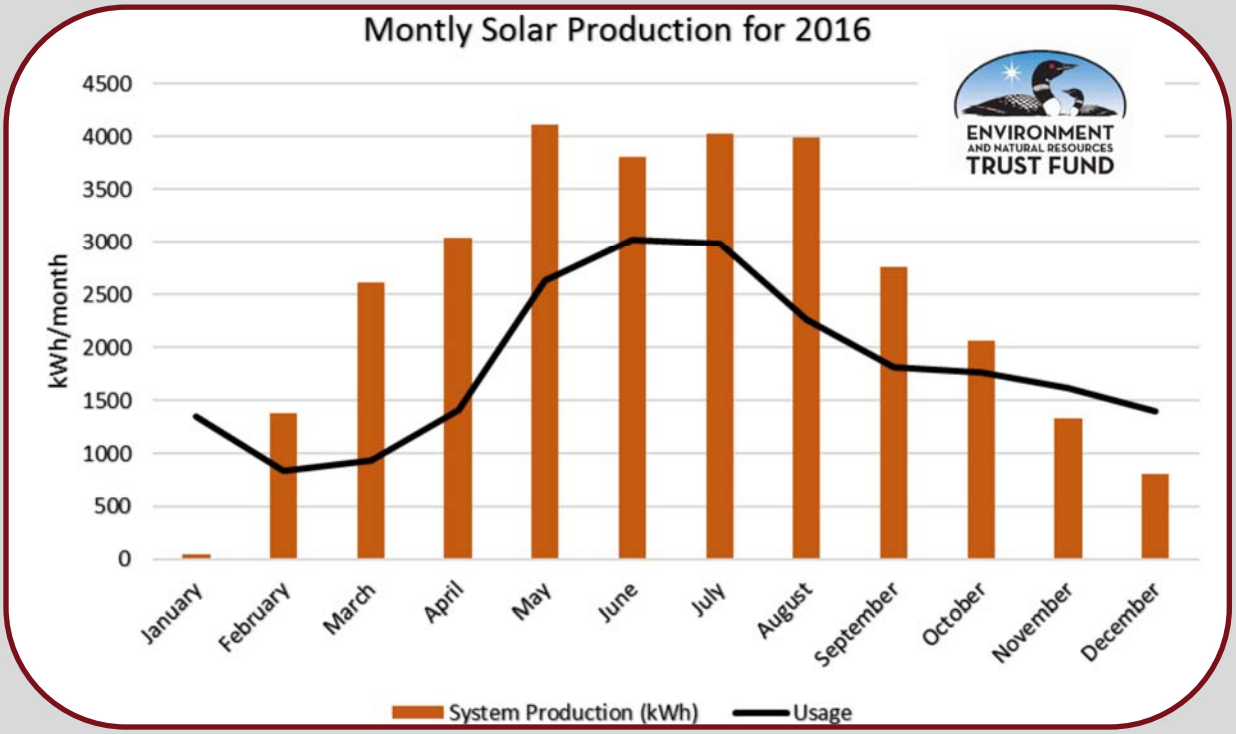
WCROC Swine Finishing Barn Solar PV System

Finishing Barn System Data

- **26.9 kW DC array installed in June 2015**
- **96 Heliene model 60M 280 modules**
  - **280 Watts each, efficiency = 17.4%**
- **3 SE9K inverters by SolarEdge Technologies, Inc.**
  - **SolarEdge power optimizer on each module**
- **3 phase fixed array mounted at 20° facing south**
- ***Funded by Minnesota Environment and Natural Re-***

Economics

- Annual production from system ⇨ in 2016 was ⇨ about 30,000 kWh worth $3,000 at 10¢/kWh
- Total system cost was $86,000($3.18/W) ⇨ 28.7 year simple pay back without incentives
- With 30% federal credit $60,200 ⇨ 20 year pay back
- Adding the Made in Minnesota incentive for 10 years @ 15¢/kWh ⇨ 11.5 year pay back



PVWatts is a free online estimating tool provided by the NREL, http://gisatnrel.nrel.gov/PVWatts_Viewer/index.html

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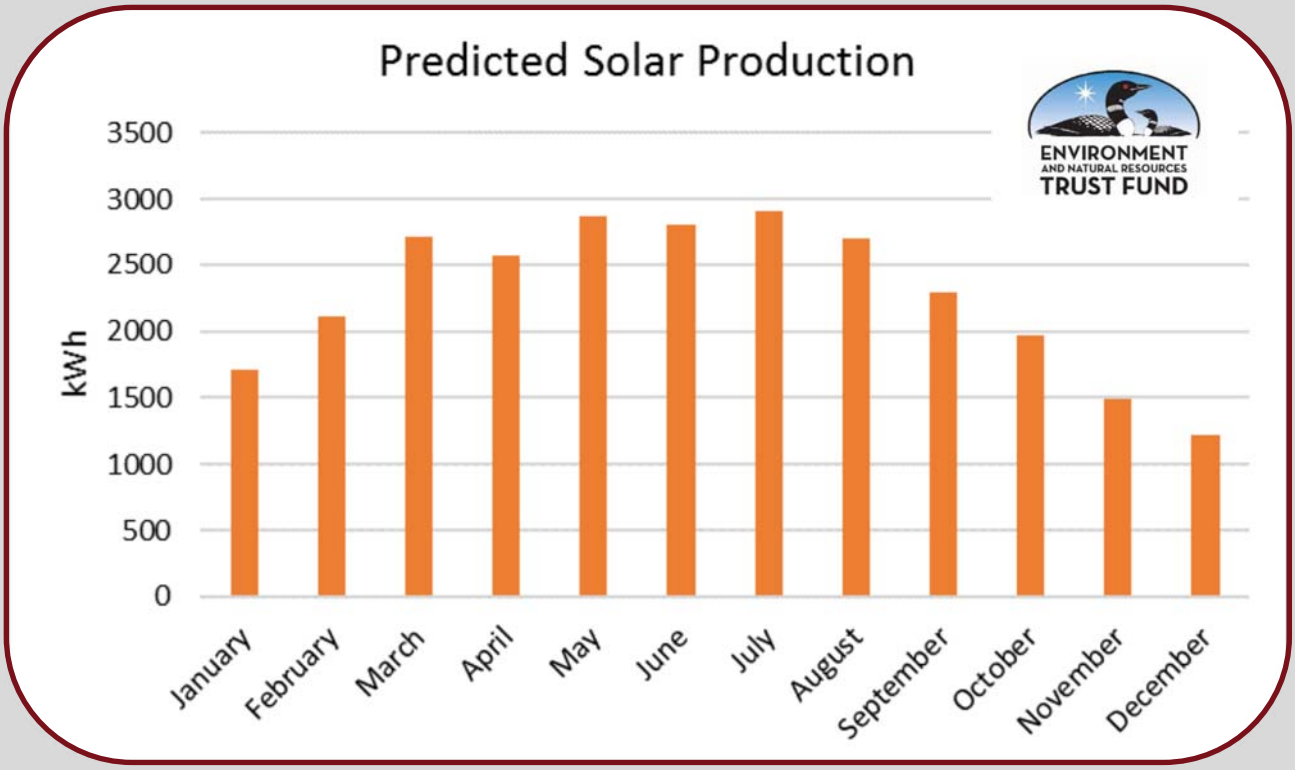
WCROC Swine Farrowing Barn Solar PV System

Farrowing Barn System Data

- **19.8 kW DC array installed in June 2017**
- **62 Heliene model 72M 320 modules**
- **2 SE9K inverters by SolarEdge Technologies, Inc.**
  - **SolarEdge power optimizer on each module**
- **3 phase ground mounted array mounted at 30°**
- ***Funded by Minnesota Environment and Natural Re-***

Economics

- Annual production from system is predicted to be about 27,393 kWh worth $2739 at 10¢/kWh
- Total system cost was $59,000($2.98/W) 21.5 ⇨ year simple pay back without incentives
- With 30% federal credit $41,300 ⇨ 15 year pay back
- Adding the Made in Minnesota incentive for 10 years @ 10¢/kWh ⇨ 10.6 year pay back



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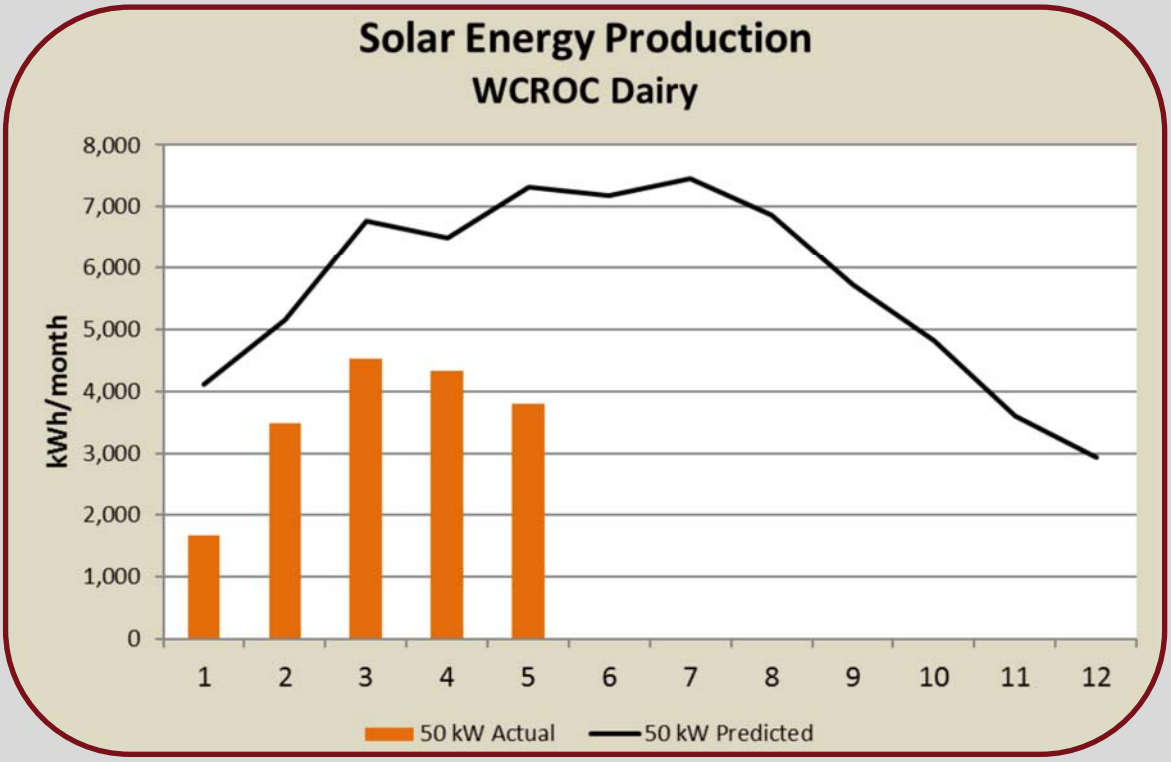
WCROC Dairy Barn Solar Energy

System Data

- **50 kW DC array installed on October 4, 2016**
  - **- TenKSolar Reflect XTG array**
  - **- 120 model 410W modules in a XT26 system**
  - **- 4 tenKsolar 10.8 kW RAIS inverter bus**
    - **-each with 18 LEED 600 W micro inverters**

Expected Performance/Economics

- Annual production from PV system projected to be 70,000 kWh worth $7,000 at 10¢/kWh
- Total solar system cost $138,000 ($2.77/W) ⇨ 19.7 year simple pay back without incentives
- Adding the Made in Minnesota incentive for 10 years @ 13¢/kWh ⇨ 8.6 year pay back



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WCROC Dairy Barn Wind Energy

System Data

-Two 10 kW wind turbines installed on June 6, 2017

- Turbine model VT10 from Ventera

- 3 blade, downwind turbine, 270 peak RPM

- Cut-in speed: 6 mph, survival wind speed: 130 mph

- Bergey 10.4 kW inverter

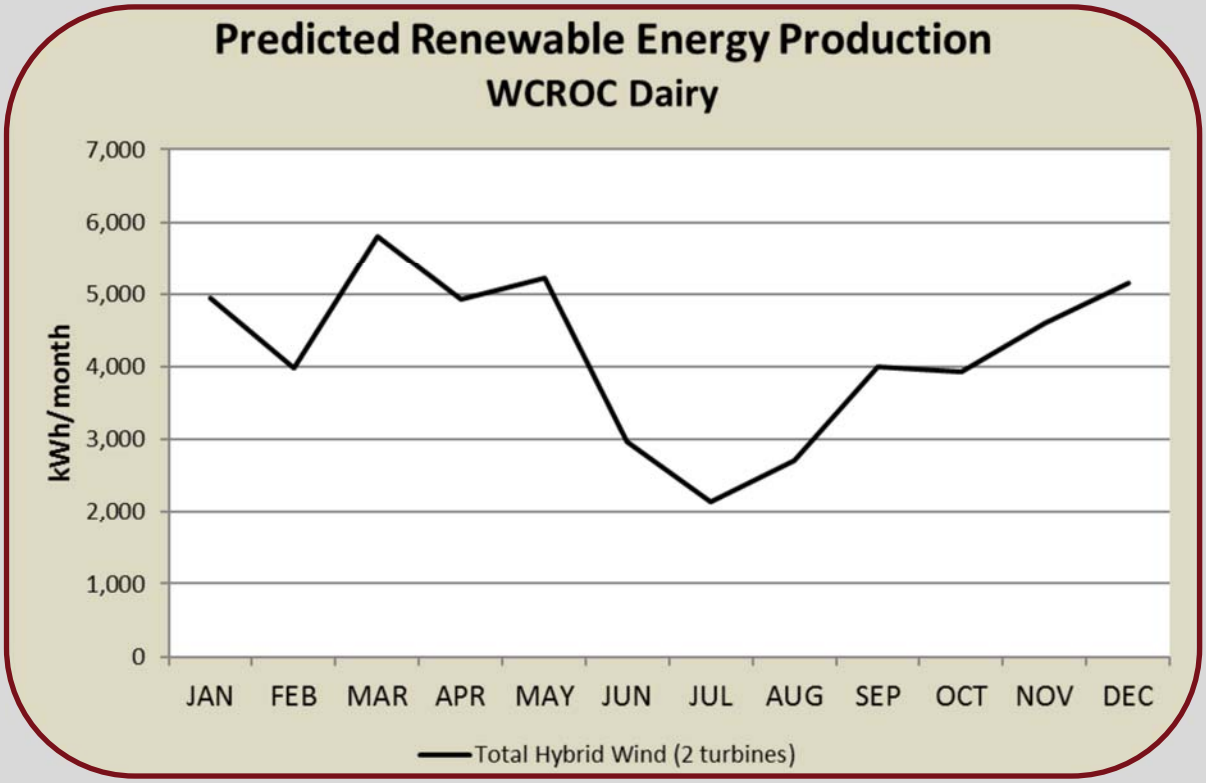
- ARE 70 foot fold-down tower

- 4 kW pole mount solar PV system on one turbine

- Base diameter: 15 ft

Expected Performance/Economics

- Annual predicted generation for each turbine is 22,400 kWh worth $2240 at 10¢/kWh
- Total wind system cost was $78,400 per tower ⇨ 35 year simple pay back without incentives
- With 30% federal credit $54,880 ⇨ 24.5 year pay back



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Electric and Thermal Energy Strategies for Minnesota Swine Farms:

Finance and Economics

Presented by:
Michael Reese, Renewable Energy Director
West Central Research and Outreach Center

Presented at:
2017 MN Pork Congress, Minneapolis
January 18, 2017

Why renewable energy and energy efficiency for farms?

1. **The technology has improved** (less expensive, more reliable, produce more, easier / safer to interconnect and maintain).
2. **The systems can be practical and may provide a reasonable financial return.**
3. **State and Federal incentives are available to farmers.**
4. **Ag commodity processors and retailers may place a premium (or mandate) low carbon footprint products.**
5. **Renewable energy fits the farming philosophy** (Land-based, creates independence, may improve efficiency, production of a commodity).

University of Minnesota West Central Research and Outreach Center

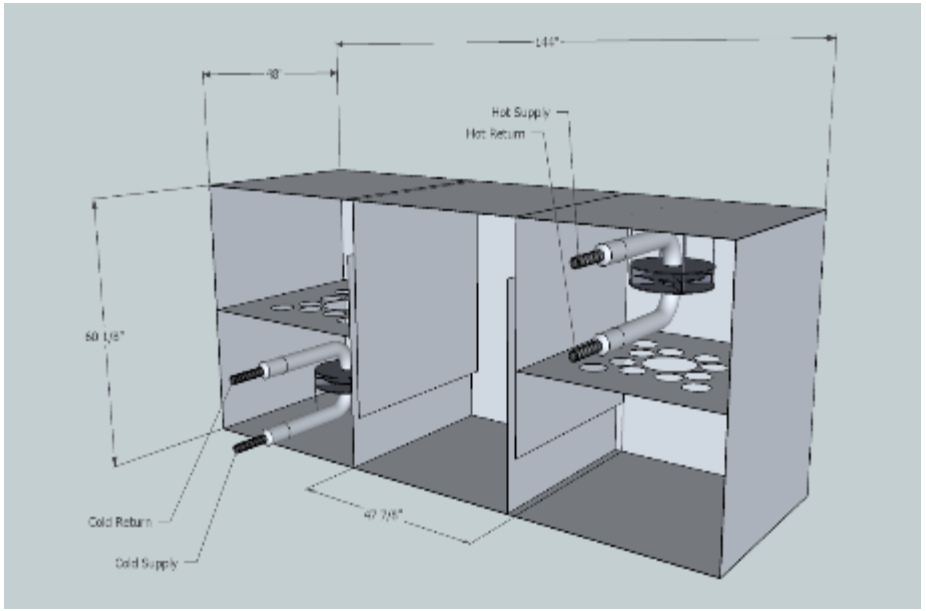
WCROC 27 kW Solar PV System on Swine Finishing Facility

WCROC 50 kW Solar PV System (TenKSolar Ground Mount)

WCROC Solar Thermal Systems

Evacuated Tube Collector

Absorption Chiller


144"
48"
Hot Supply
Hot Return
60 1/8"
47 7/8"
Cold Return
Cold Supply


Flat Plate Collector

WCROC 10 kW Ventera Wind Turbines

Installation in Winter 2017

SPECIFICATIONS:

Wind Turbine—Model VT10—240
10kW at 29mph-13m/s
Cut—In Wind Speed: 6mph-2.7m/s,
Survival Wind Speed: 130 mph-58 m/s
Total Weight of turbine and blades:
580lbs – 263kg
3 blade, downwind,
Diameter: 22 feet-6.7m
Swept Area: 380 SF/35.25 SM
RPM: 270 peak,
Blade: Glass fiber engineered plastic,
injection molded
Generator Rating: 15kva 240vac
at 250rpm, 3 phase

In general, the best current opportunities for swine producers:

1. Energy Efficiency Improvements

2. Solar Photovoltaic (Solar Electric)

-Other opportunities possible on case-by-case basis.

Potential for Energy Efficiency Improvements at WCROC Swine Facilities

Energy Conservation Measure	Barn Applied to	Investment Costs	Electricity + Propane	
			Payback Period (years)	Annual Return on Investment
Night Temperature Setback	N	$ 500.00	**0.2**	**458.8%**
Variable Speed Fans	N	$ 1,000.00	**3.4**	**25.7%**
Earth Tube	Fa	$ 10,000.00	**3.9**	**21.8%**
Heat Lamp Controllers	Fa	$ 3,000.00	**6.1**	**17.1%**
LED Lighting	N	$ 12,000.00	**17.0**	**1.9%**
Geothermal Heat Exchange	Fa	$ 175,000.00	**27.7**	**-0.4%**
Traditional Air Conditioning	Fi	$ 80,000.00	**-**	**-4.01%**
Solar Chimney	N	$ 6,000.00	**-**	**-7.1%**

AKF Group LLC, 2016 (Study commissioned by WCROC)

Why Solar PV?

1. Capital costs have decreased significantly in last decade
2. Low Operation, maintenance, and repair – Increased longevity and durability
3. Technology has improved
4. Generation best matches load or highest generation during peak loads
5. Grants and incentives available to farmers and other businesses
6. Large southern facing roofs on swine barns MAY BE a benefit

***Solar PV will NOT be a good fit for all swine farms!**

Grants and Incentives: (Partial List)

1. **Property Assessed Clean Energy (PACE)**
   -5 to 10 year loan paid back through real estate tax
2. **USDA Rural Energy for America Program**
   -Grant for up to 25% of capital cost - Loan program available
   -Competitive application process – low success rates
3. **MN AGRI Livestock Facility Loan Program**
   -Grant for up to 5% of an energy system tied to livestock facilities - $50k max ($25k /year)
   -About 60% of qualified applicants are funded

Grants and Incentives: (Partial List)

4. Utility Incentives:

Made-in-Minnesota Solar Program – Provides payments between $0.10-$0.13 / kWh for 10 years for commercial systems below 40 kW nameplate in an IOU service territory

Xcel Solar Rewards – Payments for $0.08 . kWh for 10 years for residential or business systems less than 20 kW.

Net Metering – For systems less than 40 kW in nameplate capacity.

-Check with your utility for other potential incentives such as **CIP payments**.

