Outline

- Introduction
- On-going engineering research at PSCI
  - Occupational exposure of barn workers
  - Application of nanoparticles to reduce emissions
  - Energy use in swine barns
- Strategies for improving barn energy efficiency
- Take home messages

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PSCI Engineering Research Goals

- To **improve barn environment** through the development of economical and practical techniques ensuring the health and safety of barn workers and animals
- To **reduce the environmental footprint** of pork production through breakthroughs in the science of odour and gas emissions, nutrient and water management, utility and resource efficiency

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Occupational exposure of barn workers

- Background
  - Knowledge gaps:
    - correlate studies on control measures with reduction of worker occupational exposure
    - compare commercial monitoring devices vs. standard assessment methods
  - Compliance with Workplace Safety and Health Regulations
  - Funded by MLMMI

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Occupational exposure of barn workers

- Objectives
  - Evaluate the impact of engineering and management measures on:
    - Ammonia (NH_3) and dust concentrations
    - Occupational exposure of barn workers
    - Pig performance.
  - Compare conventional and standard methods for measuring NH_3

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Measures

- Canola oil sprinkling
- Low crude protein diet
- Manipulation of manure pH
- High level of cleaning
- Control (conventional)

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Analytical methods

- Respirable dust: NIOSH 0600 Particulates not otherwise regulated, respirable
- Ammonia (NH_3):
  - Standard: NIOSH 6015 Ammonia
  - Conventional: GasBadge Pro (Industrial Scientific)

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Area sampling

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Personal sampling

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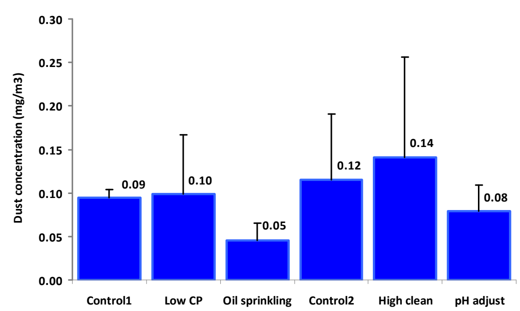
Respirable dust concentration



Threshold Limit Value (TLV) for respirable nuisance dust: **3.0 mg/m³**

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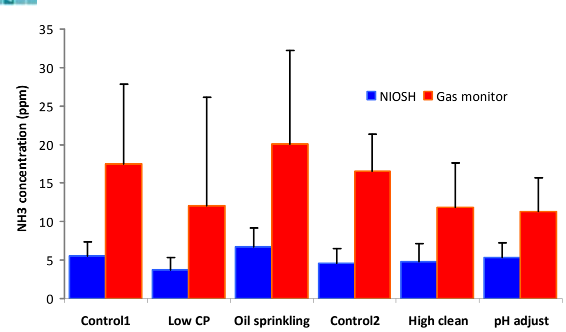
NH_3 concentration



Threshold Limit Value (TLV) for NH_3 : **25 ppm**

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Exposure project

- Current findings:
  - Canola oil sprinkling tended to result in lower respirable dust levels
  - Low crude protein diet can reduce ammonia concentrations
  - Personal monitoring showed higher level of worker exposure compared to area sampling
  - Ammonia gas monitors tended to yield higher readings than the standard (NIOSH) method

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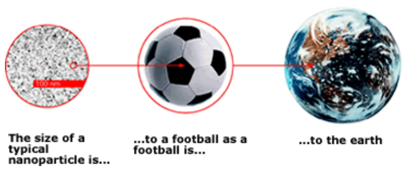
Use of nanoparticles to control emissions

- Nanoparticles – highly-reactive materials; extremely small size and large surface area
- Normal materials (e.g., carbon fibers) – different properties at nanoscale (100x stronger than steel)
- 1 nm = 1 billionth of a meter



