part II: Conductive Cooling – Data Collection

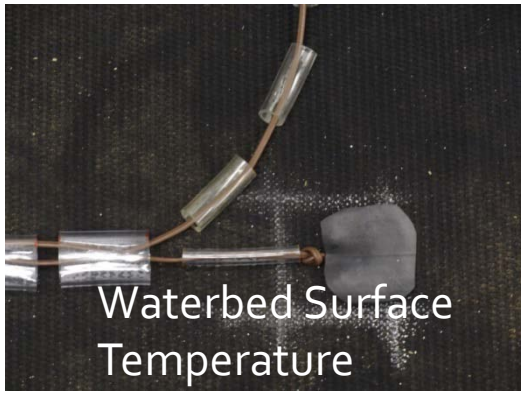
- Continuously:
  - Standing/lying behavior
  - Vaginal temperature
  - Thermocouples: input/output water temperatures, bed surface temperatures
  - Flow meters: water flow rate
- Five Times Daily:
  - Respiration rates
  - Skin temperatures in various locations
- Twice Daily:
  - Milk production
  - Rectal temperature
  - Sweating rate
  - Feed Intake

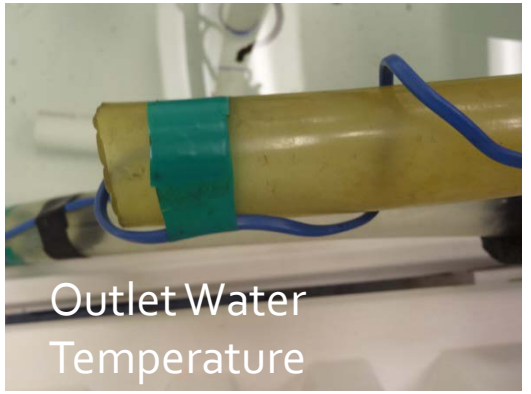

Milk Production


Feed Intake


Sweating Rate


Lying Time Monitor

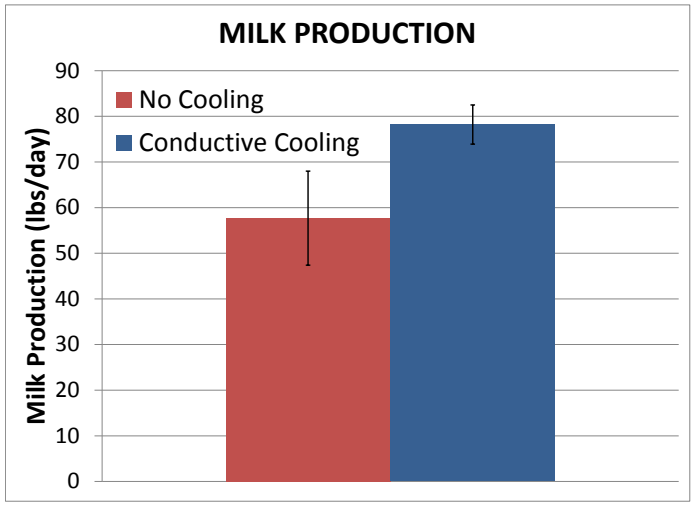

Waterbed Surface Temperature

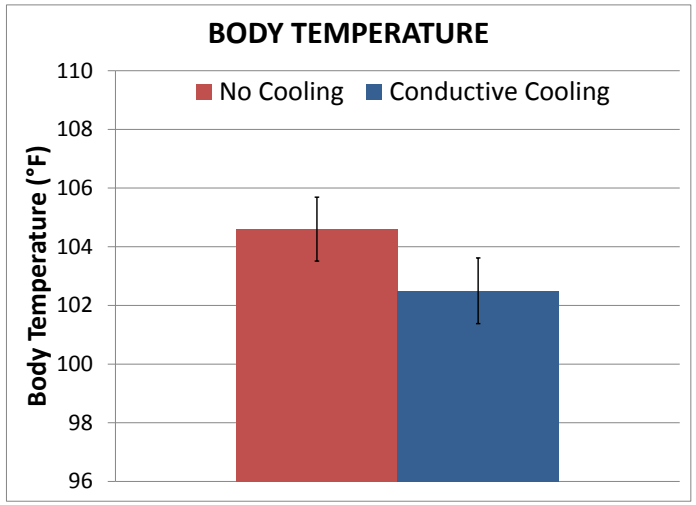

Outlet Water Temperature

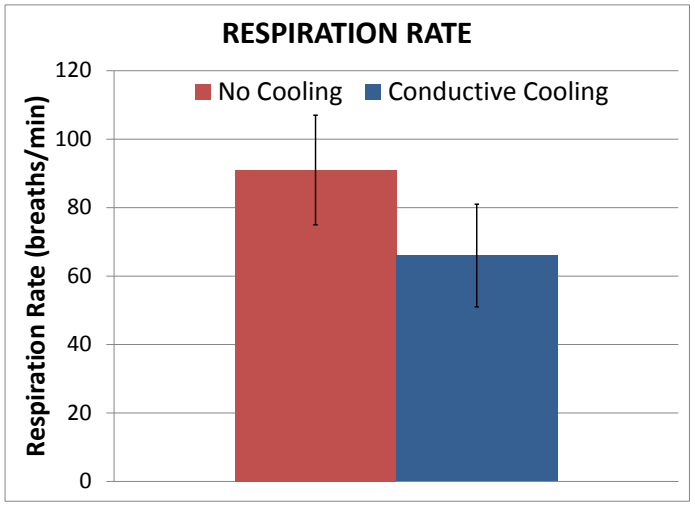
Part II: Conductive Cooling Impact

Best data from Week 3 (Higher heat stress, higher cooling)

~850 Watts (60% of total body heat) were removed while cow was lying down







Milk Production (lbs/day)

Control: 57.7 +/- 10.3

Experimental: 78.2 +/- 4.3

Average Body Temperature

Control: 104.6 +/- 1.09

Experimental: 102.5 +/- 1.12

Respiration Rates

Control cows: 91 +/- 16.4

Experimental cows: 66 +/- 14.7

Future Research Plans

- PART I: Quantify and capture waste heat from biogas generators
- PART II: Optimize conductive cooling of dairy cows with waste heat
- PART III: Communicate results to dairy farming community

THANK YOU!

Questions?