5. Federal Investment Tax Credit (ITC)

-30% ITC through December 31, 2019 – then rate decreases

-Capital costs x .3

6. Modified Accelerated Cost Recovery (MACRS) Depreciation

-MACRS Depreciation for Years 0-5

-85% of solar PV capital costs (due to ITC benefit)

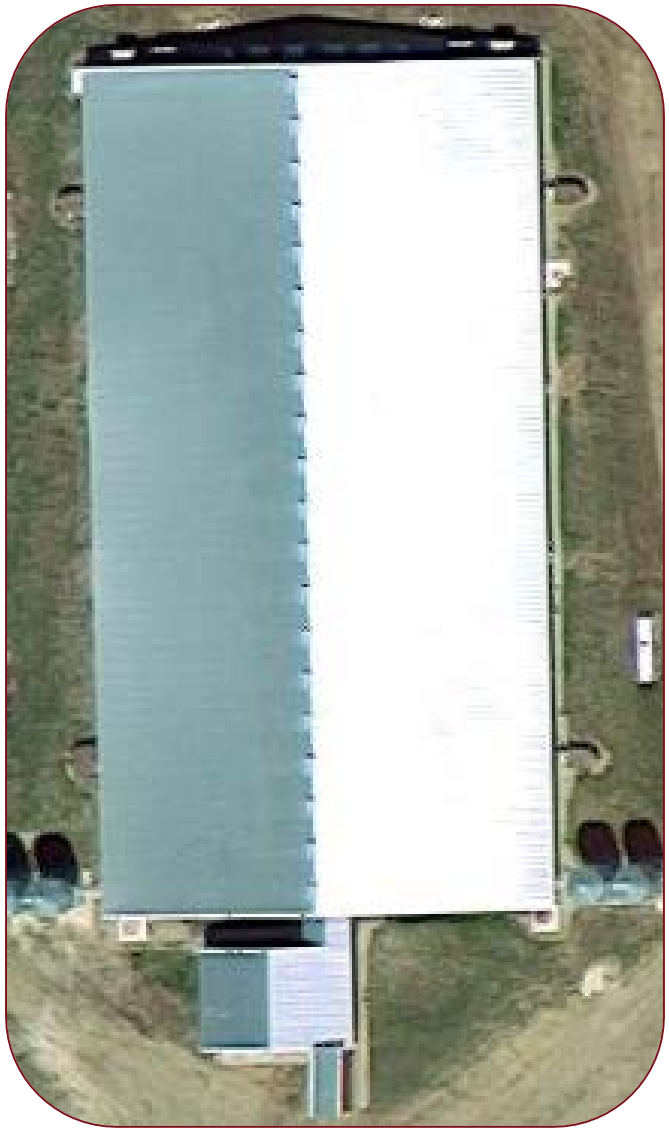
-Depends on federal tax rate for individual (Eg. 28% or 38%)

Case Study: 2400 Head Swine Finishing Unit

Owner is participating in energy audit study and requested solar PV analysis

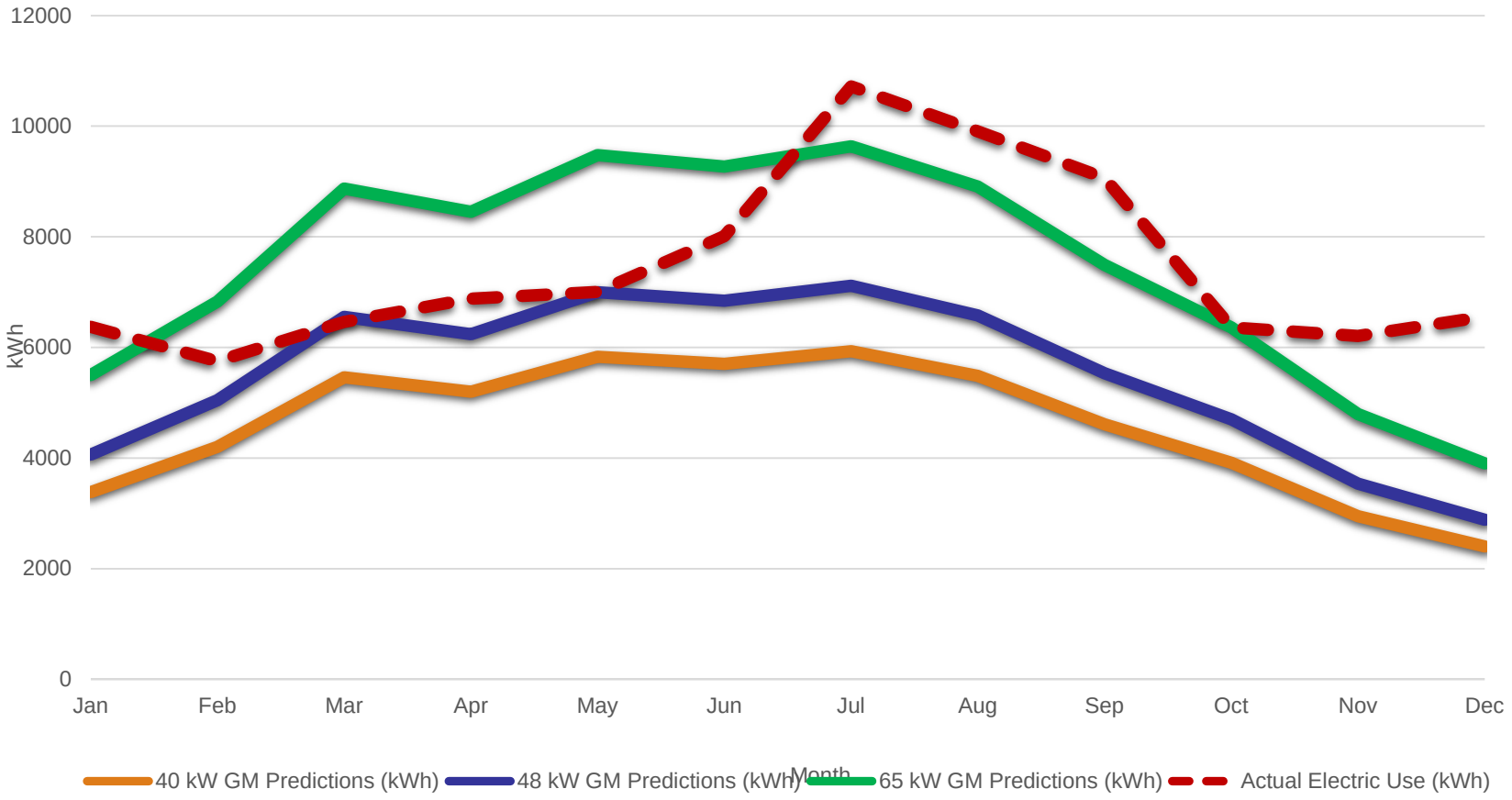
Specifications:

- 2400 head divided into two 1200 head rooms
- 100 feet x 200 feet (20,000 square feet)
- Building is oriented north and south
- Tunnel ventilated
- 5,800 hogs per year
- 89,287 kWh total electrical energy use per year
- 7,441 kWh average electrical energy use per month
- 10,720 kWh per month maximum (July)
- 5,749 kWh per month minimum (Feb)



Case Study: 2400 Head Swine Finishing Unit

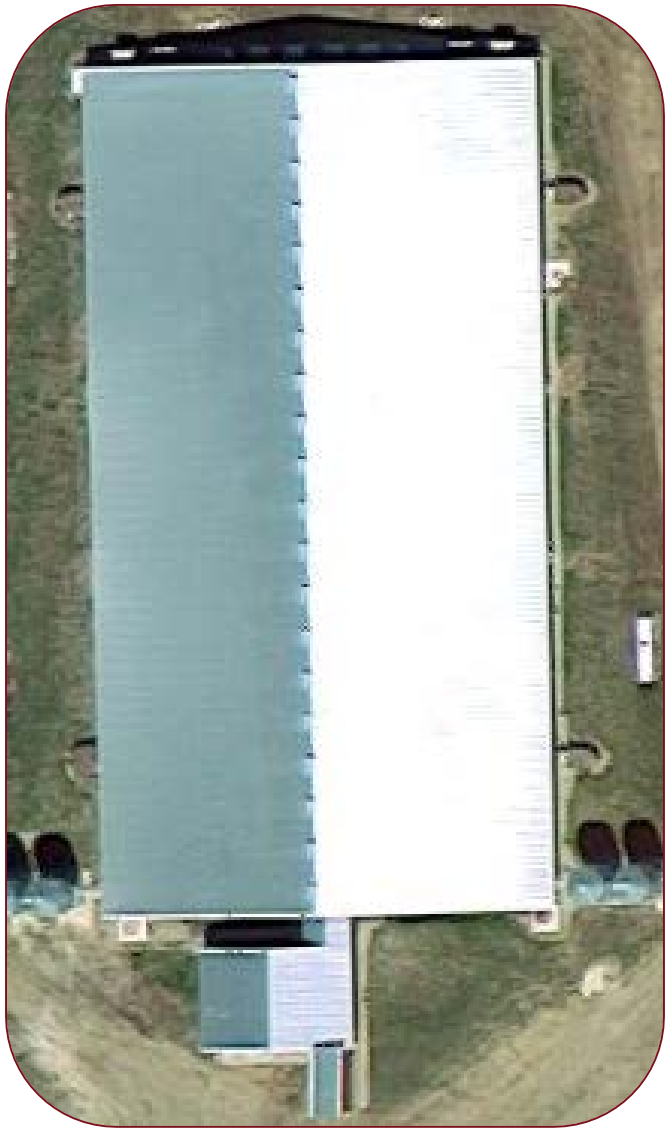
System Sizing - Load vs Projected Generation



Case Study: Financial Pro Forma for Solar PV

Assumptions:

- Capital cost equals $3 /watt of nameplate
- Production estimated by multiplying nameplate capacity (in watts) by 1.4
- $0.10 / kWh in Year 1 (3% escalator)
- 25-year life expectancy of solar system
- 25-year warranty on panels and brackets
- 20-year extended warranty on inverter(s)
- 1-year warranty on install
- 28% federal tax bracket
- 4% Interest – debt or owner equity
- 10-year debt
- Assumed could make full use of tax benefits
- Module degradation rate of 0.5% per year
- 3% inflation rate per year on electric rate and operating expenses



Case Study: Financial Pro Forma for Solar PV

Three sizes evaluated:

<u>20 kW nameplate with:</u>

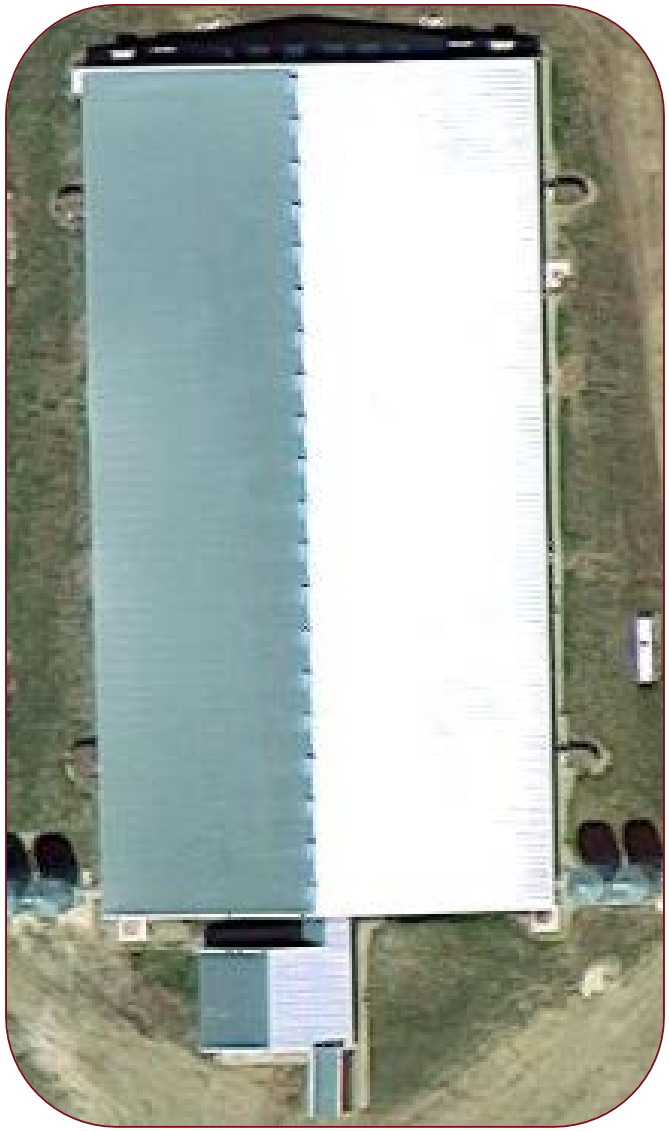
1. Tax Benefits Only
2. USDA REAP and MN AGRI Livestock Grant
3. Xcel Solar Rewards ($0.08/kWh for 10 years)
4. Xcel Made-in-Minnesota
5. All Benefits (5a – Solar Rewards, 5b – MiM)

<u>40 kW nameplate with:</u>

1. Tax Benefits Only
2. USDA REAP and MN AGRI Livestock Grant
3. Made-in-Minnesota Solar Incentive ($0.11/kWh for 10 years)
4. All Above Benefits

<u>65 kW nameplate with:</u>

1. Tax Benefits Only
2. USDA REAP and MN AGRI Livestock Grant



Case Study: Financial Pro Forma for Solar PV

YEAR	0	1	2	3	4	5	6
REVENUES							
Net kWh/yr		55073	54798	54524	54251	53980	53710
PPA Rate ($/kWh)		0.1000	0.1030	0.1061	0.1093	0.1126	0.1159
Utility Incentive (Xcel MiM)		0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
Total Savings from Electric Bill		$11,565	$11,672	$11,782	$11,896	$12,013	$12,135
EXPENSES							
Operation & Mgt.		$250	$256	$263	$269	$276	$283
Financial Management		$250	$256	$263	$269	$276	$283
Service, Warranty, & Repair		$800	$800	$800	$800	$800	$800
Electrical Usage		$0	$0	$0	$0	$0	$0
Professional Services		$250	$258	$265	$273	$281	$290
Real Estate Tax Increase		$0	$0	$0	$0	$0	$0
Land Lease		$0	$0	$0	$0	$0	$0
Insurance		$360	$371	$382	$393	$405	$417
Demand and Other Utilty Charges		$116	$117	$118	$119	$120	$121
Total Expenses		$2,026	$2,058	$2,090	$2,124	$2,159	$2,194
Operating Cash		$9,540	$9,614	$9,692	$9,772	$9,855	$9,940
Debt Principle		$84,000	$77,004	$69,727	$62,160	$54,290	$46,105
Debt Service		$10,356	$10,356	$10,356	$10,356	$10,356	$10,356
Cash Flow (Op. Cash minus Debt Serv.)		-$817	-$742	-$665	-$585	-$502	-$416
GROSS INCOME							
Revenue		$11,565	$11,672	$11,782	$11,896	$12,013	$12,135
Minus Operating Expenses		$2,026	$2,058	$2,090	$2,124	$2,159	$2,194
Minus Interest (4 %)		$3,360	$3,080	$2,789	$2,486	$2,172	$1,844
Plus Depreciation @ 28% Tax Rate		$6,720	$10,752	$6,451	$3,871	$3,871	$1,935
Plus Investment Tax Credit		$36,000					
Net Taxable Income (Loss)		$48,900	$17,286	$13,354	$11,156	$11,554	$10,031
Cummalative Cash Flow with Tax Benefits	($84,000)	($35,100)	($17,814)	($4,460)	$6,696	$18,250	$28,281
ASSUMPTIONS		**40 KW**					
Project Cost		$120,000					
Debt		$84,000					
Equity							
REAP Grant		$30,000					
MN AGRI Livestock Grant		$6,000					
ACRS Depreciation-5 years @ 28 % Tax Bracket							

Case Study: Financial Pro Forma for Solar PV

Size (Name-plate KW)	Capital Costs ($)	1st Year Production (KWh)	1st Year Revenue ($)	ITC	MACRS Depre-ciation	Grants	Xcel Solar Rewards	MiM	Simple Payback (Years)
20 kW	$60,000	28,000	$2,800	●	●				18
20 kW	$42,000	28,000	$2,800	●	●	●			9
20 kW	$60,000	28,000	$5,040	●	●		●		10
20 kW	$60,000	28,000	$5,880	●	●			●	**8**
20 kW	$60,000	28,000	$5,040	●	●	●	●		**4**
20 kW	$60,000	28,000	$5,880	●	●	●		●	**3.5**
40 kW	$120,000	55,073	$5,507	●	●				18
40 kW	$84,000	55,073	$5,507	●	●	●			**9**
40 kW	$120,000	55,073	$11,565	●	●			●	**8**
40 kW	$84,000	55,073	$11,565	●	●	●		●	**4**
65 kW	$195,000	85,028	$8,503	●	●				18
65 kW	$136,500	85,028	$8,503	●	●	●			**9**

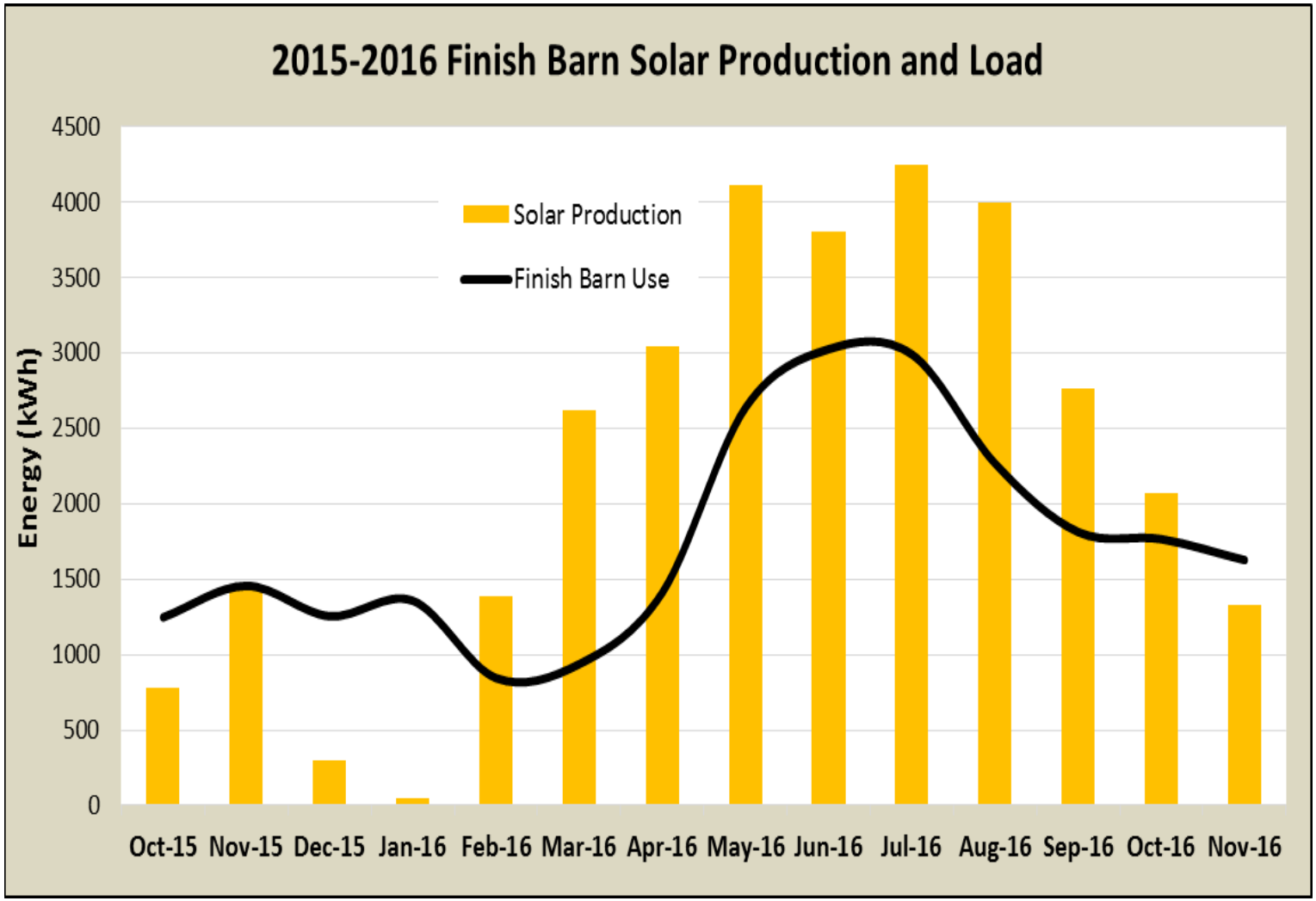
Case Study: Financial Pro Forma for Solar PV

Size (Name-plate KW)	Capital Costs ($)	1st Year Production (KWh)	1st Year Revenue ($)	ITC	MACRS Depre-ciation	Grants	Xcel Solar Rewards	MiM	Simple Payback (Years)
20 kW	$60,000	28,000	$2,800	●	●				18
20 kW	$42,000	28,000	$2,800	●	●	●			9
20 kW	$60,000	28,000	$5,040	●	●		●		10
20 kW	$60,000	28,000	$5,880	●	●			●	**8**
20 kW	$60,000	28,000	$5,040	●	●	●	●		**4**
20 kW	$60,000	28,000	$5,880	●	●	●		●	**3.5**
40 kW	$120,000	55,073	$5,507	●	●				18
40 kW	$84,000	55,073	$5,507	●	●	●			**9**
40 kW	$120,000	55,073	$11,565	●	●			●	**8**
40 kW	$84,000	55,073	$11,565	●	●	●		●	**4**
65 kW	$195,000	85,028	$8,503	●	●				18
65 kW	$136,500	85,028	$8,503	●	●	●			**9**

Other Considerations:

1. Capital Costs (Is it turn key? Permits, etc.)
2. Warranties
3. Work with a reputable contractor
4. Utility service territory – Demand Charges
5. Can you fully utilize tax benefits?
6. Lower GHGs / Public Perception
7. Roof versus Ground Mount
   - -Space available / suitability for solar panels
   - -Snow – Cover panels, shift load / roof collapse
   - -Age of roof /building
   - -Obstacle for vehicles, snow blowing, etc
   - -Cleaning
   - -Multi-benefit - Shade / shelter

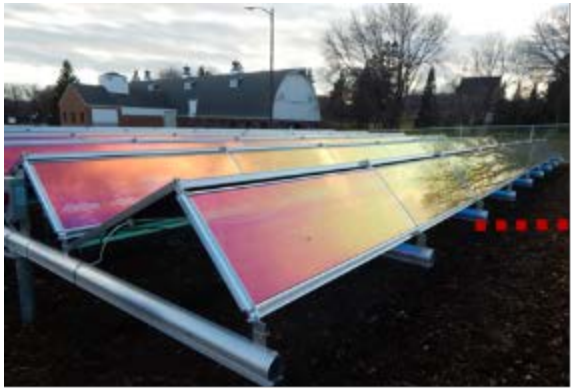
WCROC 27 kW Solar PV System on Swine Finishing Facility



WCROC 27 kW Solar PV System on Swine Finishing Facility

December 22, 2016

Multi-benefits



Take Home Message:

- ✓ Energy efficiency upgrades can have a short-term return-on-investment
- ✓ A solar PV system may be financially viable for your swine farm
- ✓ State, federal, and utility grants and incentives are available
- ✓ Reputable contractors are available to remove complexities
- ✓ U of MN energy research is helping to lower costs and serve as an unbiased source of information

2017 Midwest Farm Energy Conference,

June 13 -14, 2017

West Central Research & Outreach Center - Morris

- Excellent speakers including:

  Mr. Mark Greenwood, AgStar Financial

  Dr. Brian Buhr, Dean – U of MN College of Food, Agricultural, and Natural Resource Sciences

  Dr. Barry Dunn, President, South Dakota State Univ.

  Dr. Jay Harmon, Iowa State

- Tours of innovative, farm-scale renewable energy systems

- For more information or to register, go to: http://wcroc.cfans.umn.edu/mfec-registration

Renewable Energy

Staff:

1. **Rob Gardner**, Assistant Professor
2. **Joel Tallaksen**, Scientist
3. **Eric Buchanan**, Scientist
4. **Cory Marquart**, Assistant Scientist
5. **Kirsten Sharpe**, Junior Scientist
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MN Environmental and Natural Resources Trust Fund through LCCMR
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U of MN IREE
U of MN Rapid Agriculture Response Fund
State of Minnesota
Xcel RDF
And the Renewable Energy Team!