Source: http://www.nanoforum.org/educationtree/Images/nanofootball.gif

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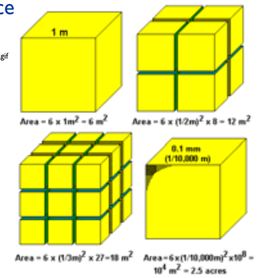
Use of nanoparticles

- Small size = increased surface area

Source: http://www.uwgb.edu/dutchs/Graphics-Geol/GEOMORPH/SurfaceVol0.gif



- Applications:
  - Industrial – coating, pigment
  - Medical – drug delivery, etc.
  - Military – IR, VX gas
  - Environmental remediation
    - wastewater treatment (Hu et al., 2005)
    - water and air purification (Kim et al., 2006; Jain and Pradeep, 2005; Nonami et al., 2004)
    - groundwater remediation (Varadhi et al.,2005; Elliot and Zhang, 2001)

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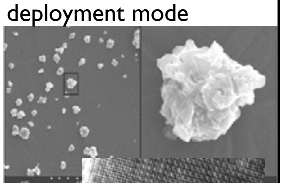
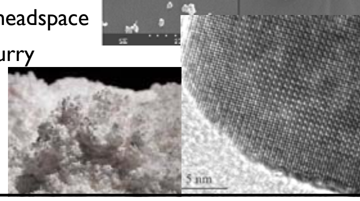
Use of nanoparticles

- To assess impact of nanoparticles on manure gases and determine best deployment mode
- To test various deployment modes:
  - Embedded in filter
  - Dispersed in headspace
  - Mixed with slurry





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Screening of nanoparticles

- Tested 24 commercially available nanoparticles:

- aluminum oxide
- magnesium oxide
- calcium oxide
- aluminum oxide plus
- magnesium oxide plus
- titanium dioxide
- zinc oxide
- lanthanum oxide
- manganese oxide
- iron oxide
- calcium oxide plus
- tungsten oxide
- silver
- bismuth oxide
- silicon oxide
- silicon dioxide
- palladium
- samarium oxide
- tin oxide
- iron nickel
- copper oxide
- indium tin oxide
- silicon carbide
- indium oxide

...zinc oxide (ZnO) showed the greatest potential to reduce gas emissions from manure slurry (Asis, 2008).

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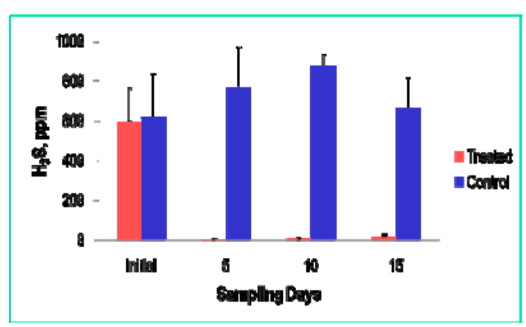
Room-scale tests

- Two identical and fully instrumented environmental chambers
- Deployment methods:
  - Mixing with slurry
  - Recirculation filter

Mixing – effect on H_2S levels



Maximum reduction rate: 99%

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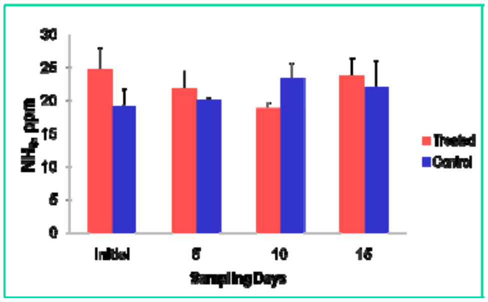
Mixing – effect on NH_3 levels



Maximum reduction rate: 24%

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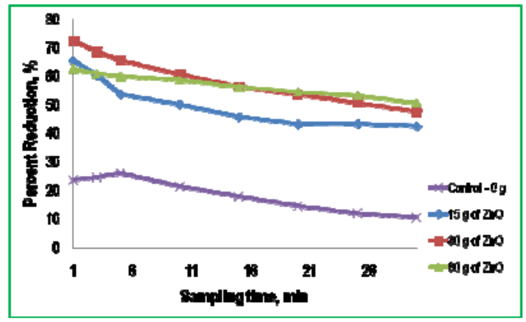
Filtration – effect on H_2S levels



Maximum reduction rate: 72%

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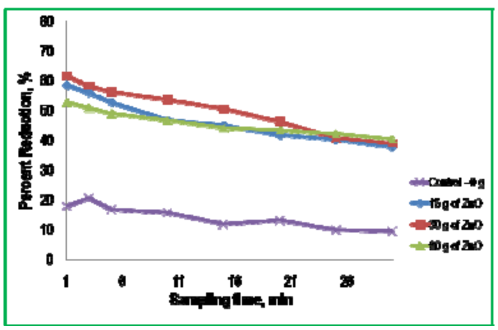
Filtration – effect on NH_3 levels



Maximum reduction rate: 62%

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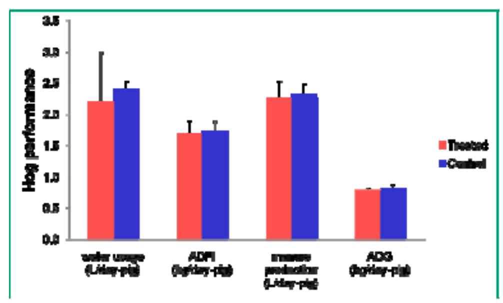
Effect on pig performance



No significant effect on ADG and ADFI

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Use of nanoparticles

- Current findings:
  - Significant reduction in H_2S levels (more than 95%) when ZnO nanoparticles were incorporated into the slurry
  - More than 60% reduction in NH_3 using filter with ZnO nanoparticles
  - No adverse impact on hog performance and manure properties

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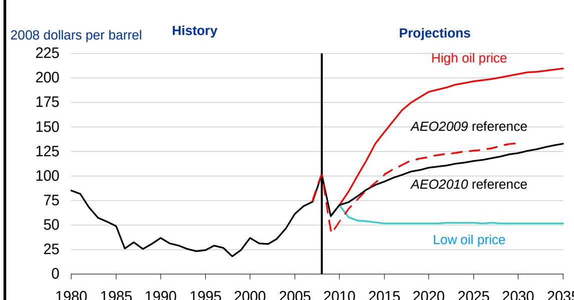
Energy use in swine barns

Oil prices – historical and projected



Source: R. Newell, 2009. *Annual Energy Outlook 2010.*

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Energy use in swine barns

Utilities – 3rd largest cost component

Study conducted at the Prairie Swine Centre (2008):

- Average utility cost (electricity and natural gas) - $5 to $12 per pig produced
- Heating and ventilation – **major portion of total utility cost**
- For a typical 600-sow farrow-to-finish barn (2007-08 prices):
  - electricity bill: ~ $55,000/yr
  - natural gas cost: ~ $53,000/yr

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Project objectives

- Benchmark energy use in the industry
- Evaluate energy conservation measures
- Actual in-barn assessment of selected measures
- Develop decision-support tool

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Benchmarking results

Type of barns	Size range	$/100 kg pig sold		$/animal marketed	
		Range	Average	Range	Average
Farrow-Finish	300 to 1,500 sow	3.5 – 12.0	6.3	3.0 – 12.0	6.8
Farrow-Finish w/o feedmill	300 to 2,000 sow	6.0-11.5	6.3	3.8-13.0	6.5
Grow-Finish	10,000 to 40,000 feeders/weanling	1.2-2.6	1.7	1.3-2.1	1.7
Nursery	130,000-140,000 feeders/weanling	1.7-2.2	2	0.5-0.7	0.6
Farrow-wean	150 to 1,200 sow	8.2-17.8	12.2	0.8-4.3	1.9