Reducing Fossil Fuel Use in Swine - One Piece at a Time

Lee J. Johnston, Professor

University of Minnesota

West Central Research and Outreach Ctr.

NPB Swine Educators Conference
St. Louis, MO
September 27, 2016

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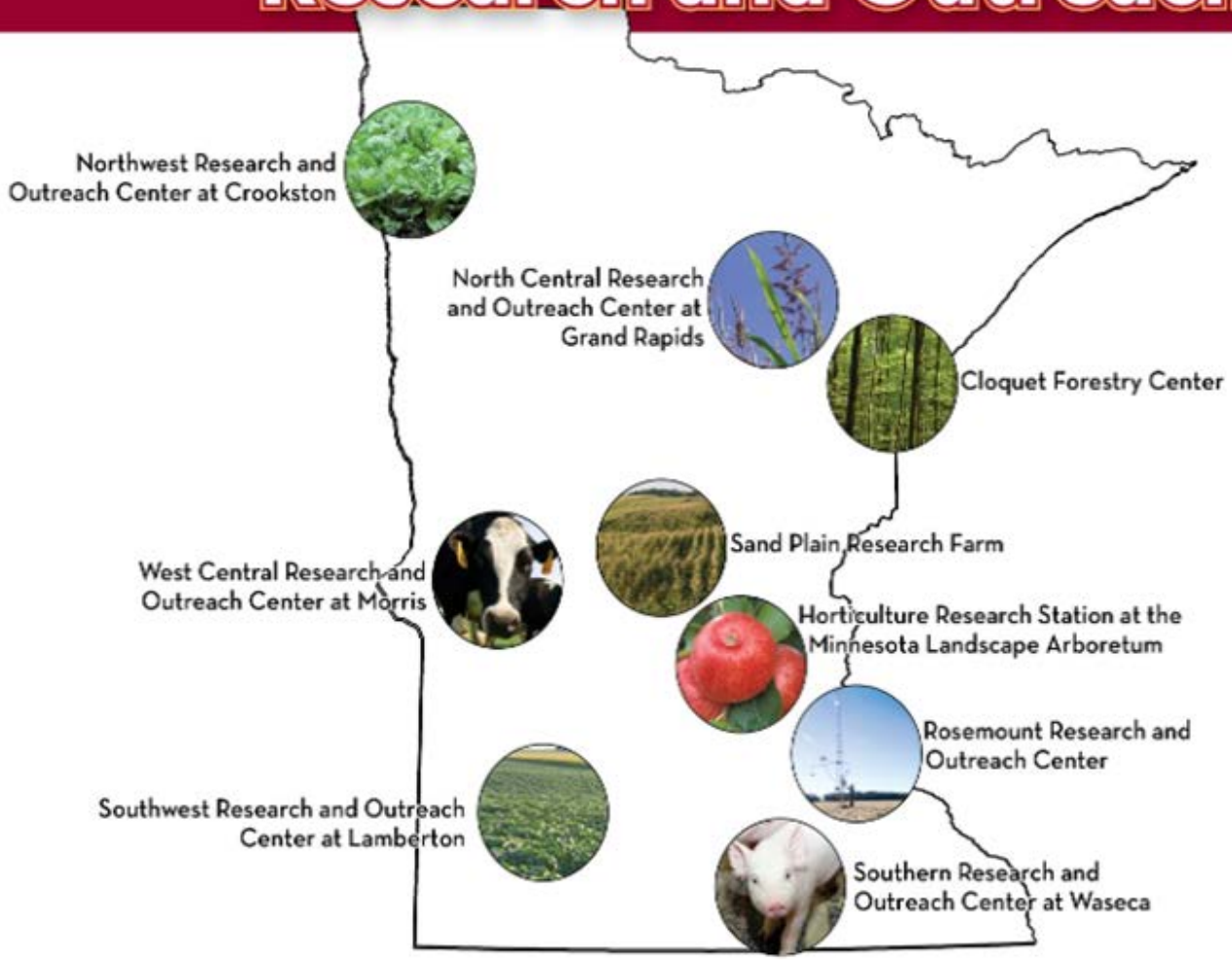
Research and Outreach



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Greening of Ag Project

- Consumer supply chains are asking for reduced environmental impacts
- Modern production agriculture uses significant fossil fuel resources
  - Fertilizer, crop protection products, diesel, electricity, heating fuels
- Is there a way to reduce the use of these fuels without compromising or maybe improving production?

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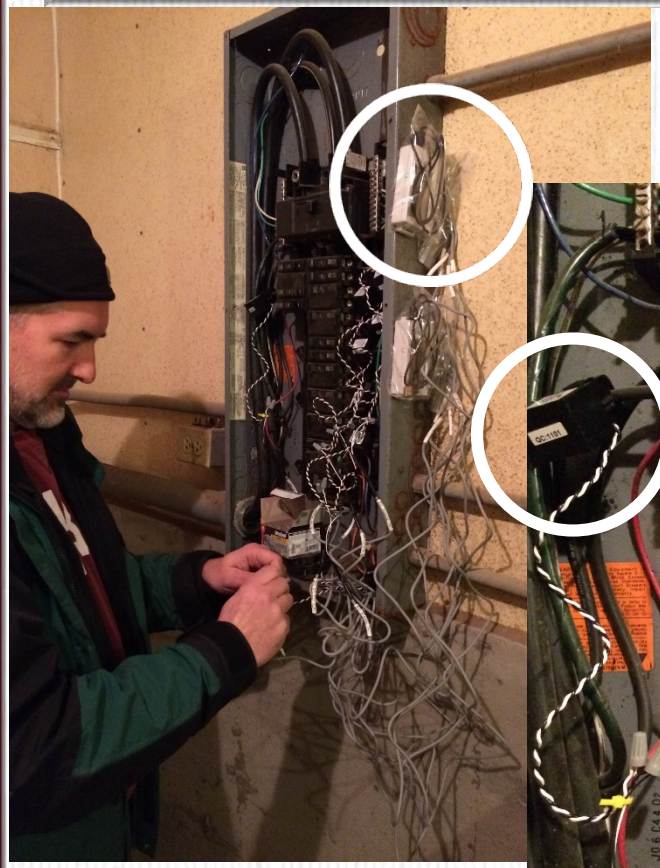
Greening of Ag Project

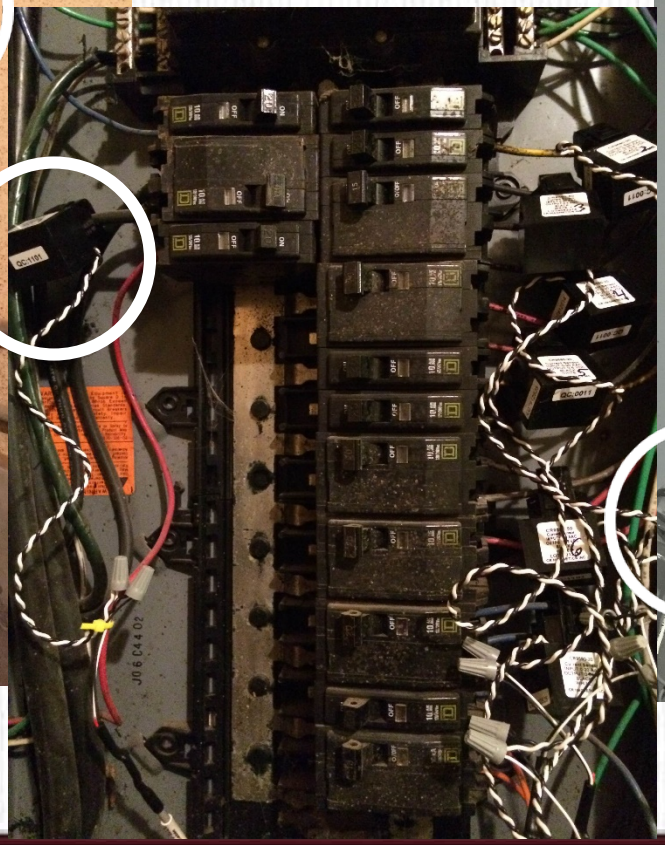
- Currently, three pronged
  - Dairy production
  - Crops production
  - Swine production
- Upcoming aspects
  - Algae production
  - Horticulture?

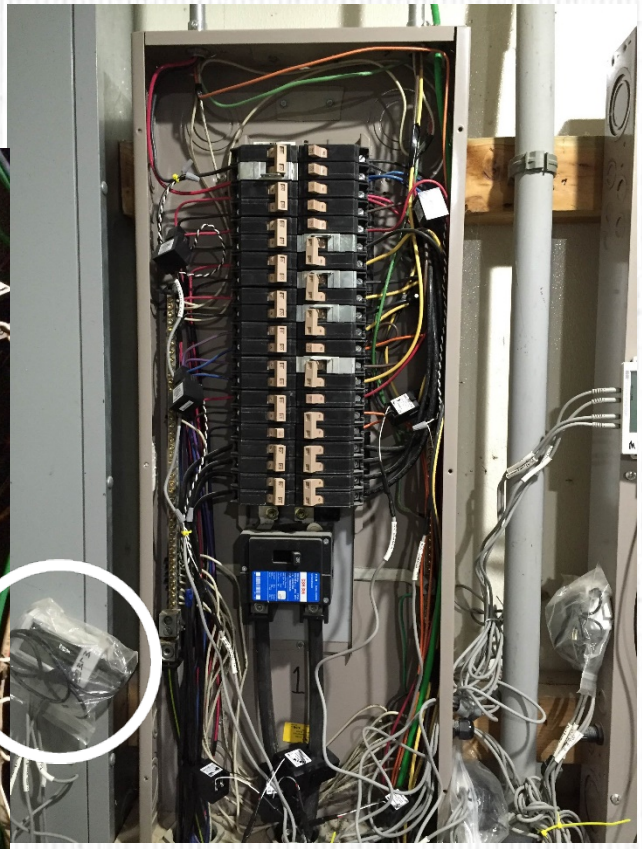
Swine Barn Energy Monitoring

- Monitoring monthly electrical use of representative loads within each barn
- Recording electrical use in each barn
- Monitoring use of heating fuels in each barn
- Recording pig production from each barn

Sensors and Dataloggers







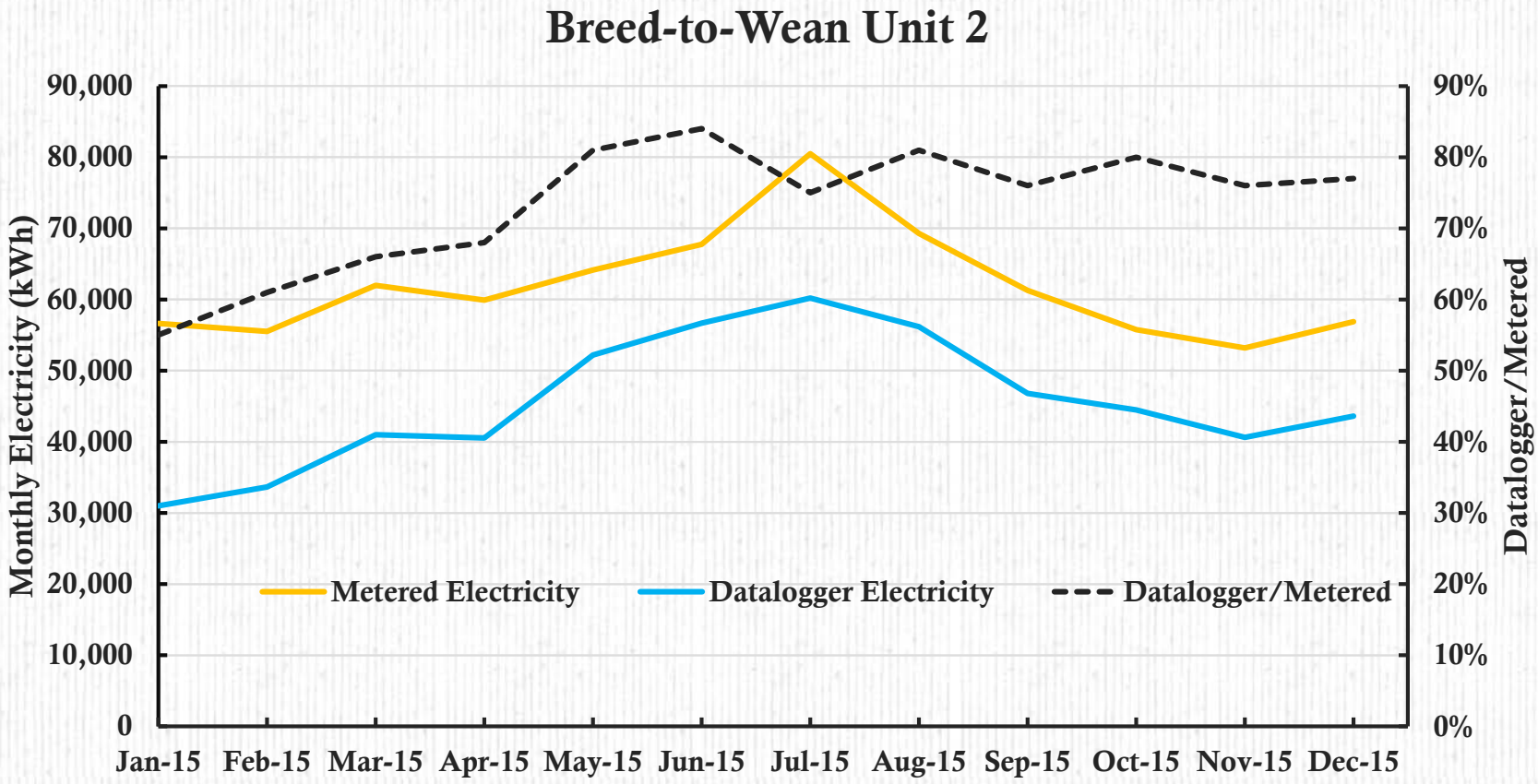
Swine Barn Energy Monitoring

Breed to Wean Barns

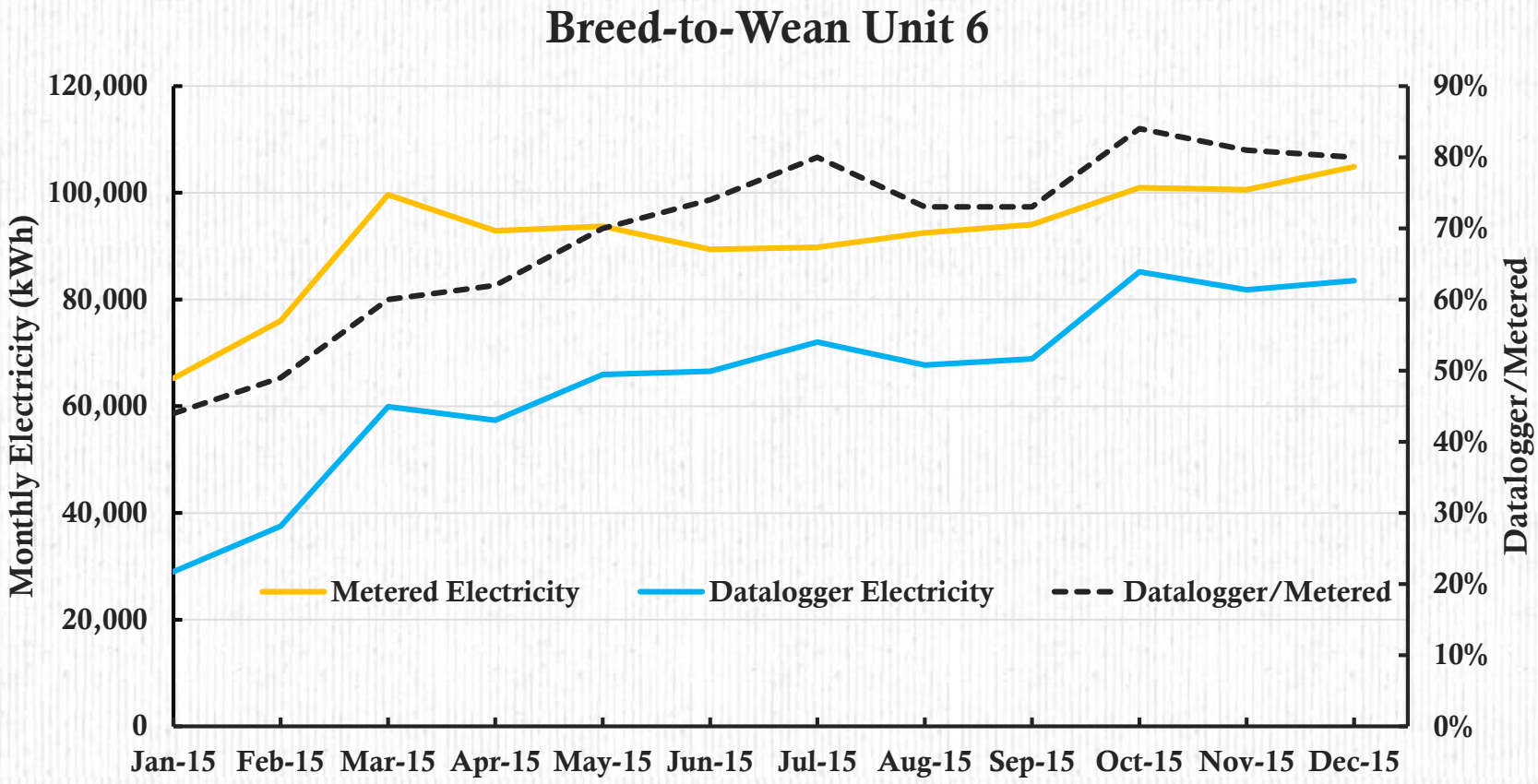
- Breed to wean barn #2
  - Gestation barn unit is curtain sided
  - Farrowing rooms are power ventilated
- Electrical usage
  - Uses 54,880 kWh/month on ave.
  - About 2500 sows
  - 57,965 weaned pigs per year
  - **11.4 kWh per weaned pig**

- Breed to wean barn #6
  - Gestation barn is cross-ventilated
  - Farrowing rooms are power ventilated
- Electrical usage
  - Uses 87,100 kWh/month on ave.
  - 3,300 sows
  - 85,874 weaned pigs per year
  - **12.2 kWh per weaned pig**

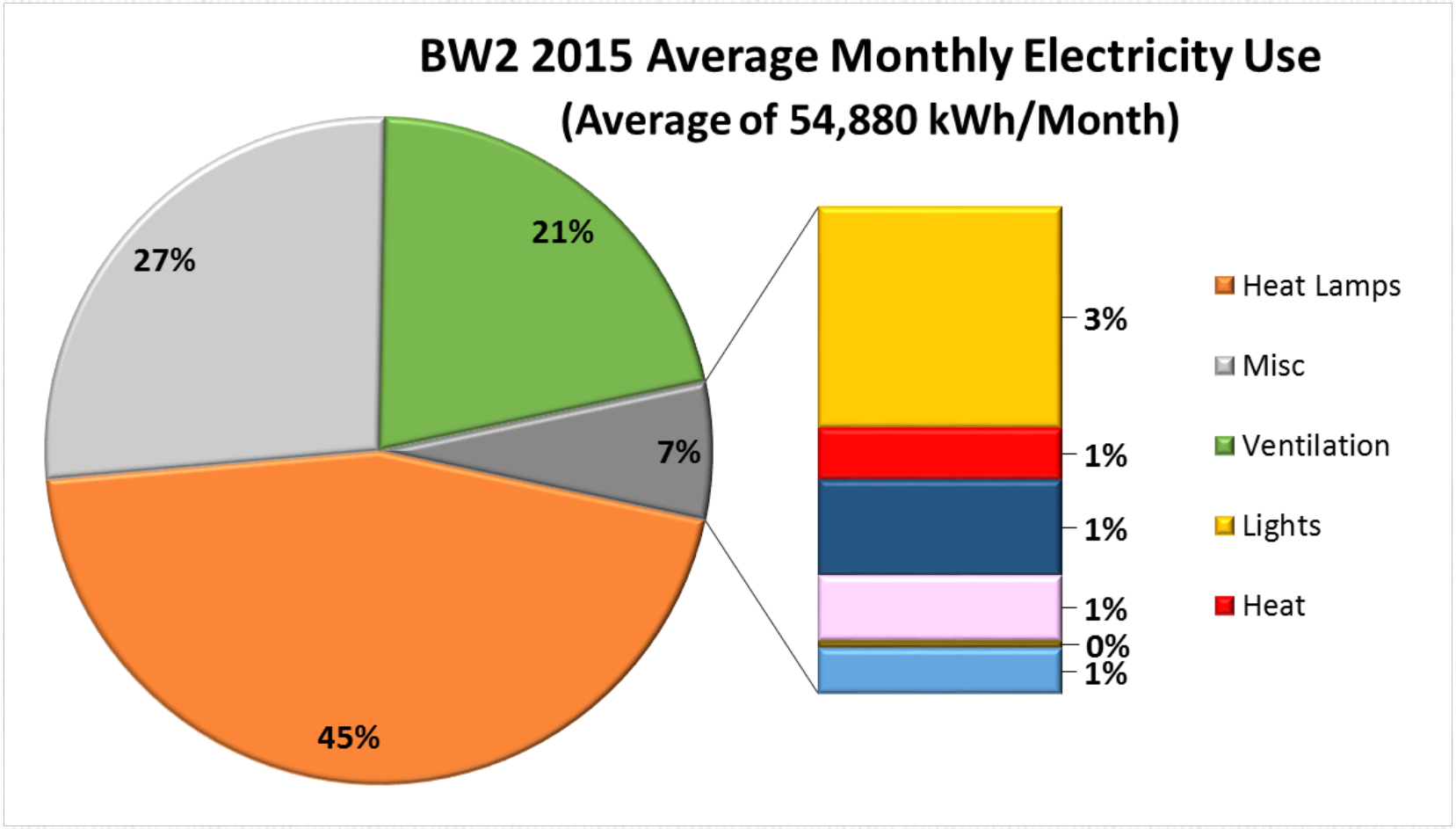
Proportion of Electrical Loads Recorded



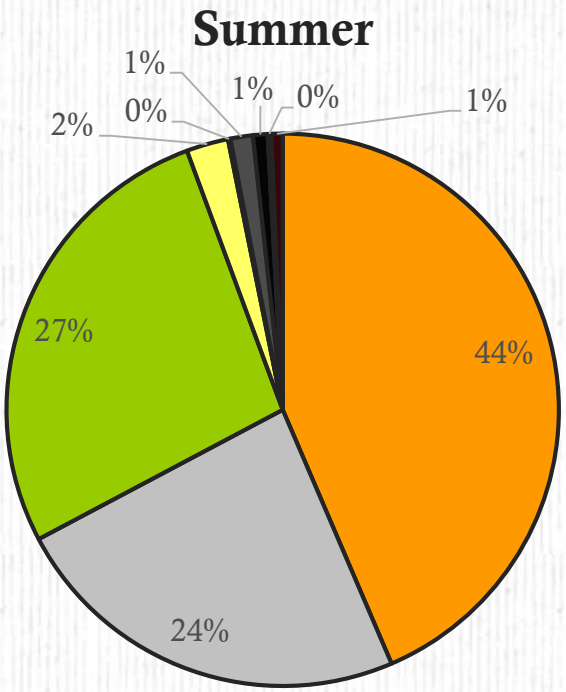
Proportion of Electrical Loads Recorded



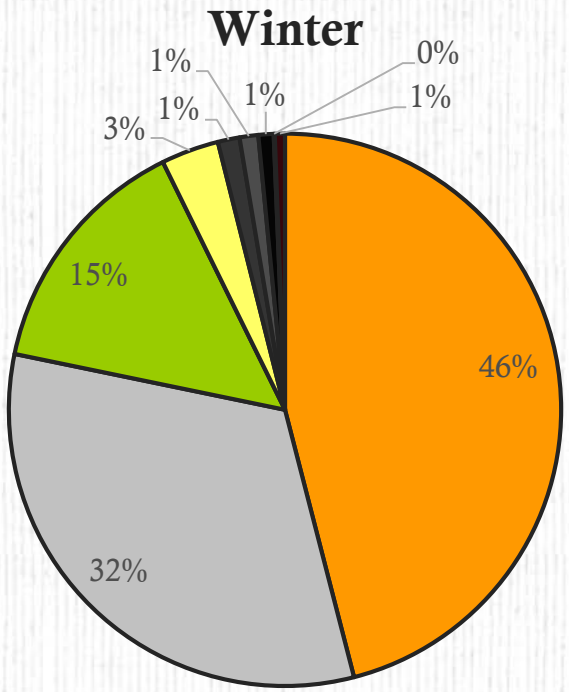
Monthly Electricity Use – Breed to Wean Unit