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Evaluation of conservation measures

- Use of computer simulation software package - TRNSYS
  - o based on steady state energy conservation laws formulated in thermodynamic quantities
  - o Interface – consists of "input" and "output" quantities
  - ➢ Outputs - solved using successive substitution

Inputs → TRNSYS → Outputs

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Computer simulation model

Base room model: actual G-F room in PSC barn

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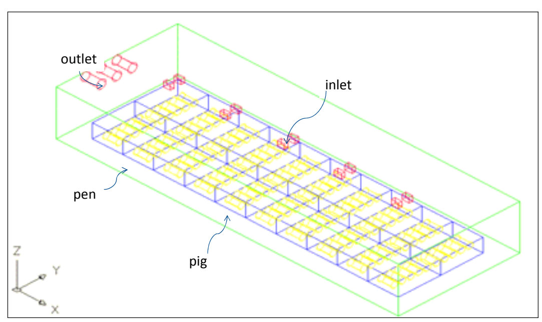
Computer simulation model



Isometric view of a barn geometry drawn using AutoCAD TM

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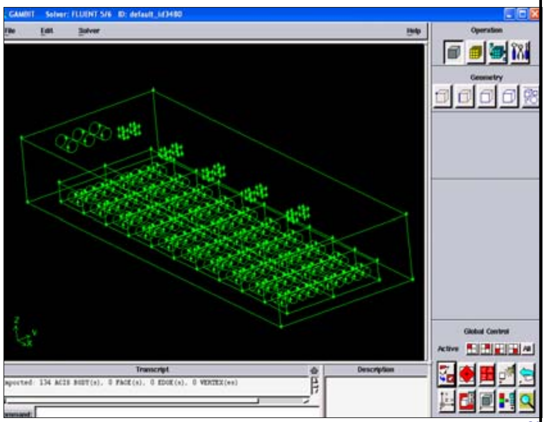
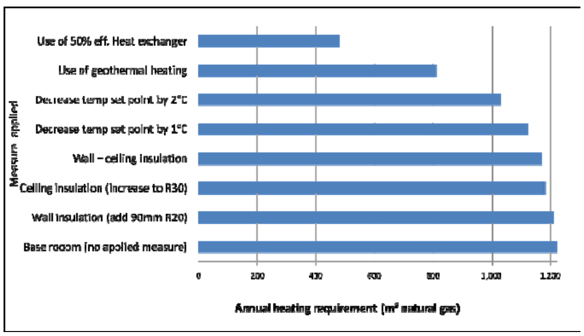


Measures evaluated

Different categories of strategies to improve the energy efficiency of swine barn buildings were identified:

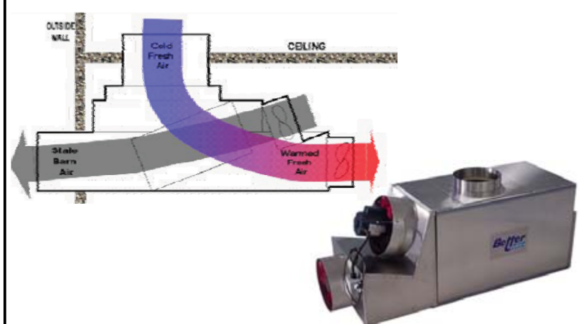
- ✓building construction and materials
- ✓decreasing room temperature set points
- ✓air to air heat exchanger
- ✓geothermal heating
- ✓energy efficient fans
- ✓lighting modifications

Simulation results



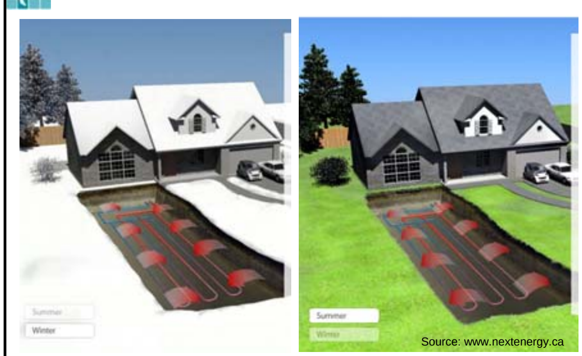
Annual heating requirement associated with different energy measures

Selected measures for barn retrofit



Heat Exchanger

Selected measures for barn retrofit



Geothermal Heating

Barn retrofit

Barn retrof

Barn

Barn retrofit

Barn retrofit – geothermal system

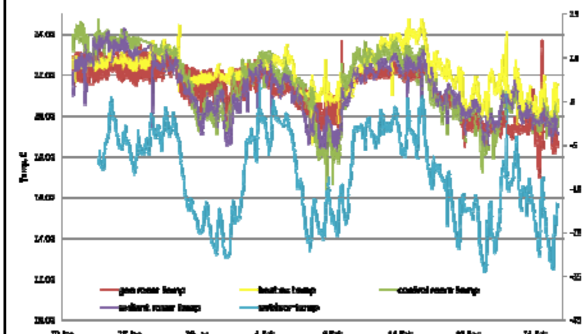
Barn ret

Barn ret

Barn retrofit

Barn retrofit

Barn retrofit



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Results from 5-week data collection

Room	Avg. Room Temp. °C	Consumption for heating	
Control room	21.55	226.71	m^3 natural gas
Heat exchanger room	22.10	42.51	m^3 natural gas
Geothermal heating room	21.25	1206	kWh electricity
Radiant heater room	21.28	331.56	m^3 natural gas

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Energy use in swine barns

- Current findings:
  - Air temperature maintained near set-point
  - Geothermal system and heat exchanger consumed less energy (so far)

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Tips for improving barn energy efficiency

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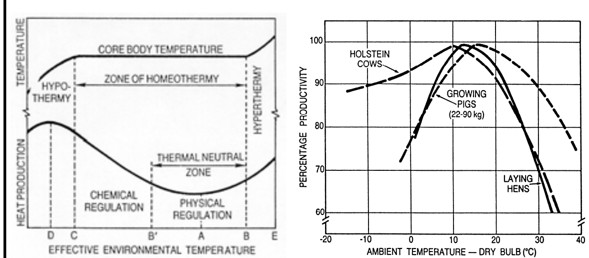
Why do we need to control the environment?

- Environmental temperature impacts animal metabolic heat production, and overall productivity (Esmay and Dixon, 1986).



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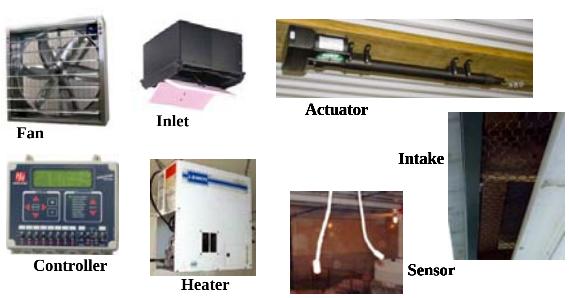
Heating and ventilation components



For optimum performance without wasting energy, the operator has to know each component very well.

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Pop Quiz!

- How do you know if your ventilation system is operating properly?
  - a. Controller readings match the set-points
  - b. Contractor set those things (better be right!)
  - c. Barn staff says so (we're comfortable!)
  - d. Settings exactly the same as my neighbour (must be right!)
  - e. Pigs are happy.

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Bonus question…

- Granted that the pigs are happy, how do you know if your ventilation system is actually not wasting energy?

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Heating and ventilation – things to know

Over-ventilation can waste substantial energy.

- Fans running above the required rate
- Improper fan sizing and staging
- Rooms not filled to design capacity

Over-ventilation and its consequences for a 1,000 head barn with 50-lb pigs.