Seasonal Electric Loads: Breed to Wean Unit 2



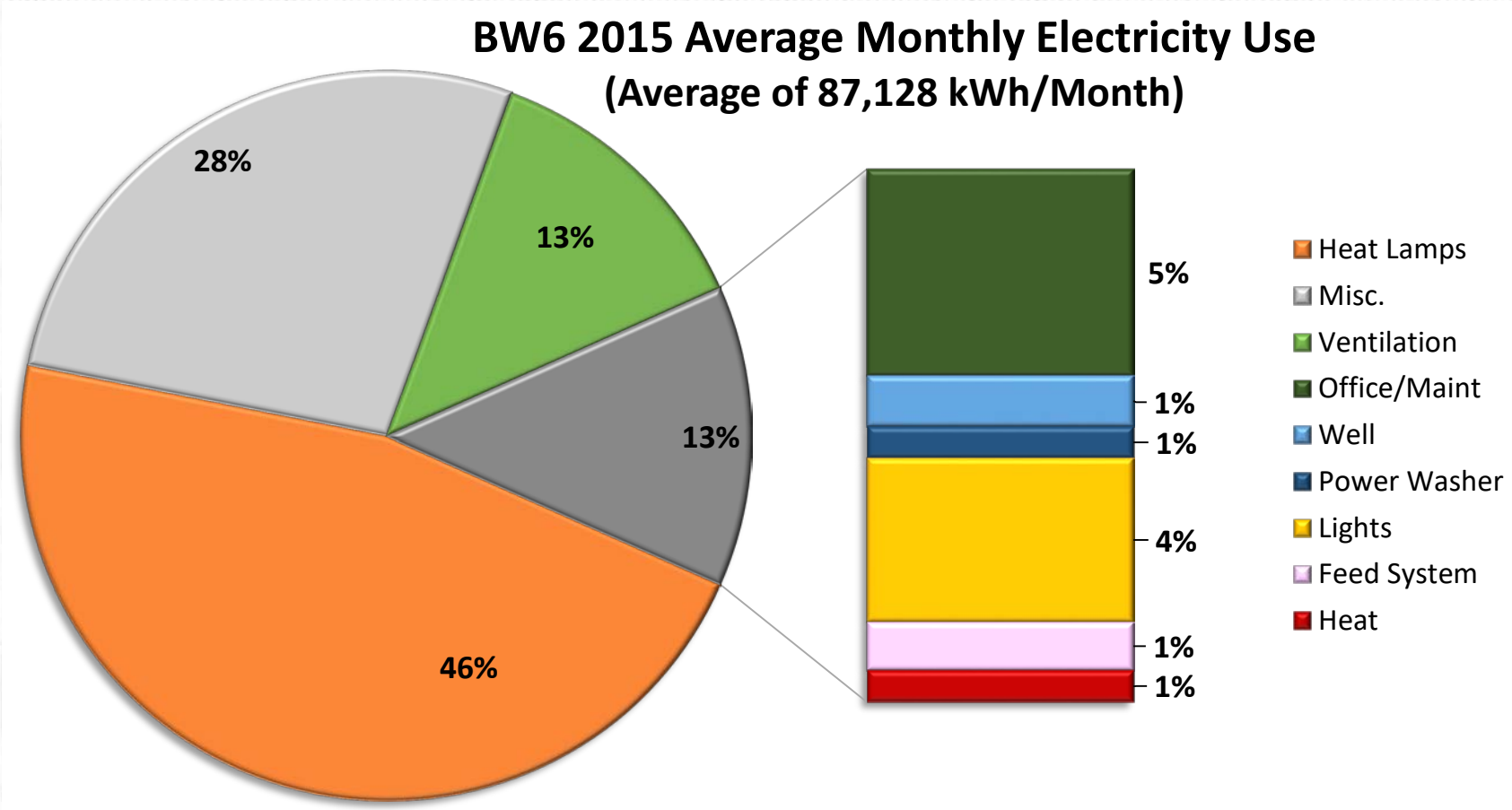
Ave. = 62,522 kWh/mo



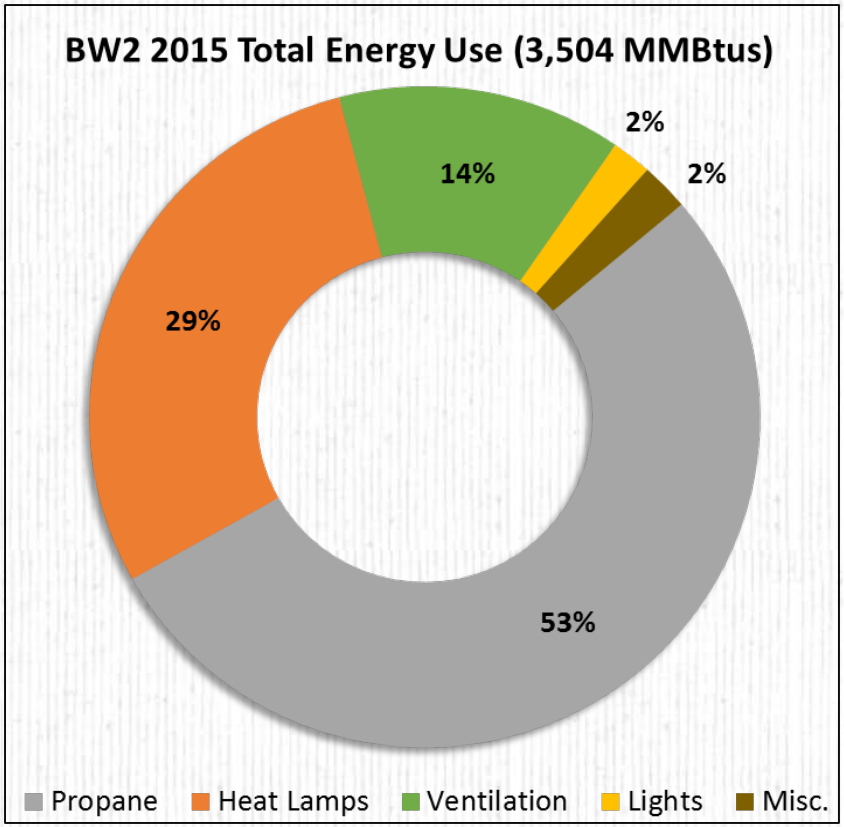
Ave. = 52,754 kWh/mo

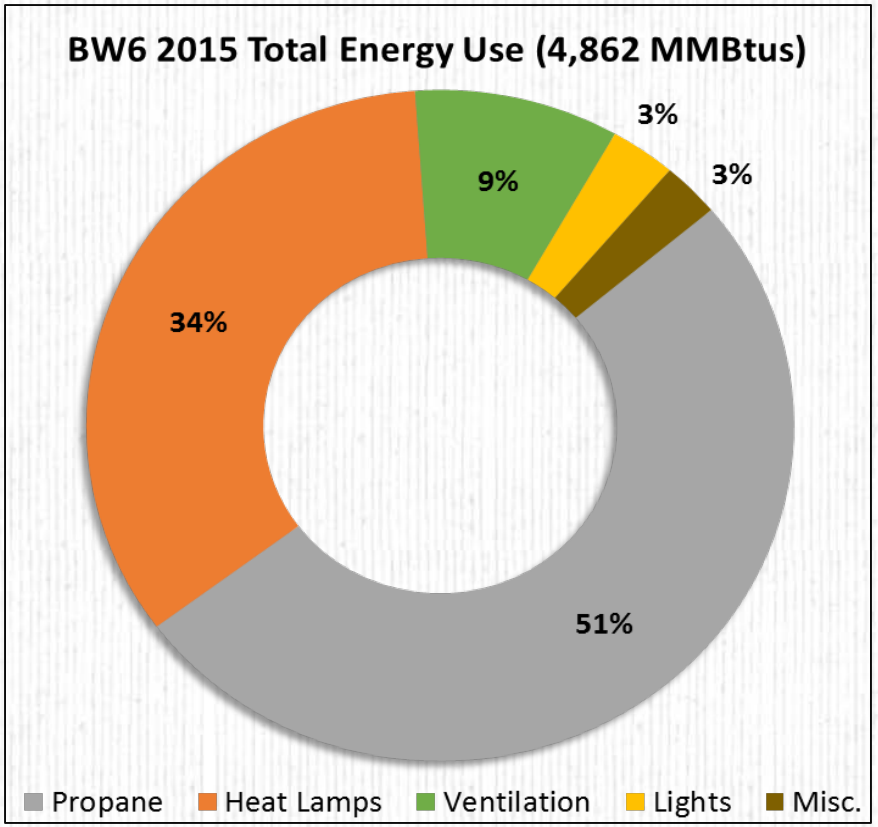
Heat Lamps | Misc. | Ventilation
Lights | Heat | Power Washers
Feed System | Manure System | Well

Monthly Electricity Use – Breed to Wean Unit



Total Fossil Energy Use (Heat + Elec): Breed to Wean Units





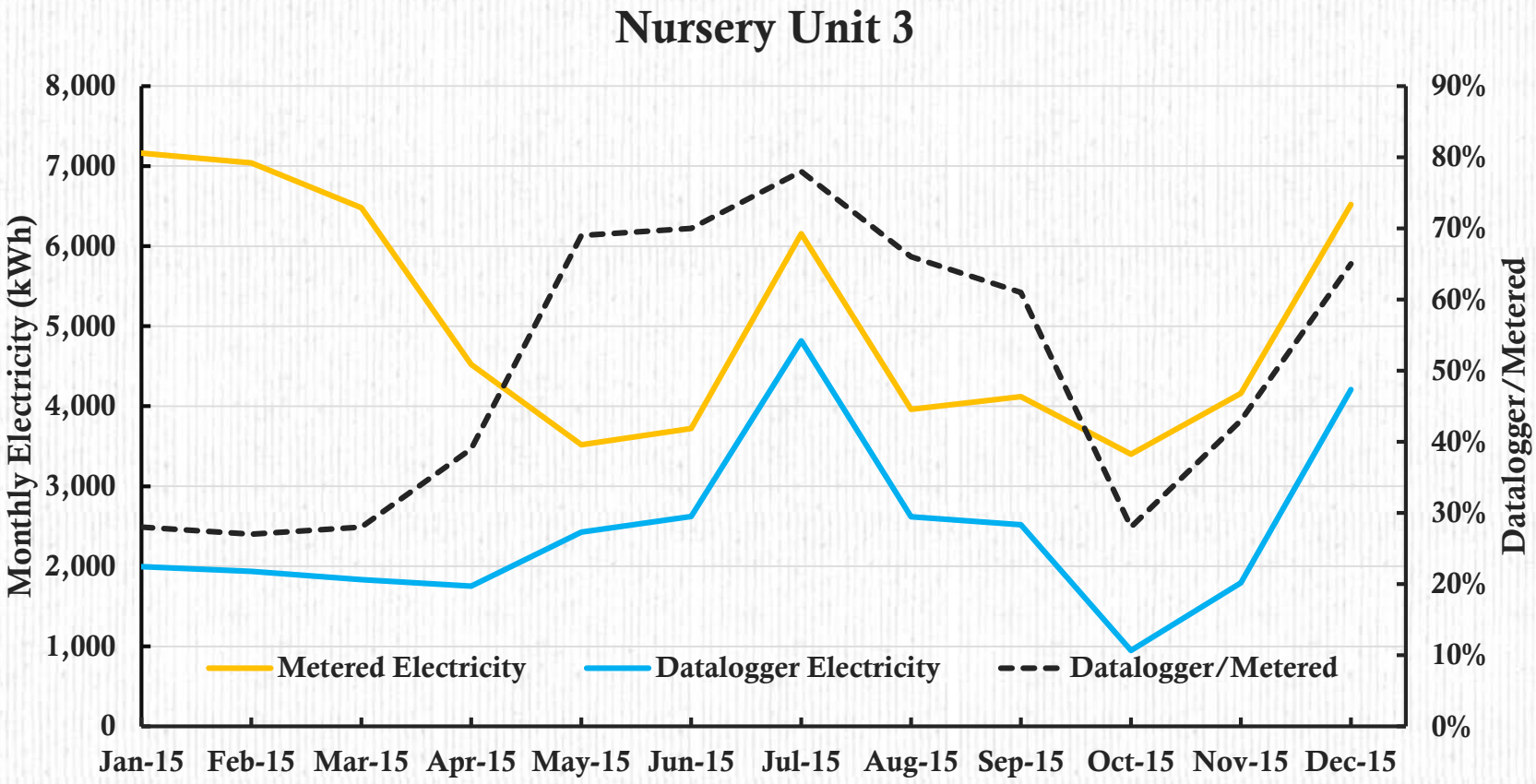
Swine Barn Energy Monitoring

Nurseries

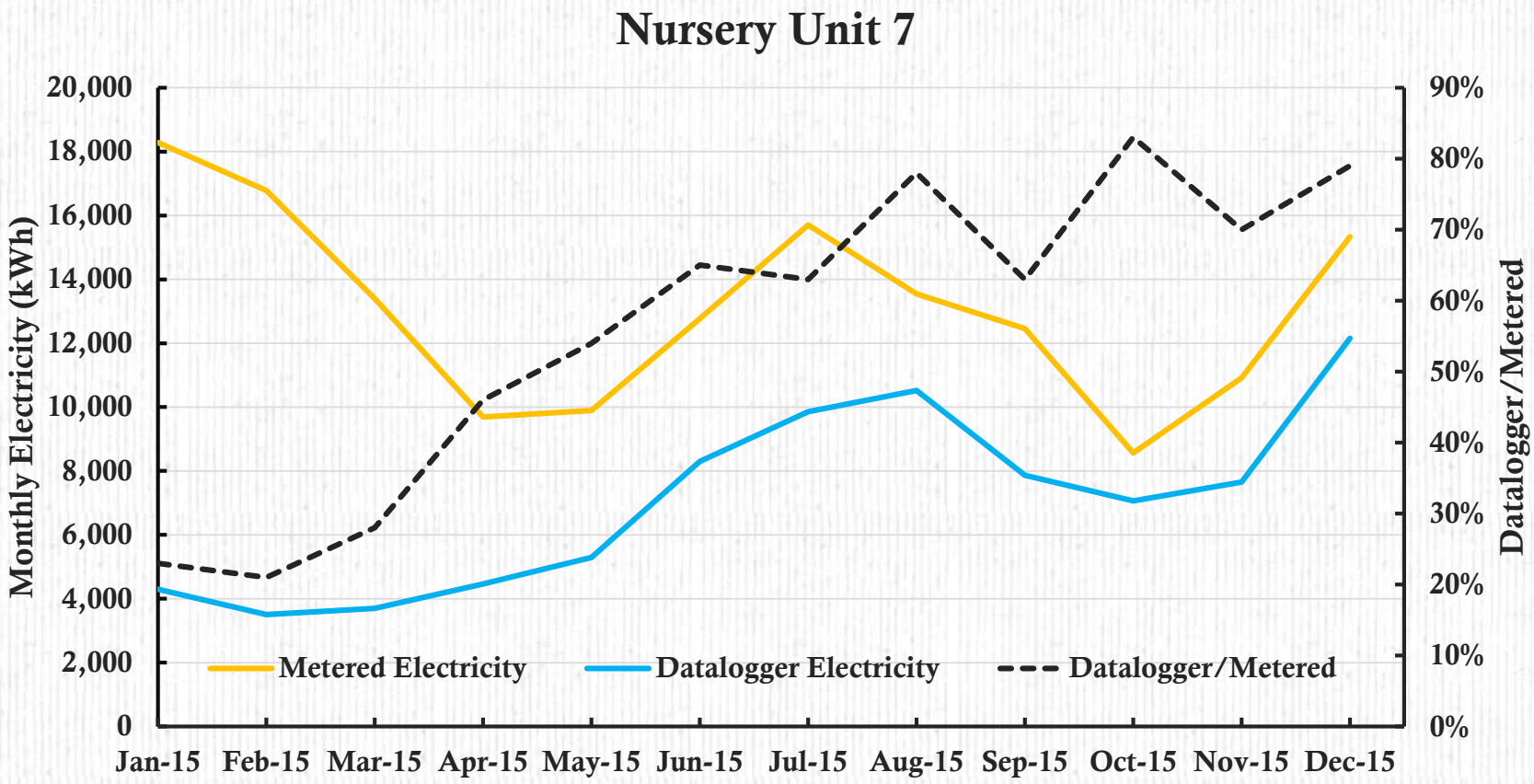
- Nursery barn #3
  - Nursery rooms power ventilated
- Electrical usage
  - Uses 3,700 kWh/month on ave.
  - 19,596 pigs per year
  - **2.3 kWh per pig produced**

- Nursery barn #7
  - Nursery rooms power ventilated
- Electrical usage
  - Uses 13,100 kWh/month on ave.
  - 76,700 pigs per year
  - **2.05 kWh per pig produced**