% over-ventilation relative to baseline case (proper ventilation settings)	Increase in cost of Liquid Propane (LP) over baseline case	% increase in LP cost (over baseline case)
10% over	$1,049 LP increase	27%
20% over	$1,960 LP increase	51%
30% over	$2,970 LP increase	77%
40% over	$4,060 LP increase	105%

Source: Sorensen, 2009.

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Heating and ventilation – things to know

Monitor static pressure in the barn.

Static pressure - measure of the resistance to air movement through the ventilated airspace.

- Higher static pressure – fans need to work harder to overcome this resistance, therefore requiring more energy.

Fan speed (RPM)	Airflow rate at indicated static pressure, CFM: 0 Pa (0 in. H_2O)	12.5 Pa (0.05" H_2O)	25 Pa (0.10" H_2O)	31 Pa (0.125" H_2O)
1675	2172	2112	2028	1988
1355	1775	1622	1473	1385
855	1110	816	273	--
586	482	83	--	--

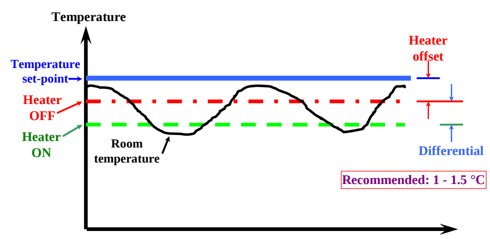
Recommended Static Pressure level: 10 – 25 Pa (0.04 – 0.10 inch H_2O)

Source: Jacobson and Chastain, 1994.

Heating and ventilation – things to know

Ensure proper staging of fans and heaters.

Common Mistake: Heater operation triggers increase in fan speed. Need proper On/Off settings for fans and heaters.



Source: Brumm, 2009.

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Heating and ventilation – things to know

Know your heating and ventilation system components.

- Most common heating and ventilation problems - can be avoided or resolved by knowing the operation of the system
- With modern systems – more capabilities, control/monitor several parameters in multiple zones; if operated wrong, can cause poor conditions and waste significant energy

Heating and ventilation – things to know

Avoid incorrectly sized fans and heaters.

Common Mistake: installing bigger equipment, because 'bigger is better' and it costs only a few dollars more.

Example:

Heater: 100,000 BTU-hr	vs	150,000 BTU-hr
- proper design size		- 50% more capacity, but may cost only <10% more
- runs longer		- runs in short bursts, does not reach correct operating temp., inefficient burn
- more uniform temp.		- large temperature swings
- longer burn time, helps in clearing moisture and gases		

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Heating and ventilation – things to know

Know how much energy your barn consumes.

Need to know: how, where, when, and how much energy is being used in different areas of the barn?

Tools:

- Energy audit – detailed analysis
- Examination of past energy bills
- Energy use tracking programs

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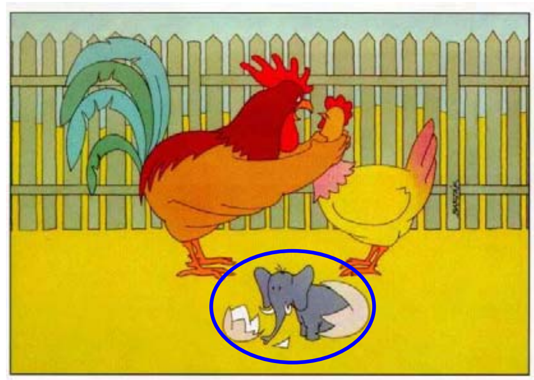
When you don't monitor your barn closely…



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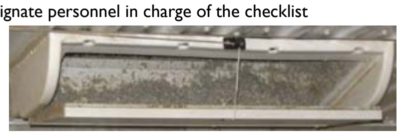
Heating and ventilation – things to know

Implement a monitoring and maintenance checklist.