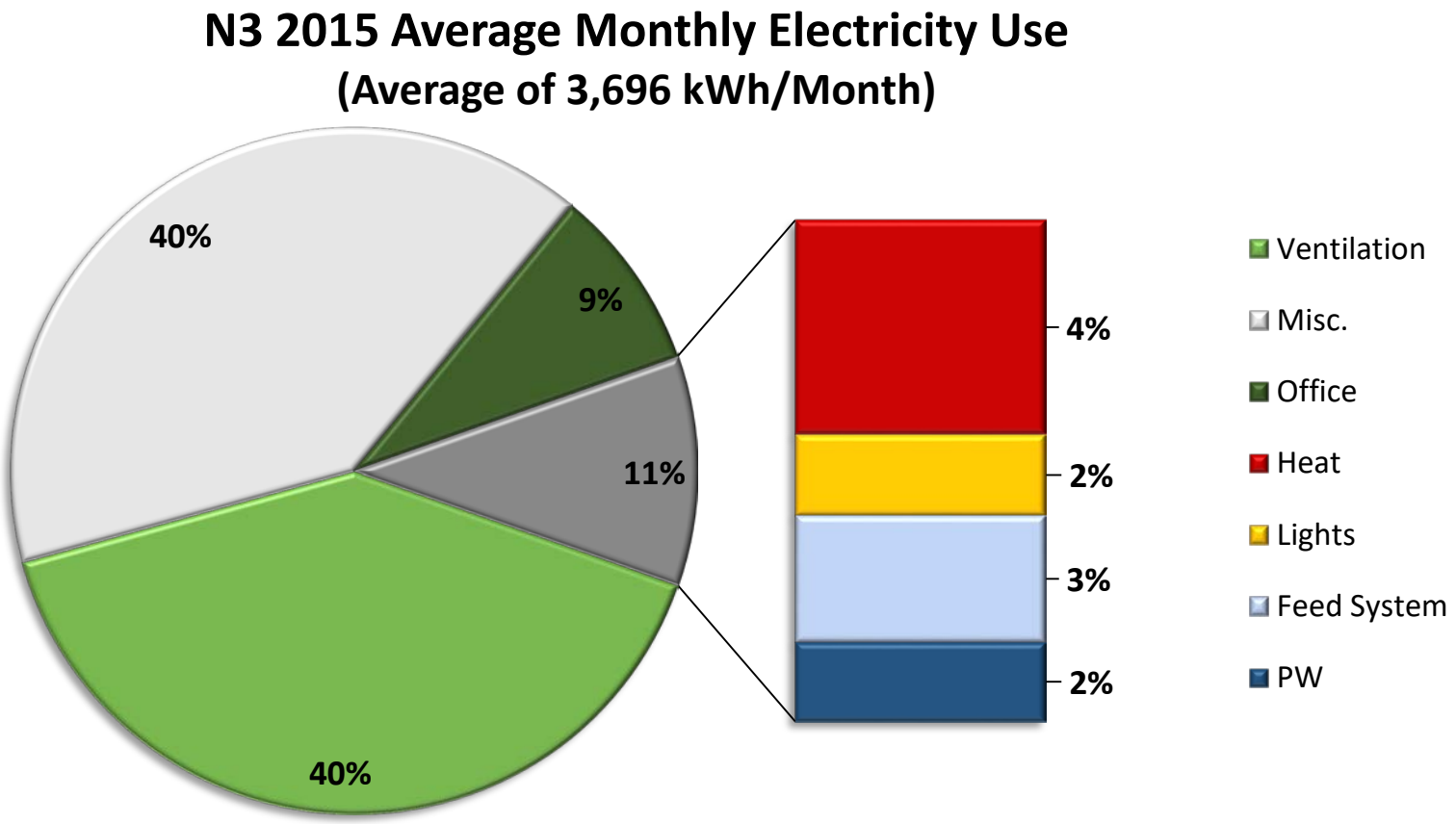
Proportion of Electrical Loads Recorded



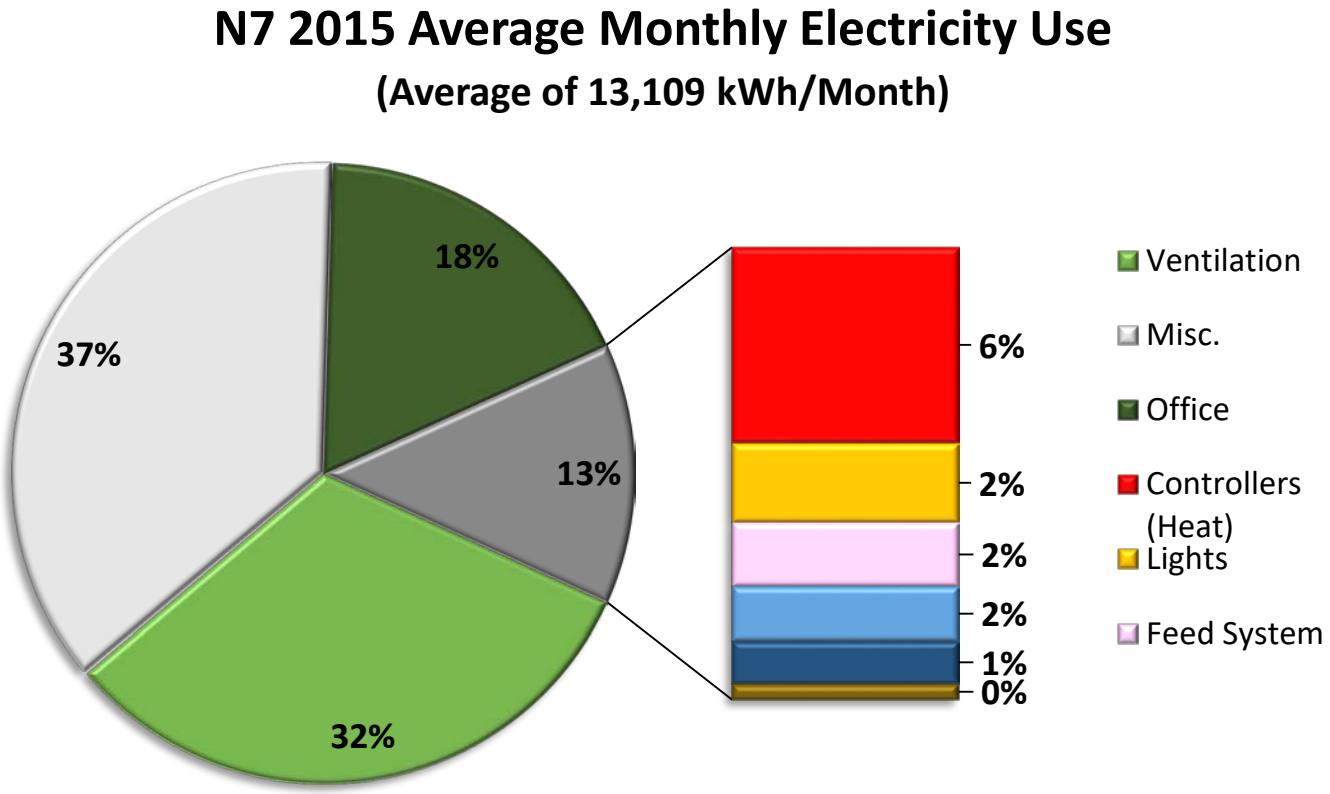
Proportion of Electrical Loads Recorded



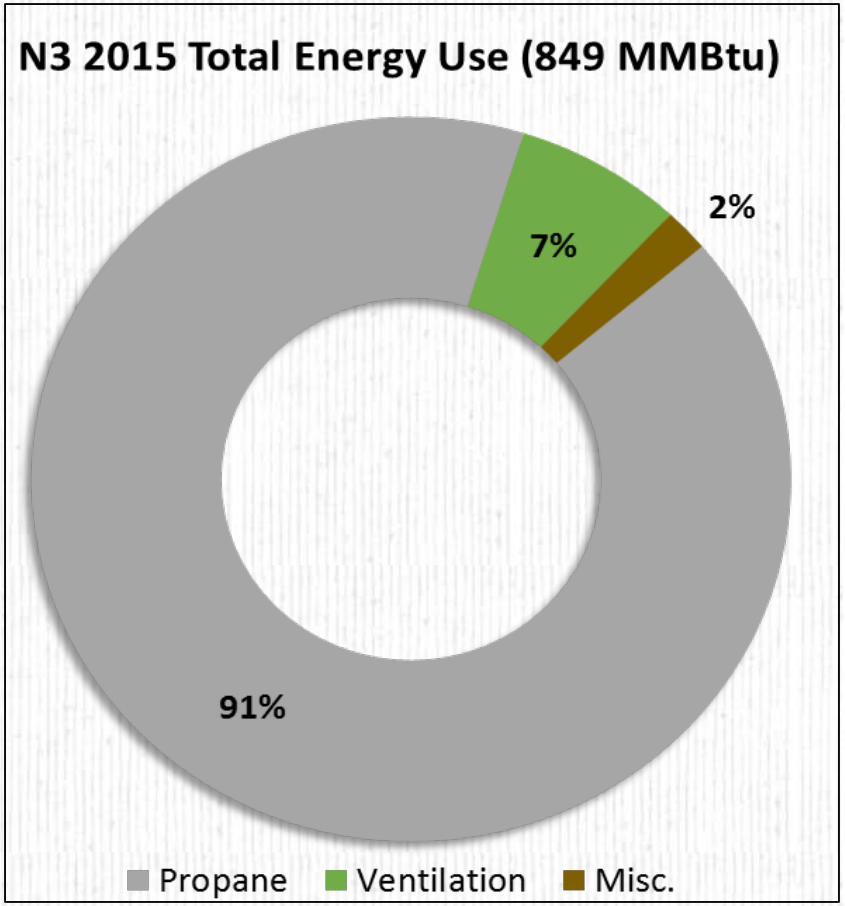
Monthly Electricity Use - Nursery

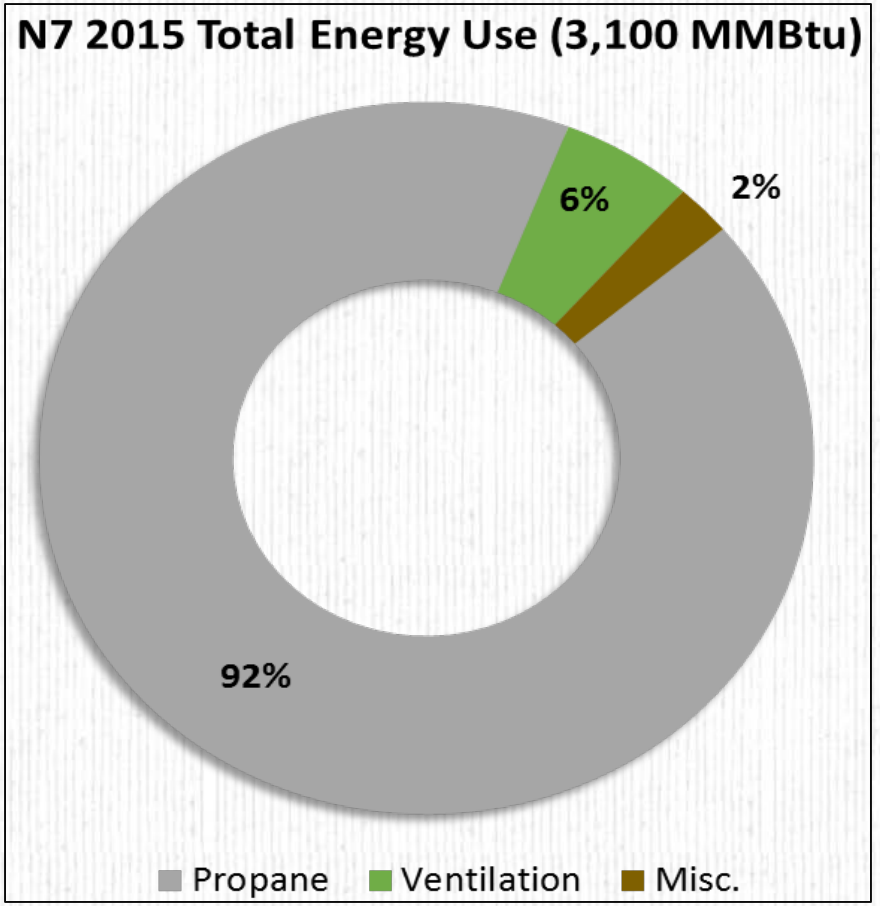


Monthly Electricity Use - Nursery



Total Fossil Energy Use (Heat + Elec): Nurseries





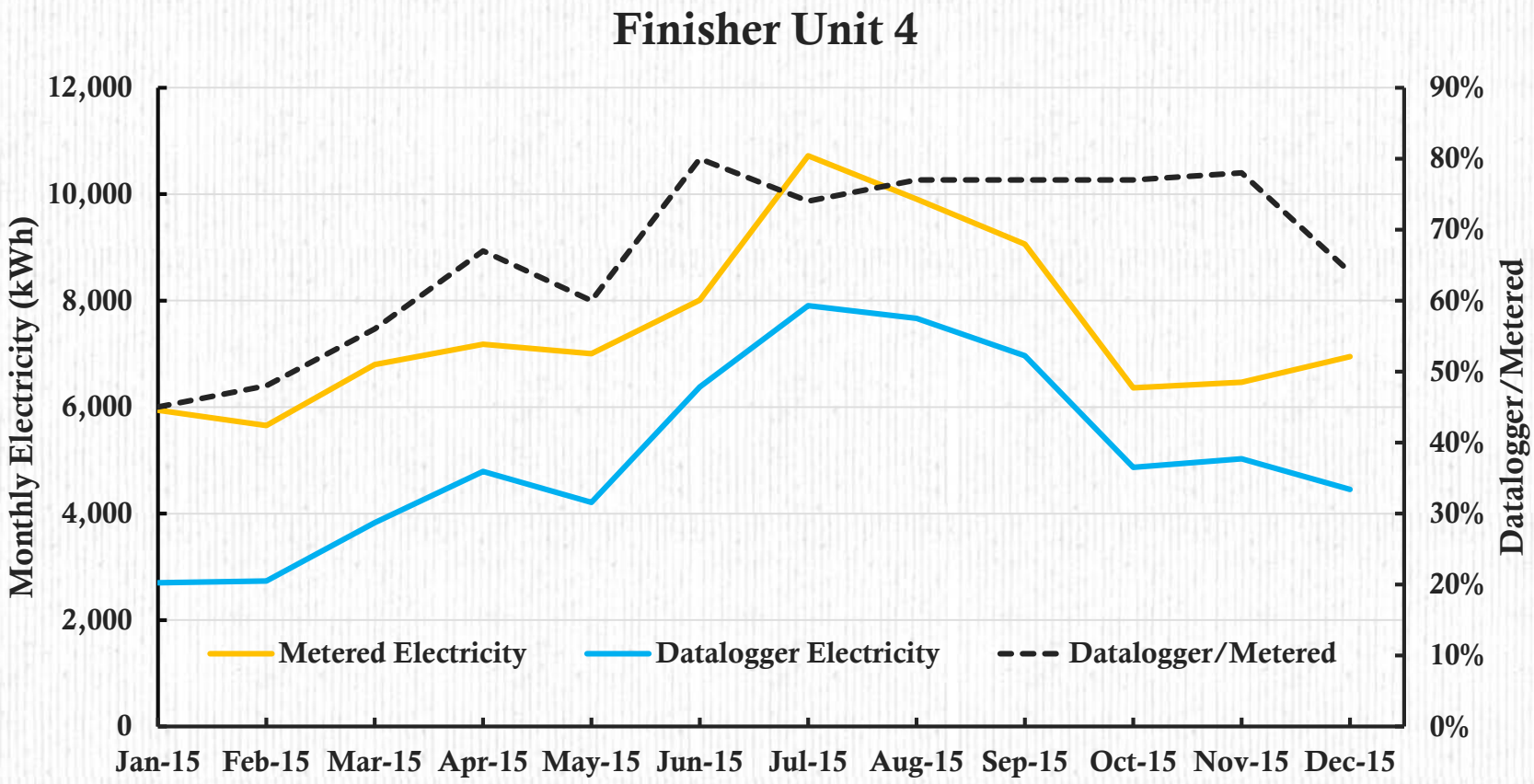
Swine Barn Energy Monitoring

Finishing Barns

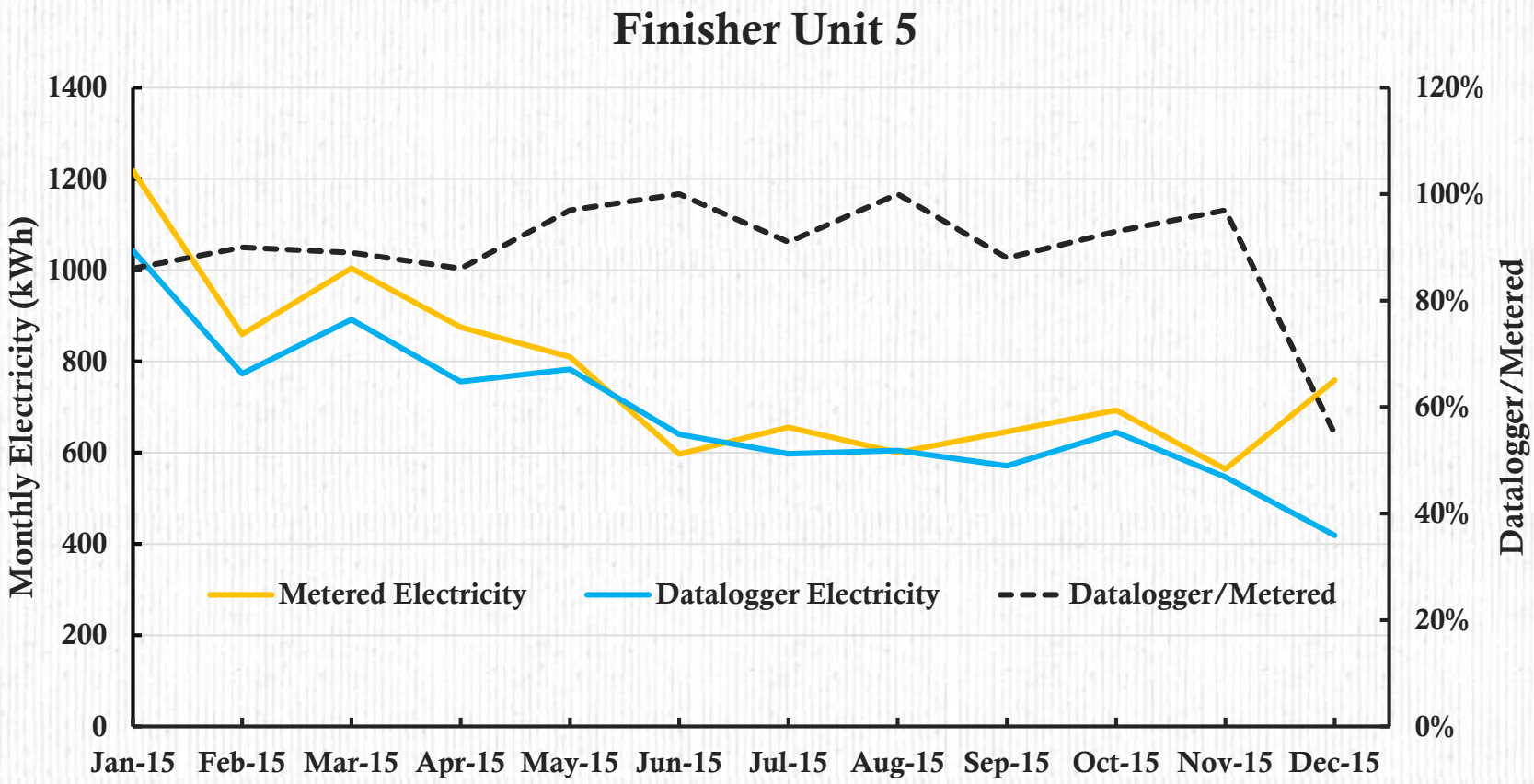
- Finish barn #4
  - Pig rooms are tunnel ventilated
- Electrical usage
  - Uses 7,500 kWh/month on ave.
  - 5,837 pigs per year
  - **15.4 kWh per finished pig**

- Finish barn #5
  - Pig rooms are curtain sided
- Electrical usage
  - Uses 770 kWh/month on ave.
  - 3,000 pigs per year
  - **3.1 kWh per finished pig**