- All settings - need to be regularly monitored and adjusted accordingly; change with growth stage, season, practices

Example: set-points, staging, offset, dead band, duty cycle, etc.

- periodic checks, adjustments and maintenance activities - required throughout the growth cycle and as season changes
- seasonal tasks in preparation for winter and summer
- designate personnel in charge of the checklist



Source: MacDonald, 2008

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Monitoring and maintenance checklist

Heating and Ventilation System Monitoring and Maintenance Checklist
Prairie Swine Centre Inc.

Name of person responsible: ____________ Name of barn: ____________				Winter (before Nov 15)	Summer (before June 1)	Action required (if any)	Date required action completed	Completed by:
Heating	Heater furnace	Cleaned:		Yes / No	Yes / No			
		Main shut-off valve:	Opened	Yes / No				
			Shut off		Yes / No			
		Variable output valve: (if equipped)	Set to Low	Yes / No				
			Set to High	Yes / No				
		Pilot light:	Lighted	Yes / No				
			Shut off		Yes / No			
	Controller	Checked:	Temperature set-points	Yes / No	Yes / No			
			Settings of fan stages	Yes / No	Yes / No			
			Variable-speed fan bandwidth (not less than 1 °C)	Yes / No	Yes / No			
			Heater offset (1-1.5 °C below room set-point)	Yes / No				
	Sensors (temperature, humidity if equipped)	Cleaned:		Yes / No	Yes / No			
		Calibrated:	(against standard)	Yes / No	Yes / No			
	Fans	Cleaned:	Blades	Yes / No	Yes / No			
			Shutters	Yes / No	Yes / No			
			Discharge cones	Yes / No	Yes / No			

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… and the Emergency and alarm system.

Ventilation		Checked:	Fan rotation (direction of air flow)	Yes / No	Yes / No
			Belt tension	Yes / No	Yes / No
			Motors, housing, blades (i.e., damages)	Yes / No	Yes / No
			Electrical wires, plugs/sockets	Yes / No	Yes / No
	Inlets	Cleaned:	Not blocked with dirt or frozen shut	Yes / No	Yes / No
		Checked:	Uniform opening/closing of all inlets	Yes / No	Yes / No
			Opening size range at least 4 inches	Yes / No	Yes / No
			Actuators functioning properly	Yes / No	Yes / No
	Air intake (soffits/eaves screen/sidewall)	Cleaned:	Not blocked with dirt or ice build-up	Yes / No	Yes / No
		Checked:	Proper slot opening size	Yes / No	Yes / No
	Air leaks	Checked and sealed (if any):	Doors and external openings	Yes / No	
			Fan housing	Yes / No	
			Feeder/auger lines	Yes / No	
		Fan covers:	Installed	Yes / No	
			Removed		Yes / No
	Insulation	Checked:	Attic	Yes / No	Yes / No
			Hot water tank/pipes	Yes / No	Yes / No
			Walls	Yes / No	Yes / No
Emergency and alarm system		Checked:	Back-up power operation	Yes / No	Yes / No
			Emergency thermostat settings	Yes / No	Yes / No
			Alarm functions	Yes / No	Yes / No

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Source: Brumm, 2009

66

Source: Brumm, 2009

67

Source: Brumm, 2009

68

Source: MacDonald, 2008

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Take-home messages

- Know the <u>operation and functions</u> of heating and ventilation system components
- Avoid common heating and ventilation <u>mistakes</u>
- <u>Monitor</u> ventilation settings regularly and implement a <u>maintenance checklist</u>
- <u>Reduce</u> energy consumption if possible, or <u>maximize</u> efficiency of use of required energy.

The barn operator equipped with good understanding of the heating and ventilation components is the <u>best person</u> that can run the system in an optimal manner.

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Acknowledgement

- Sask Pork
- Manitoba Pork
- Alberta Pork
- SK Ministry of Agriculture
- NSERC
- MLMMI
- ACAAFS
- Elanco
- Masterfeeds

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