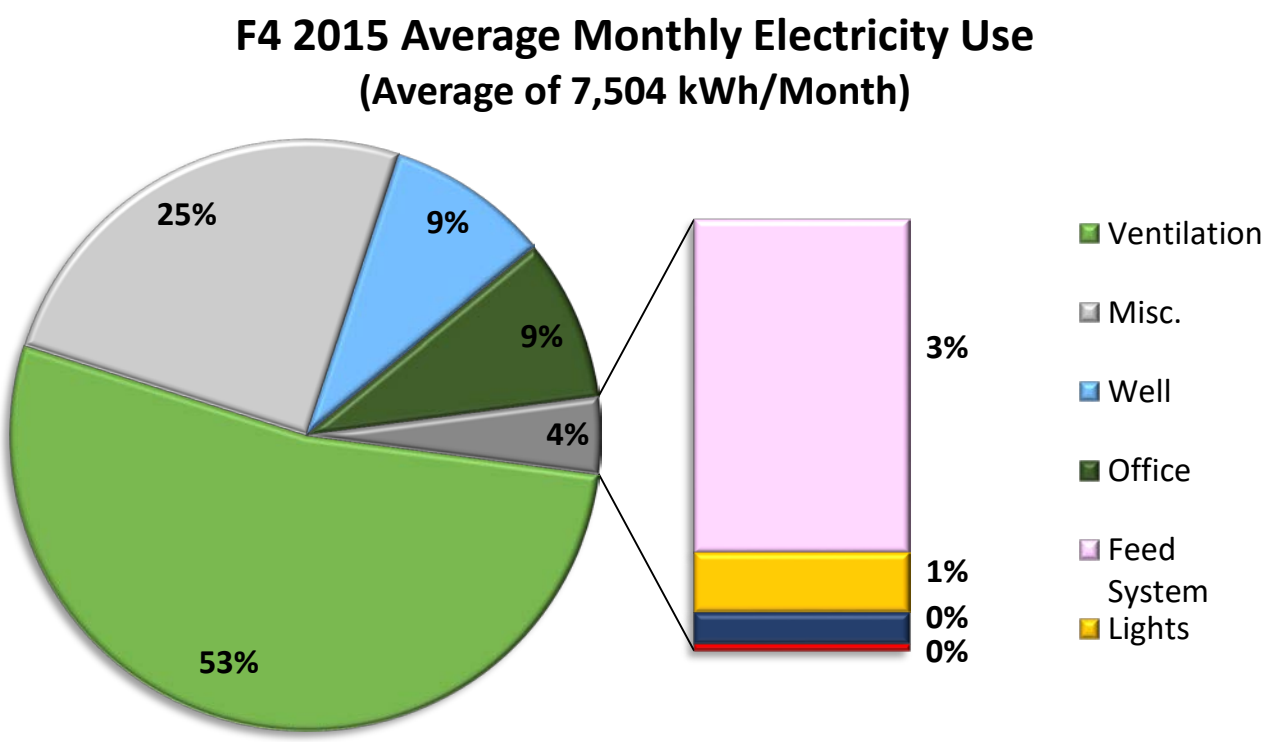
Proportion of Electrical Loads Recorded



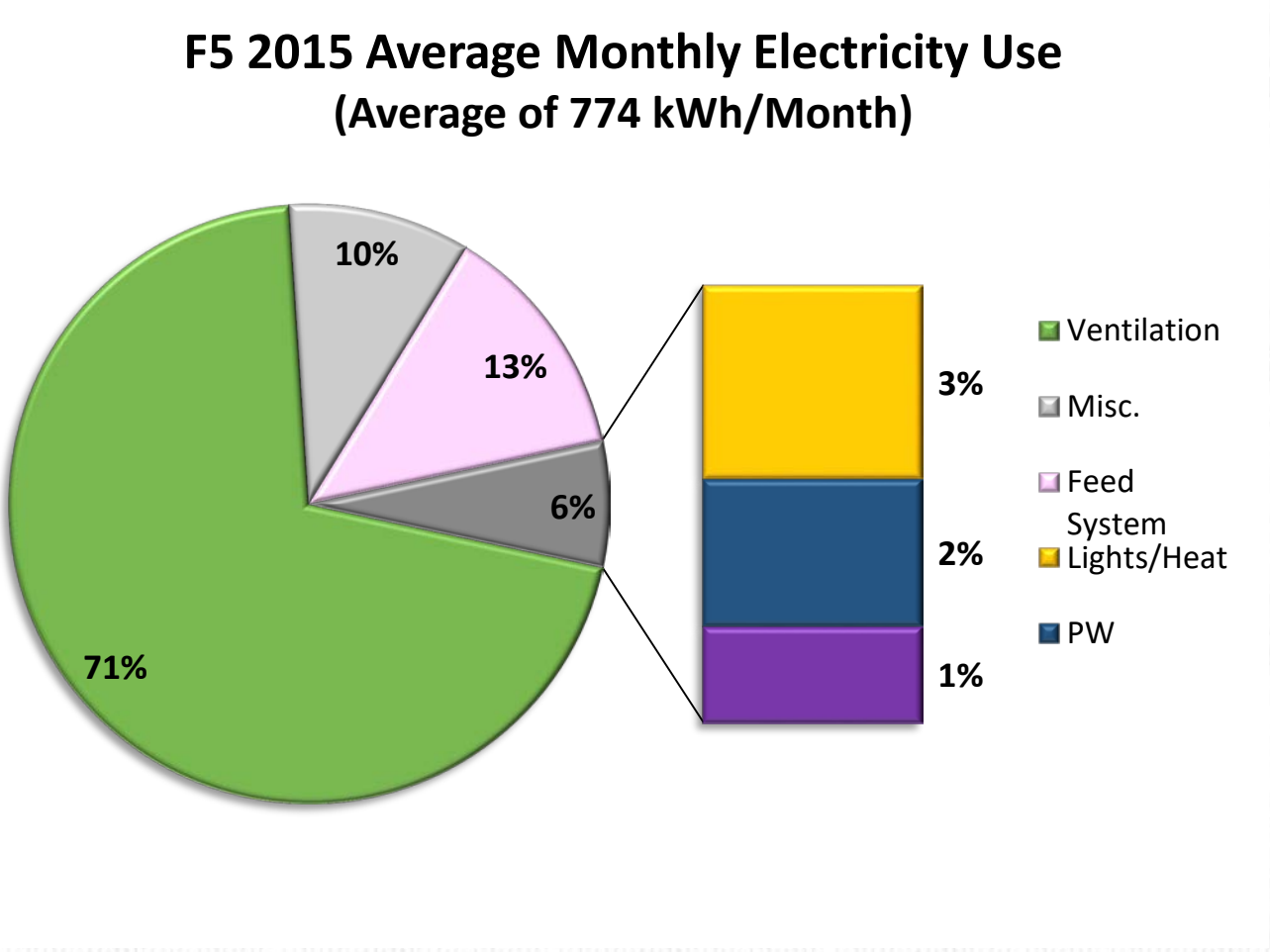
Proportion of Electrical Loads Recorded



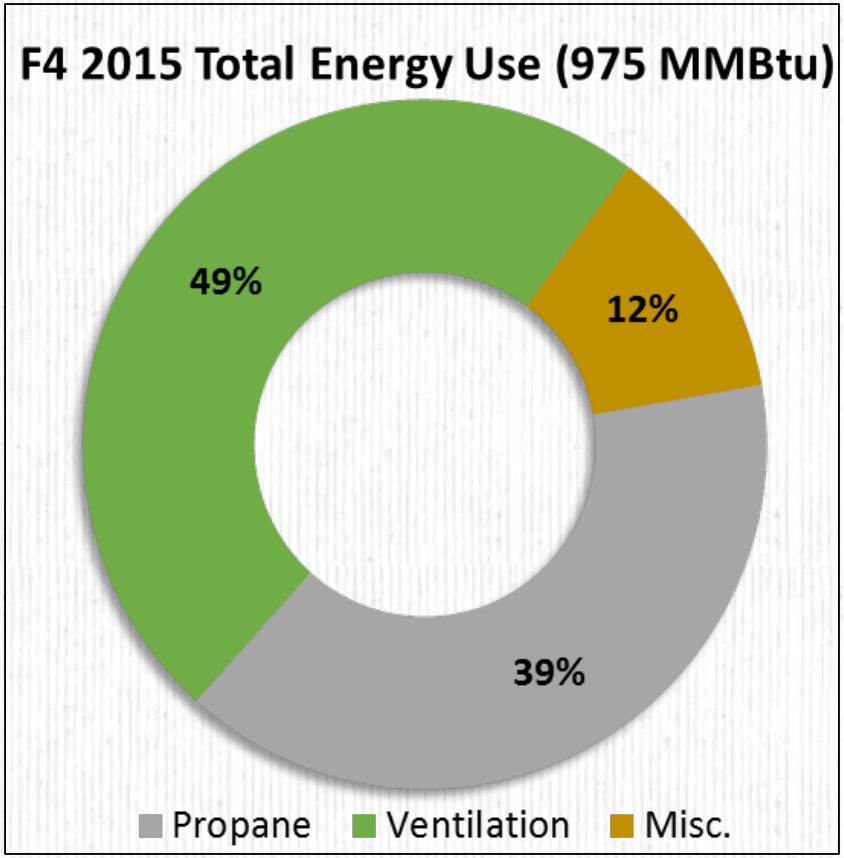
Monthly Electricity Use - Finisher

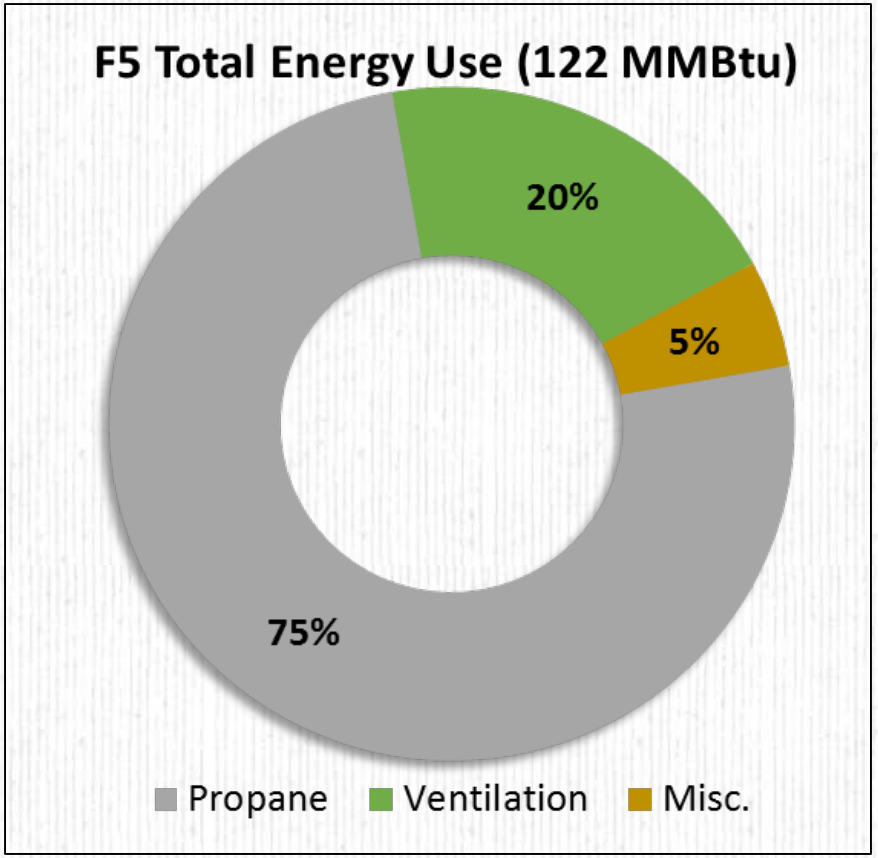


Monthly Electricity Use - Finisher



Total Fossil Energy Use (Heat + Elec): Finishers





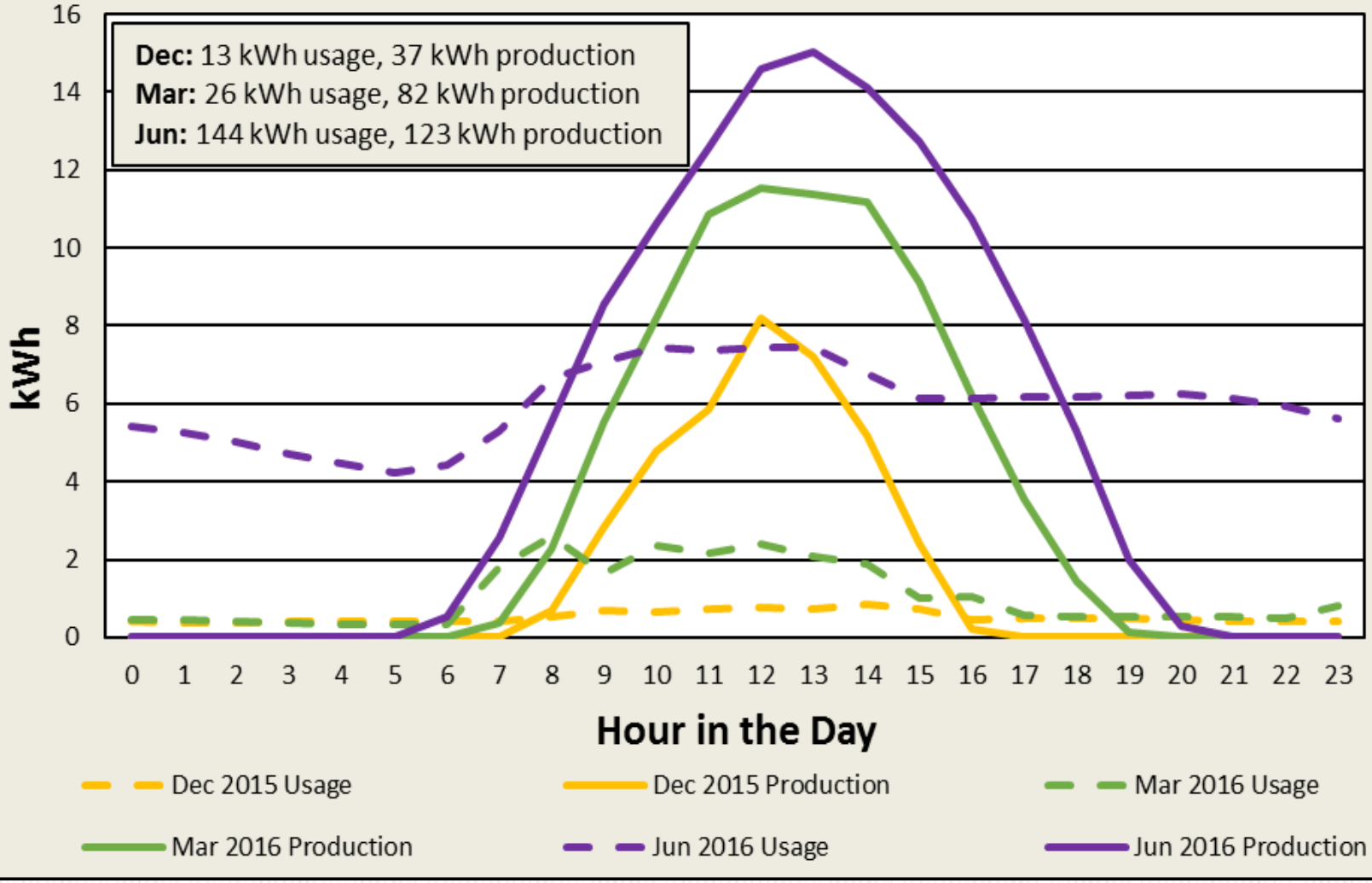
WCROC Solar PV Installation

WCROC Solar PV Installation

SolarEdge inverters

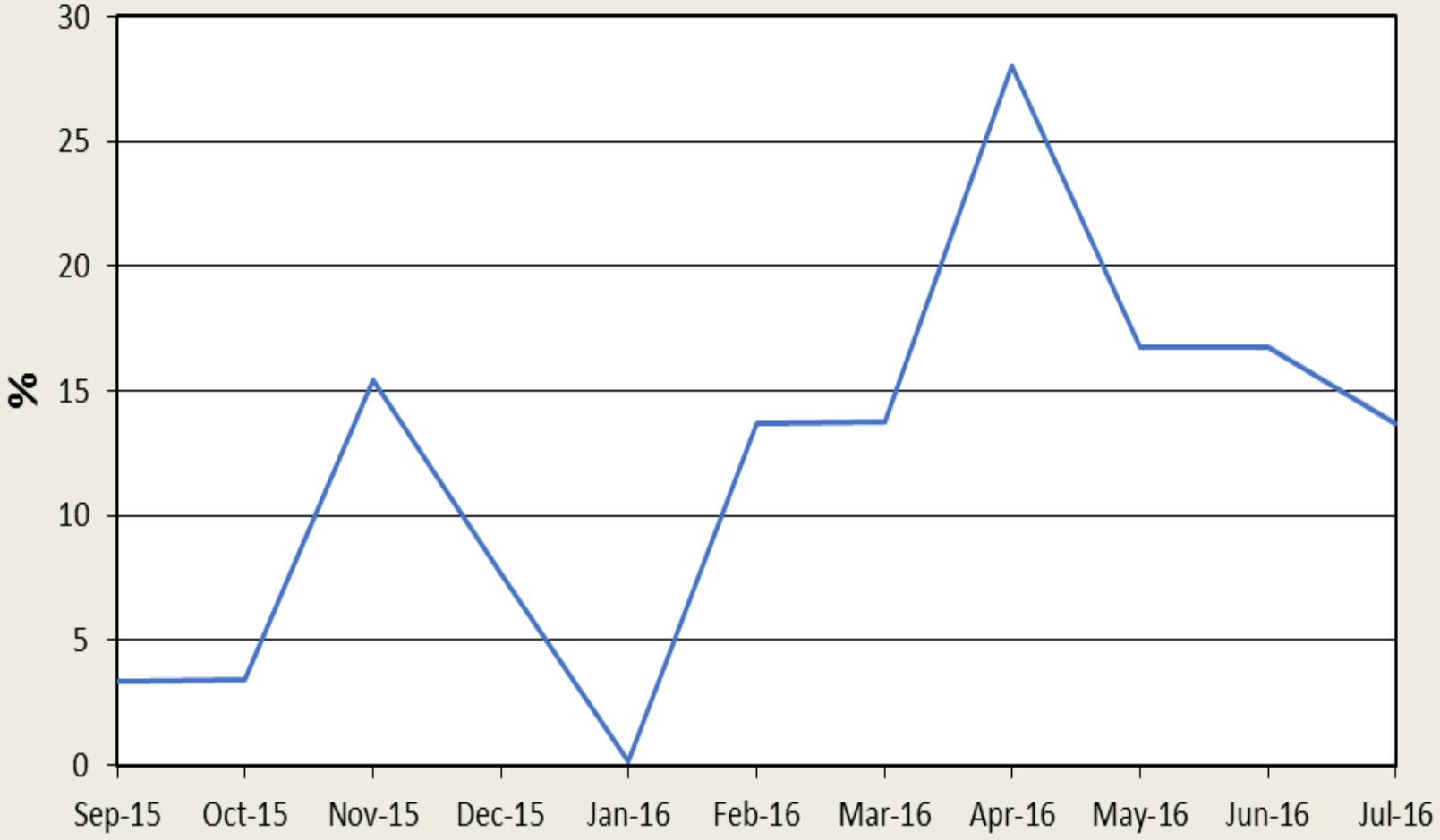
Total Electricity Usage vs. Solar PV Production

by the WCROC Finishing Barn



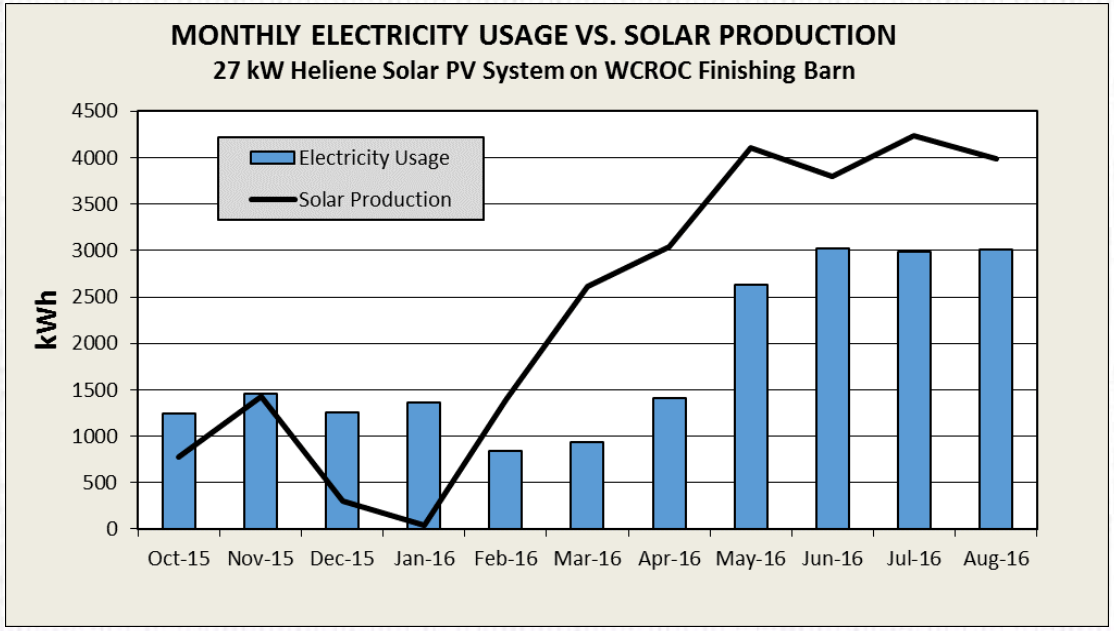
MONTHLY SOLAR PRODUCTION EFFICIENCY

27 kW Heliene Solar PV System on WCROC Swine Barn



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

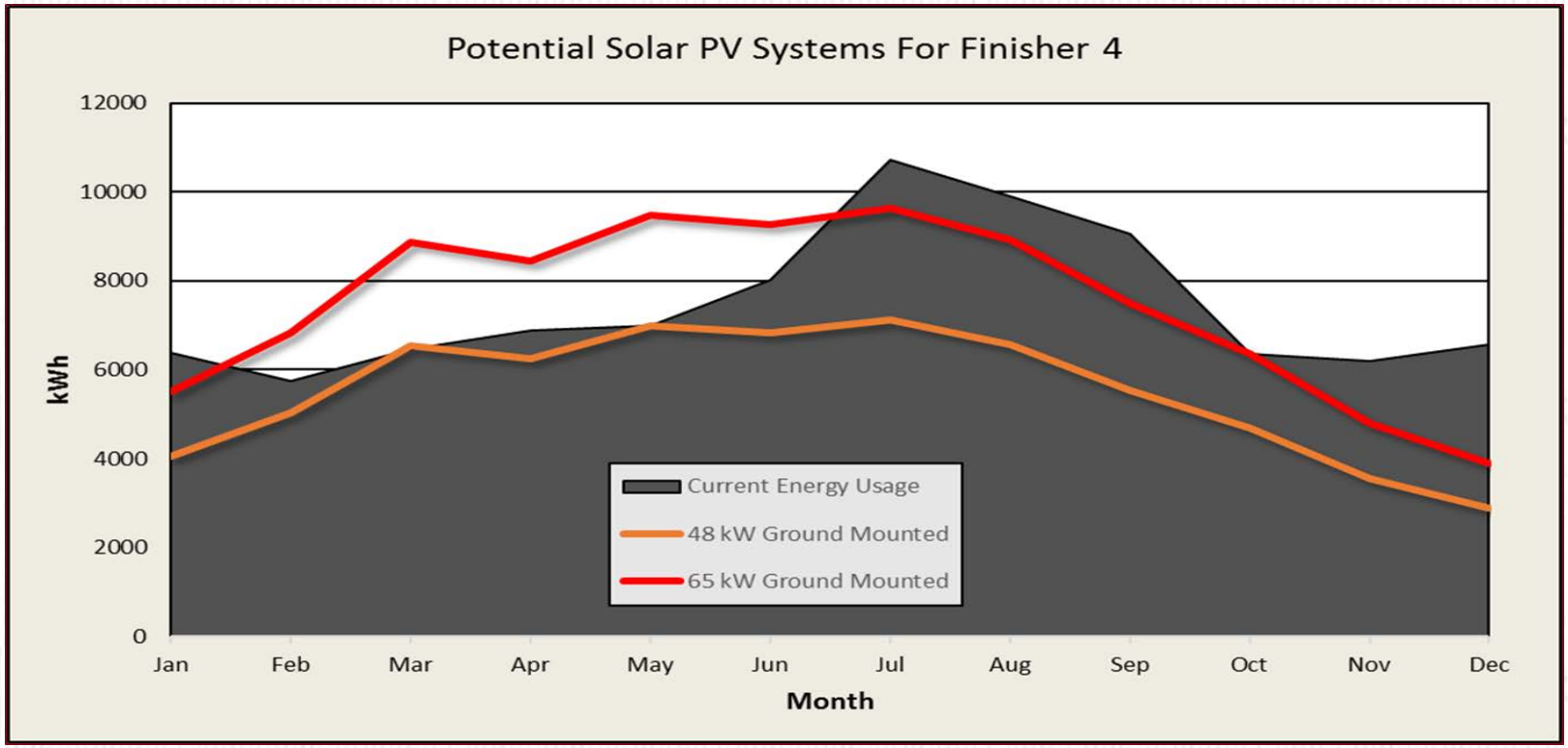
- 9.7¢/kWh (no incentives)
- 6.8¢/kWh (fed tax credit)
- 1.6¢/kWh (FTC & MiM)

Might have maintenance costs with inverters

Projected Solar PV Installation

Finisher #4

- Used PVwatts to predict performance
- Ground mounted due to barn orientation



Lowering Energy Consumption by Reduction of Temperature in Swine Facilities

L. J. Johnston*[1], M. C. Brumm[2], S. Moeller[3], S. Pohl[4], M. Shannon[5], and R. Thaler[4]

[1] University of Minnesota, West Central Research and Outreach Center, Morris

[2] Brumm Swine Consultancy, Mankato, MN

[3] The Ohio State University, Columbus

[4] South Dakota State University, Brookings

[5] University of Missouri, Columbia

UNIVERSITY OF MINNESOTA

Heating Fuel and Electricity Costs to Produce Pigs

Phase of production	Heating fuel ($/pig)	Electricity ($/pig)	Total cost ($/pig)
Farrow-to-finish	1.37	2.30	195.91
Wean-to-finish	1.92	0.76	181.97
Feeder-to-finish	1.42	1.23	184.97

MnSCU Adult Farm Business Mgt. (2014)

Pigs Prefer Cooler Nights

3.3 °C

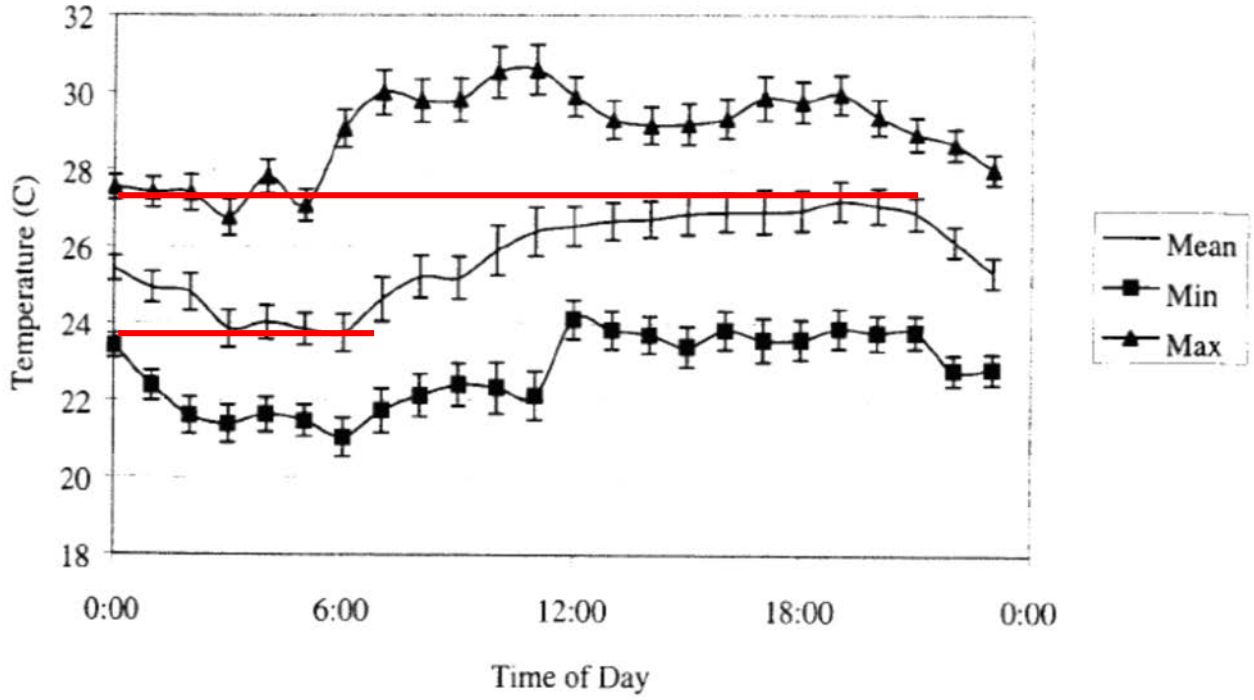


Fig. 1. Mean preferred temperatures (± SE), selected by early-weaned pigs, for a 24-h circadian cycle (averaged for all replicates; $P < 0.001$). P value represents differences in mean temperature data per hour of the day.

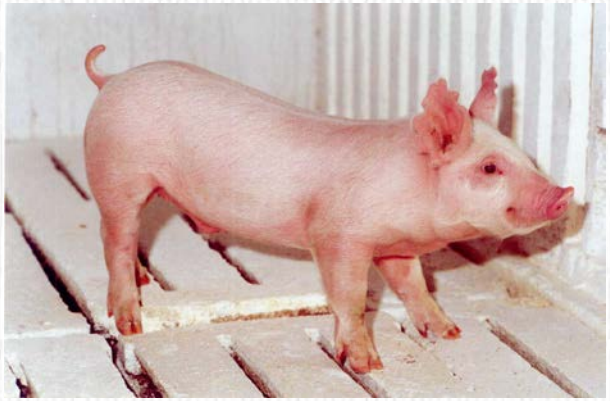
Bench and Gonyou, 2007

So why re-evaluate RNT?

- Commercial implementation of RNT was impractical in the 1990's
- Design of nursery facilities has improved
- Heating costs can be significant (remember $7 propane?)
- Heat production of pigs has increased
  - 60 Btu/h at 15 lb bodyweight
  - 137 Btu/h at 24 lb
  - 240 Btu/h at 48 lb

Objectives (XP 1)

- To determine if a RNT regimen:
  - Influences pig performance
  - Decreases consumption of fossil fuels



Cooperating Universities

University of Nebraska Lincoln

SDSU
South Dakota State University

University of Minnesota
Driven to Discover℠

Mizzou
University of Missouri - Columbia

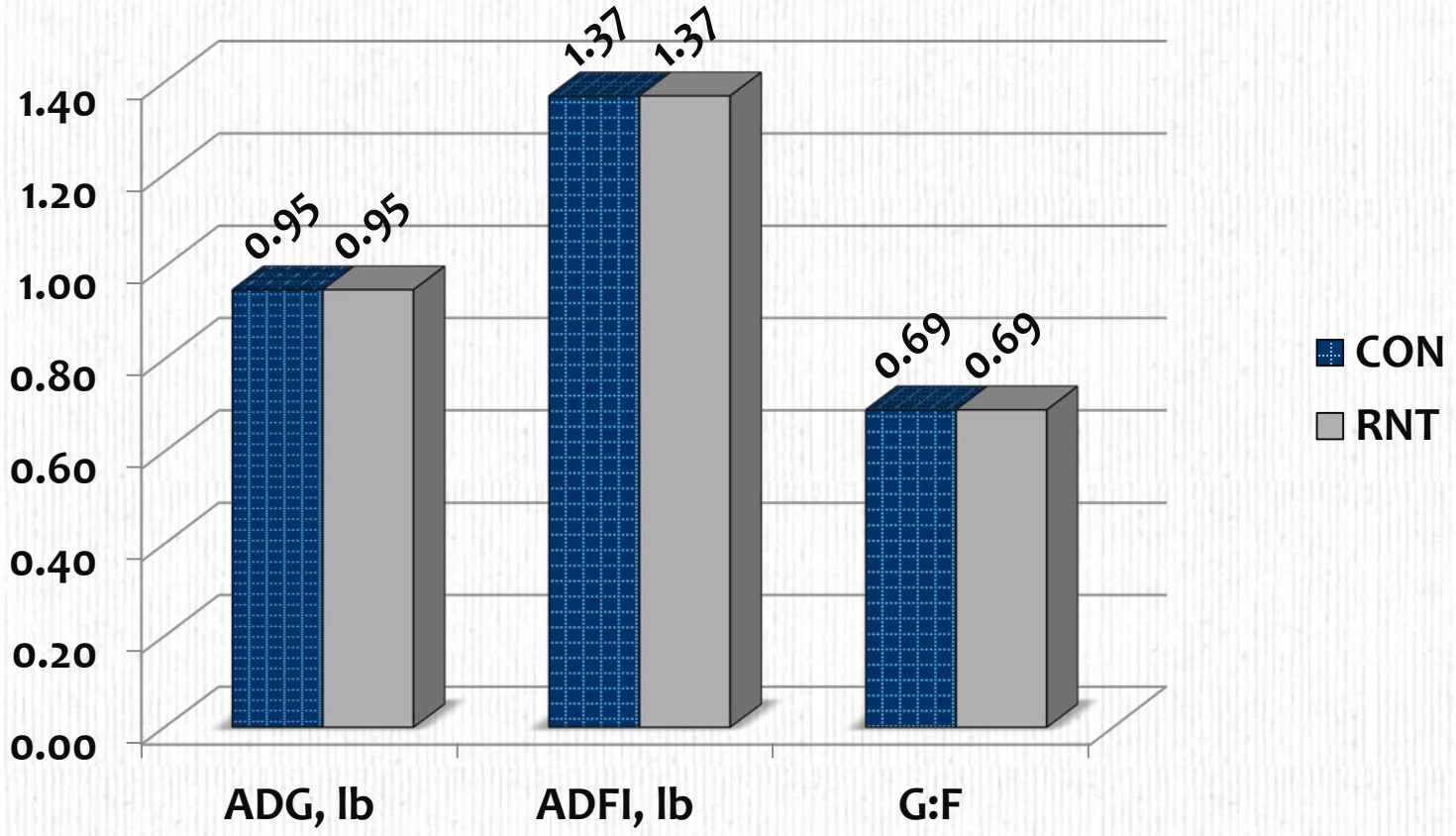
Room Treatments

- Control
  - 86 °F at pig height
  - Lowered temperature 3.5 °F per week (5-6 wk)
- RNT
  - Same as Control in week 1
  - Beginning week 2, reduced temperature 11 °F 1900 to 0700 hours daily
  - Reduced daytime temperature 3.5 °F per week

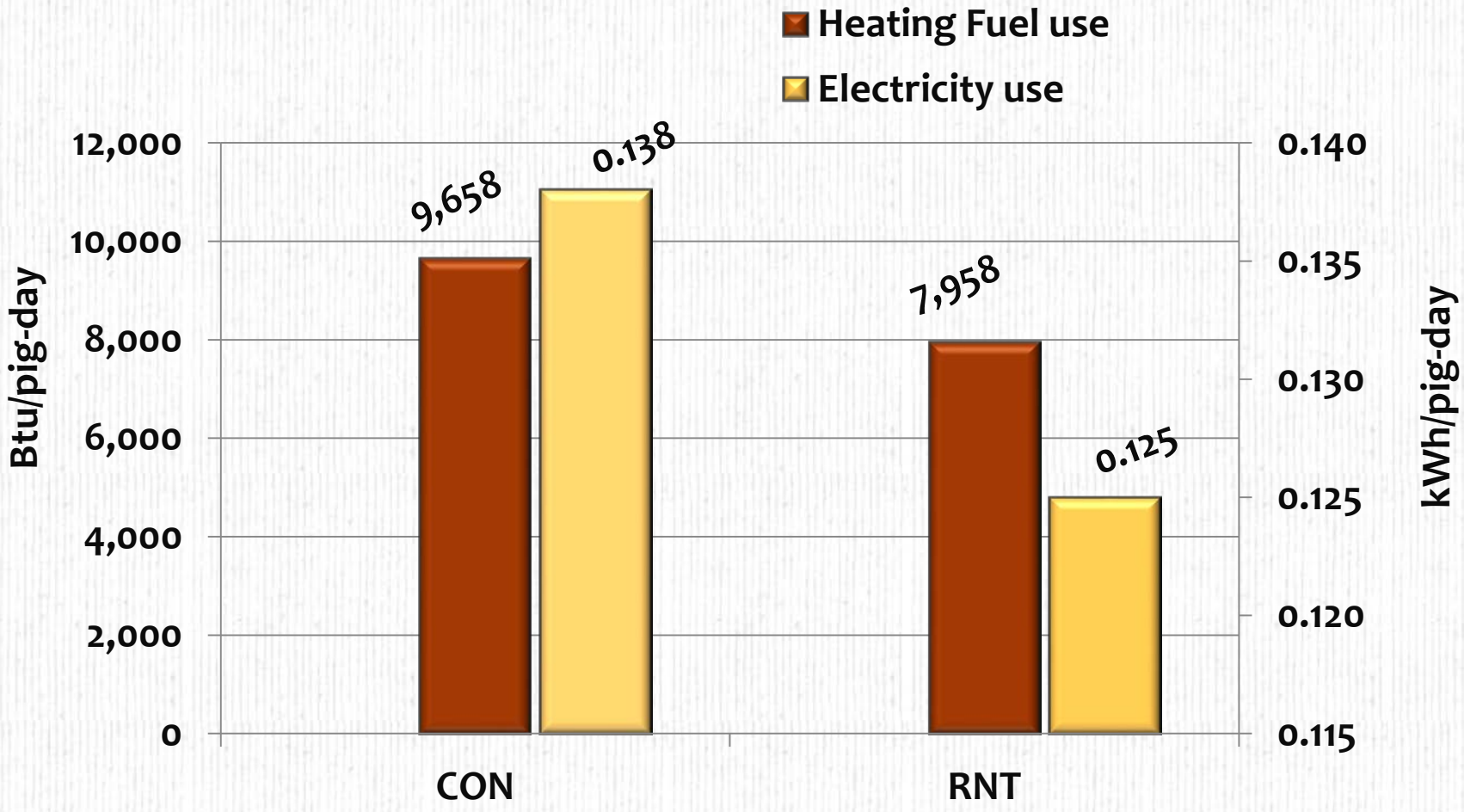
Procedures

- Animals
  - 1,638 weaned pigs weighing 13.7 lb
  - Trial lasted 35 to 42 days
- Facilities
  - Mirror-image nursery rooms used at each site
  - 6 trials conducted at 3 stations
    - NE (2 trials; 238 pigs)
    - MO (2 trials; 480 pigs)
    - MN (2 trials; 920 pigs)
- Measurements
  - Pig performance
  - Weekly heat/electricity use by room

Overall Pig Performance (XP 1)



Use of Heating Fuel and Electricity (XP 1)



Use of Heating Fuel and Electricity Across all Stations (XP 1)

	Trait			
	Heating fuel (Btu/pig)		Electrical use (kWh/pig)	
Station	CON	RNT	CON	RNT
NE	2,307	2,307	3.28	3.03
MO	1,070,833	875,000	10.9	9.45
MN	143,200	124,841	2.54	2.50

Summary (XP1)

- The RNT regimen imposed:
  - Had no effect on pig performance
  - Had no effect on morbidity or mortality of pigs
  - Numerically reduced heating fuel and electricity use by 18 and 9%, respectively.

Objectives (XP 2)

- To determine if a more aggressive RNT regimen:
  - Influences pig performance
  - Increases magnitude of fossil fuel savings

Cooperating Universities

South Dakota State University

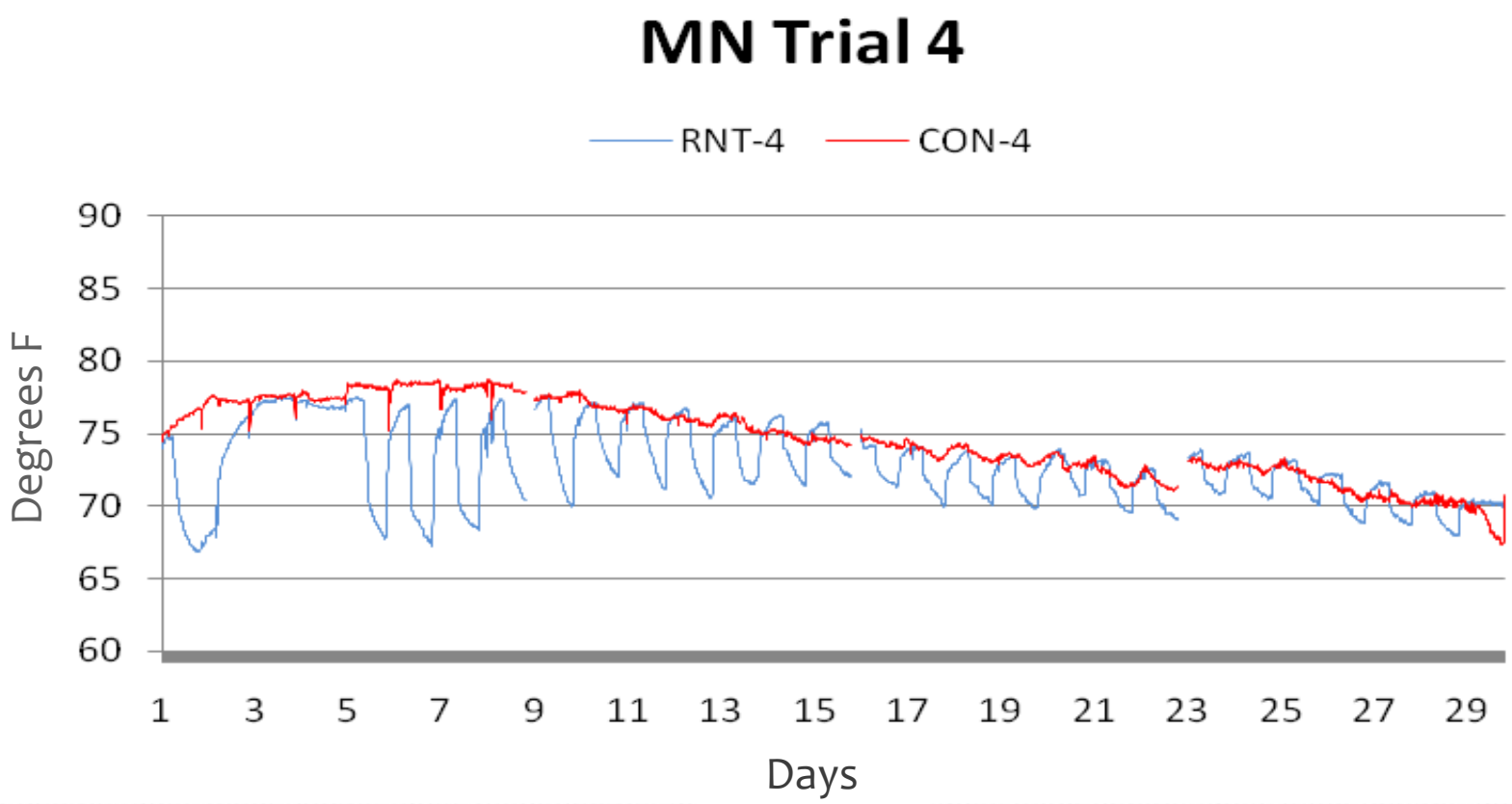
Procedures

- Animals
  - 4,298 weaned pigs weighing 13.7 lb
  - Trial lasted 28 to 42 days
- Facilities
  - Mirror-image nursery rooms used at each site
  - 10 trials conducted at 4 stations
    - OH (2 trials; 1,420 pigs)
    - MN (4 trials; 2,368 pigs)
    - MO (2 trials; 360 pigs)
    - SD (2 trials; 150 pigs)
- Measurements
  - Pig performance
  - Weekly heat/electricity use by room

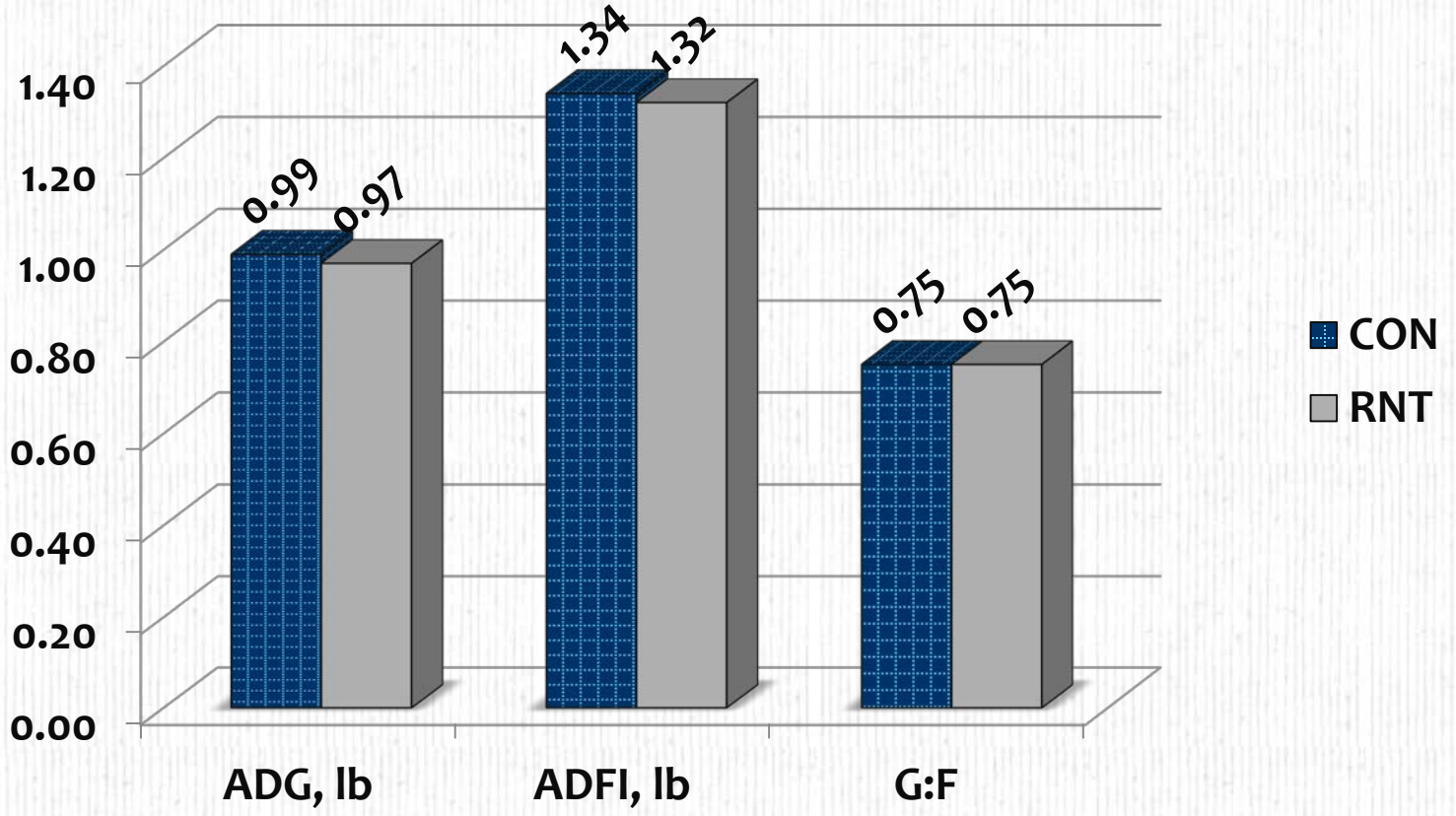
Room Treatments (XP 2)

- Control
  - 86 °F at pig height
  - Lowered temperature 3.5 °F per week (5-6 wk)
- RNT
  - Same as Control during days 1 to 4
  - Beginning day 5, reduced temperature 15 °F 1900 to 0700 hours daily
  - Reduced daytime temperature 3.5 °F per week

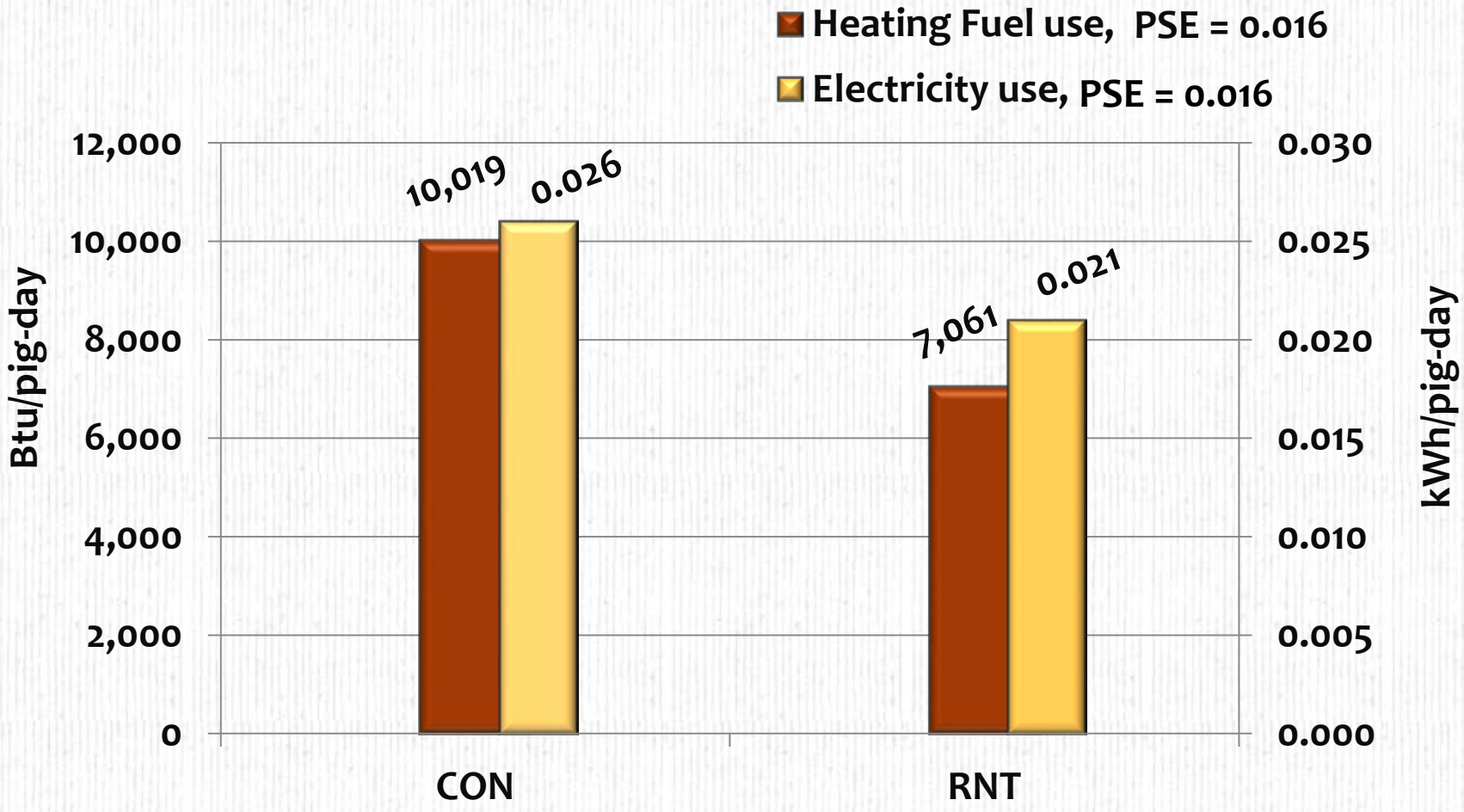
Example Temperature Profile in a MN Nursery Room (XP 2)



Overall Pig Performance (XP 2)



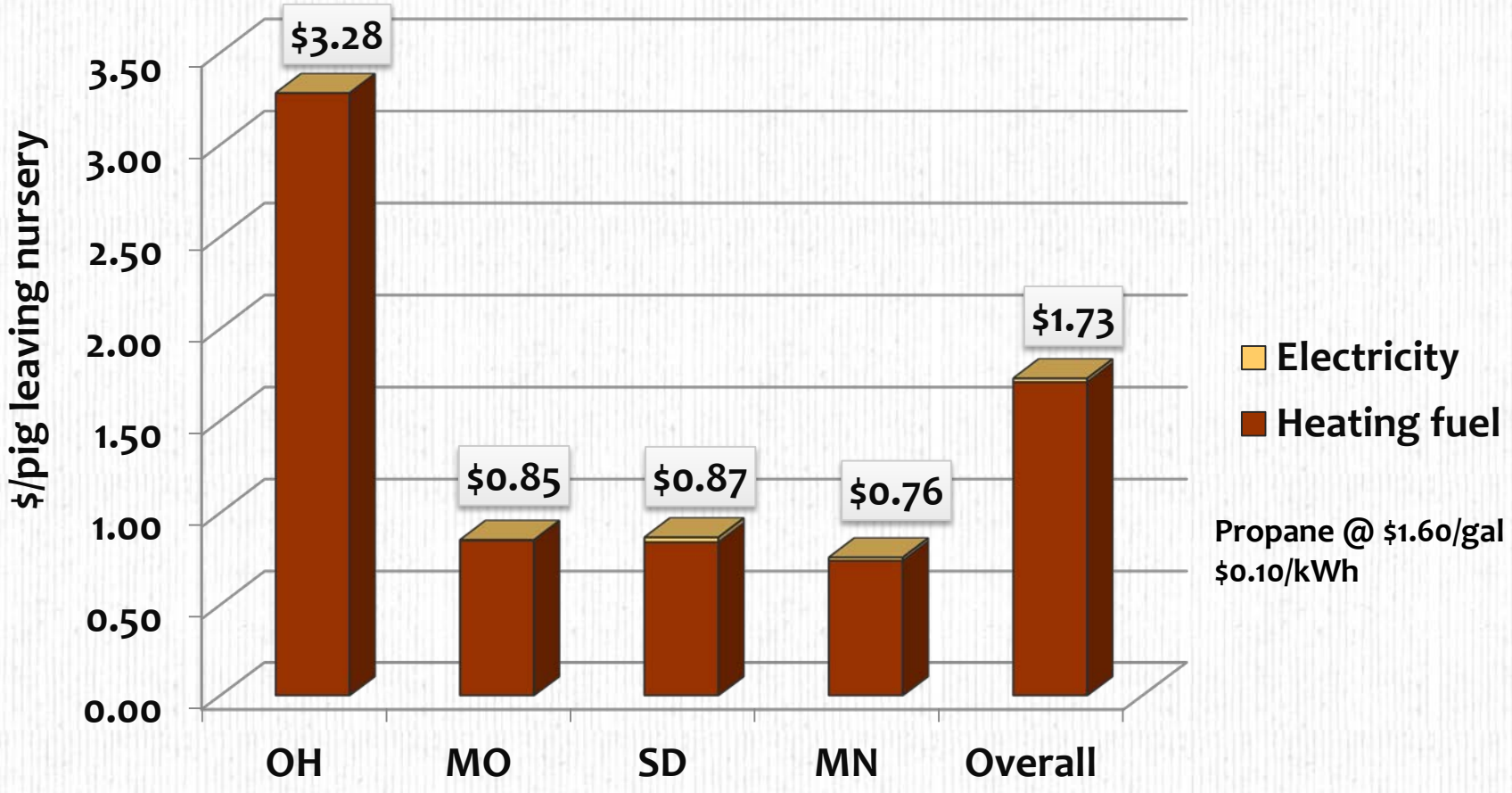
Use of Heating Fuel and Electricity
(XP 2)



Use of Heating Fuel and Electricity Across all Stations (XP 2)

	Trait			
	Heating fuel (Btu/pig-day)		Electrical use (kWh/pig-day)	
Station	CON	RNT	CON	RNT
OH	14,307	8,943	-	-
MO	14,104	12,030	0.020	0.019
SD	7,935	5,714	0.043	0.036
MN	3,009	1,557	0.032	0.026

RNT Cost Savings in Heating Fuel and Electricity



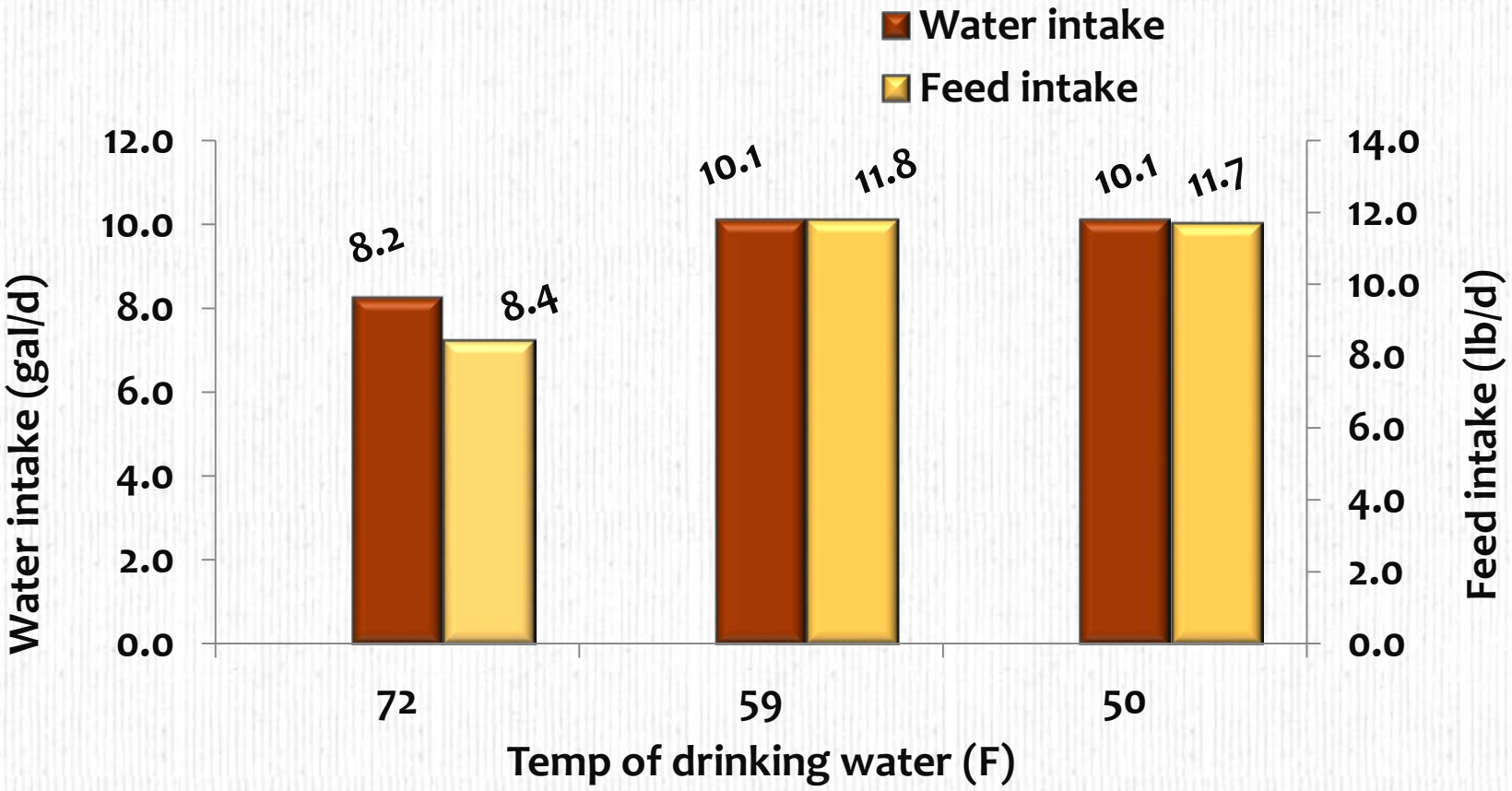
Estimated Reduction in GHG Emissions

- Propane
  - 2,958 Btu/pig/d saved x 35 d = 103,530 Btu saved
  - 103,530 Btu = 1.13 gallons saved
  - 15.2 lb CO_2 equivalents saved/pig
- Electricity
  - 0.005 kWh/pig/d saved x 35 = 0.175 kWh saved
  - 0.3 lb CO_2 equivalents saved/pig
- Total: 15.5 lb CO_2 equivalents saved/pig

Conclusions

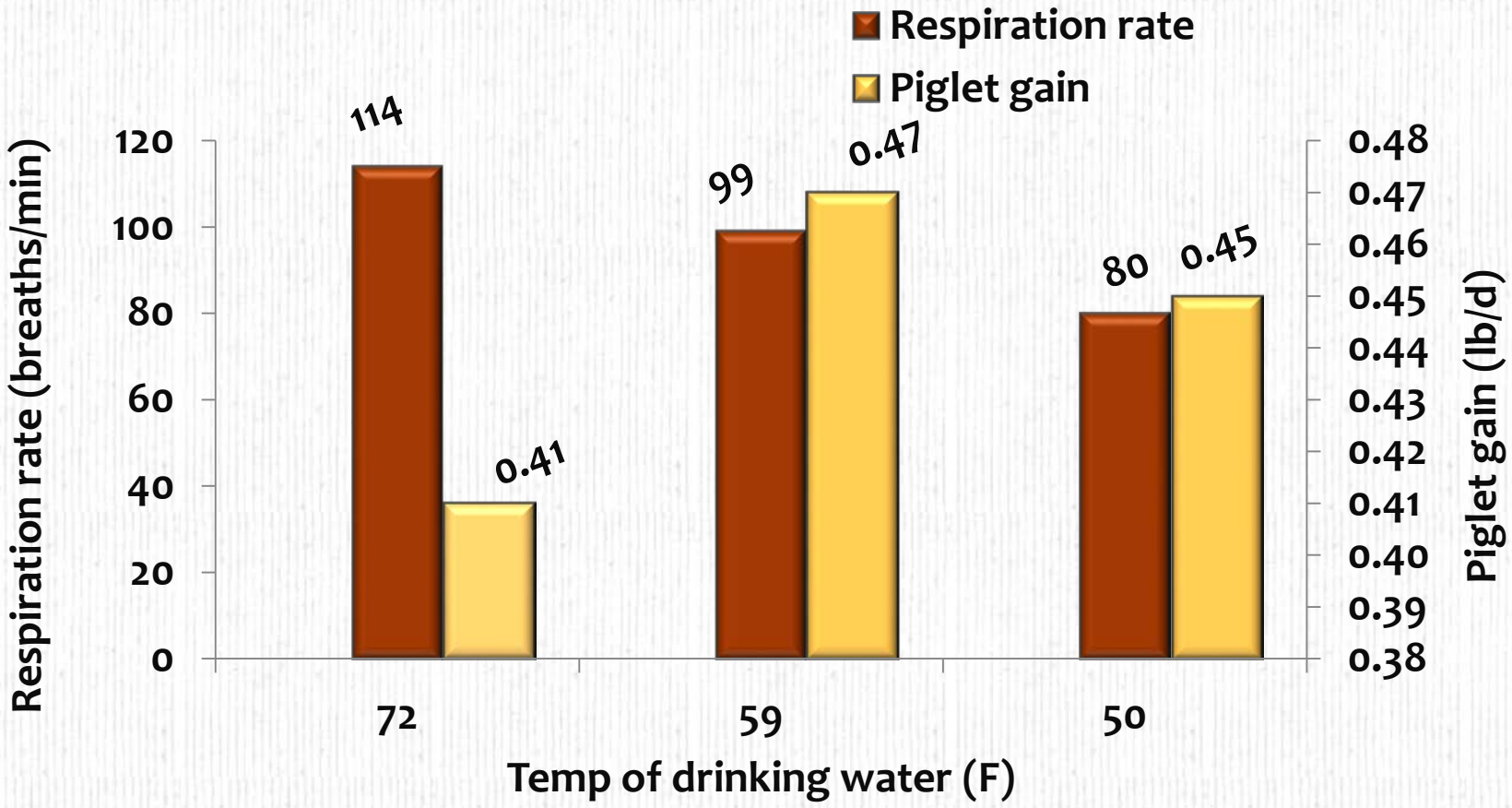
- Reducing room temperature furnace set point by 15 °F at night beginning the 5th day after arrival:
  - Did not influence pig performance or health
  - Reduced heating fuel and electrical use by 29 and 19%, respectively
  - Reduced GHG emissions by 15.5 lb CO_2 -e

Effect of Water Temperature on Performance of Lactating Sows



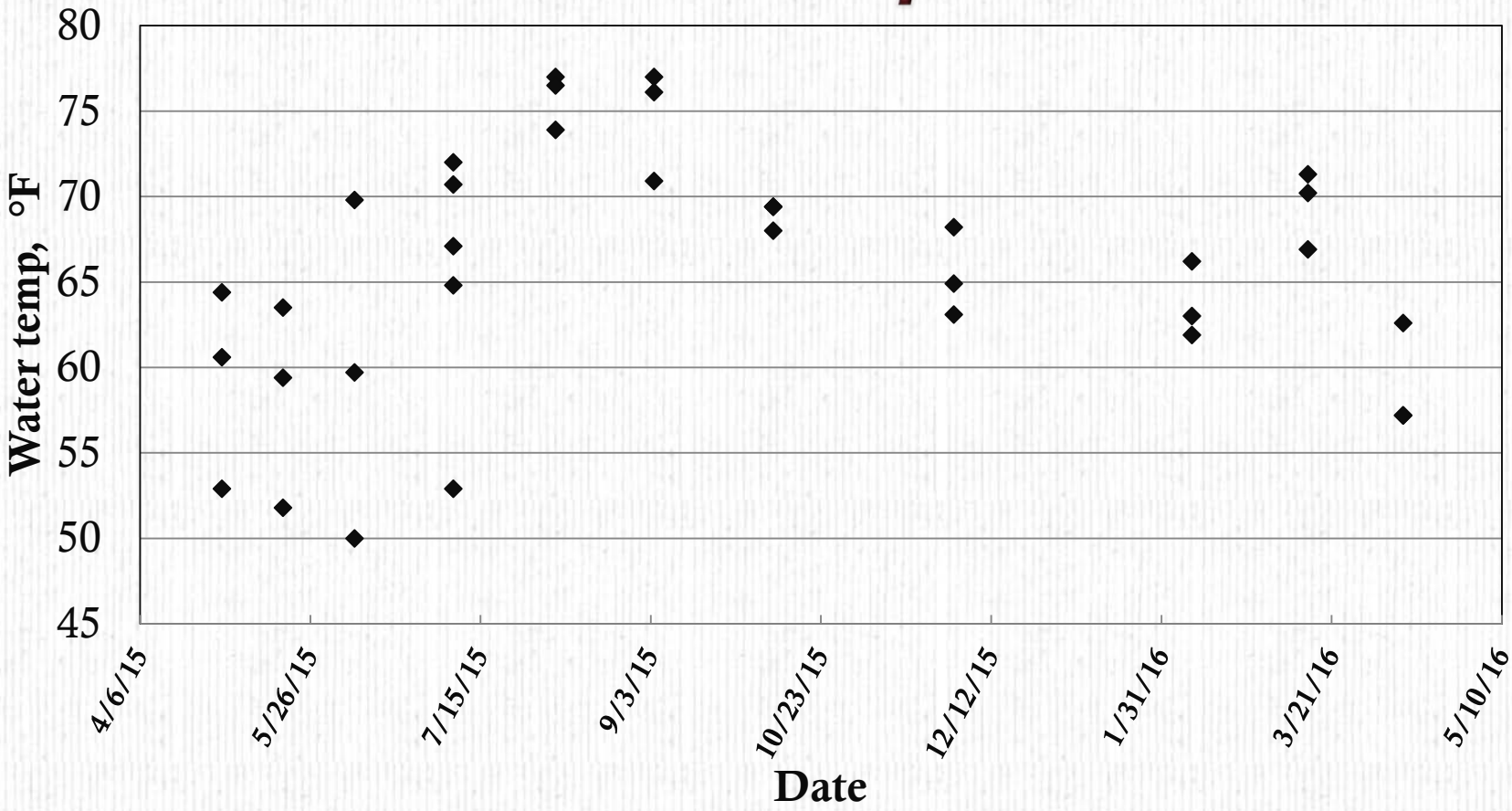
Jeon et al. (2006)

Effect of Water Temperature on Performance of Lactating Sows



Jeon et al. (2006)

Water Temperature in Farrowing Stall Water Cups

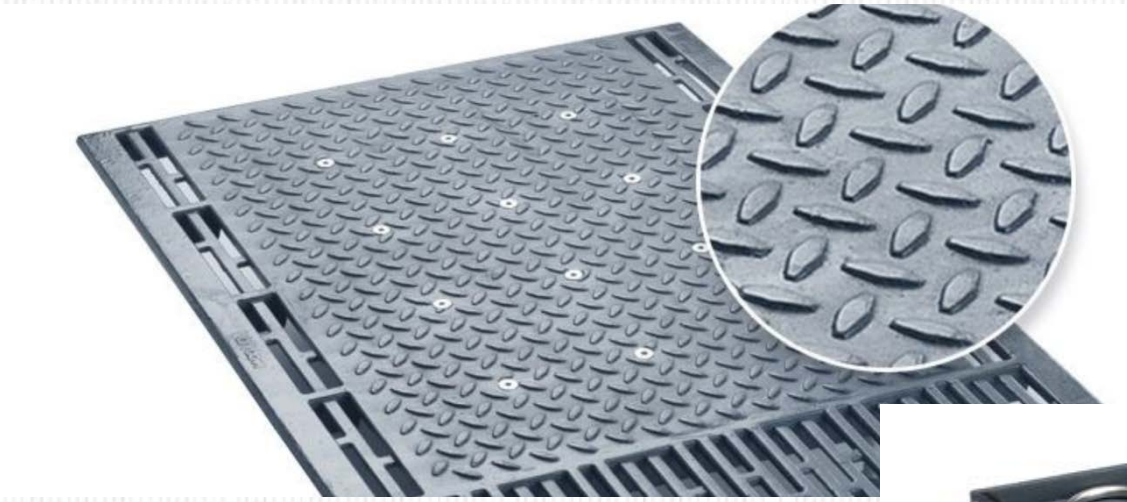


Johnston et al. unpublished

Cooling Sows with Solar Energy?

- Solar PV panels on roof of WCROC farrowing barn
- Use air-source heat pumps or chillers to cool water
- Circulate water under sow for cooling
- Supply cooled drinking water to sows

Cooling Sows with Solar Energy



Nooyen Manufacturing, Netherlands

ECM	Barn	Electrical Savings (kWh/yr)	Natural Gas Savings (therms/yr)	Propane Savings (gallons/yr)	Energy Savings (MBtu)	Energy Cost Savings ($)	Energy Cost Savings Propane ($/yr)	Installed Cost Opinion* ($)	Natural Gas Payback (yrs)	Propane Payback (yrs)
LED Lighting										
	Nursery	6,173	(88)	(97)	12.3	530	430	6,000	11.3	14.0
Daylight Harvesting										
	Nursery	4,999	(70)	(77)	10	430	351	1,500	3.5	4.3
Solar Chimney										
	Nursery	2,100	-	-	7.2	202	202	6,000	29.7	29.7
Curtain Sided Barn										
	Finishing	10,607	(224)	(246)	13.8	856	603			
Earth Tube Pre-conditioning										
	Farrowing	(1,736)	1,349	1,482	129.0	823	2,353	10,000	12.2	4.3
	Nursery	(4,388)	1,899	2,087	174.9	944	3,125	20,000	21.2	6.4
	Finishing	(1,873)	493	542	42.9	181	741	10,000	55.2	13.5
Variable Speed Fans										
	Nursery	1,979	-	-	6.8	191		1,000	5.2	
	Finishing	347	-	-	1.2	33		1,000	29.9	
Heat Lamp Controllers										
	Farrowing	7,431	(194)	(213)	6.0	573	353	3,000	5.2	8.5
Night Temperature Setback										
	Nursery	-	928	1,020	92.8	690	1,734	500	0.7	0.3
	Finishing	-	471	518	47.1	340	880	500	1.5	0.6
Water to Water Heat Pump										
	Farrowing	7,500	-	-	25.6	722		50,000	69.2	
Air Conditioning (Traditional)										
	Nursery	2,593	(17)	(19)	7.2	237	218	80,000	337.6	367.1
	Finishing	3,265	33		14.5	338	314	80,000	236.7	254.4
Air Conditioning (Geothermal)										
	Farrowing	(30,671)	4,607	5,063	356.0	427	5,653	175,000	409.8	31.0
	Nursery	(34,711)	4,634	5,092	345.0	59	5,314	200,000	3,389.8	37.6
	Finishing	(4,780)	1,229	1,351	106.6	441	1,836	150,000	340.1	81.7

Summary

- Consumers and market chains will likely continue demanding:
  - Reduced carbon footprint
  - More environmental sustainability
- Producers have tools to reduce fossil fuel use without compromising animal performance and comfort
- Changes will likely be driven more by consumer demands than economic benefit to producers

Acknowledgements

- Swine: Adrienne Hilbrands, Mark Smith, farm staff
- Renewable energy: Mike Reese, Eric Buchanan, Kirsten Sharpe, Curt Reese, George Nelson, Rachael Acevedo, crops staff
- Funders:
  - MN Pork Board
  - Excel Energy
  - UM Institute on the Environment
  - UM Rapid Ag Response Fund
  - MN Environment and Natural Resource Trust Fund through the Legislative Citizen's Commission on MN Resources