



PURDUE
UNIVERSITY

Colleges of Agriculture & Engineering
Agricultural & Biological Engineering

Digester Basics

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Workshop on Methane Recovery from Farm & Food Processing Waste

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Richmond, IN

Agenda

- Basics of Anaerobic Digestion (AD)
- AD Classifications and types
- An overview of four digester technologies
- Economic and environmental benefits of digesting manure
- Problems encountered with AD
- Energy generation potential from livestock waste in Indiana
- Promoting energy generation on-farm

What is Anaerobic Digestion?

- **Anaerobic digestion occurs when organic material decomposes biologically in the absence of oxygen**

Truncated History

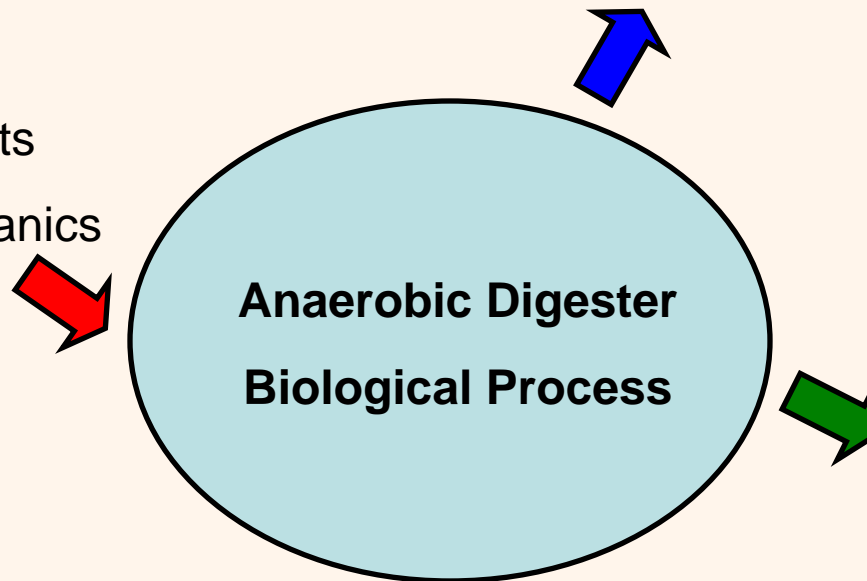
- 1970s - Energy crisis renewed interest in AD
- 1970s - 80s - Lack of understanding and overconfidence resulted in numerous failures
 - China, India and Thailand reported 50% failure rates
 - Failures of farm digesters in U.S. approached 80%

Shefali Verma, Fu Foundation Engineering and Applied Science, Columbia University

Anaerobic Digestion Process Overview

Manure

- Pathogens
- Macronutrients
- Unstable organics



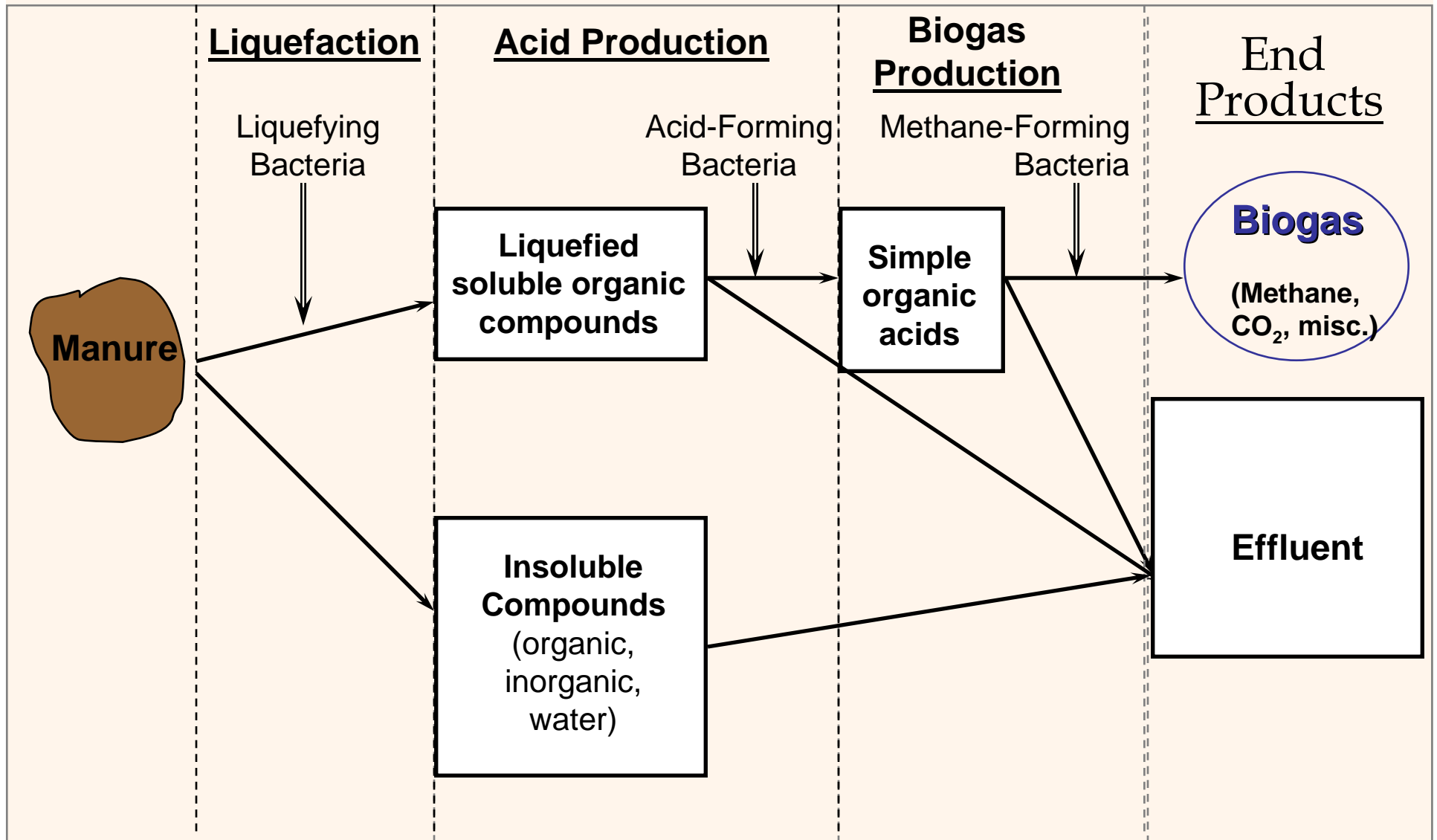
Biogas – Methane (CH₄)

- 50 – 80 % CH₄/vol
- 20-50% CO₂/vol
- Trace gases (H₂S)
- ~ 600 BTU per ft³

Treated Effluent

- Pathogen reduction
- Nutrient rich
- Stable (low odor)

Anaerobic Digestion Process



Biochemical Methane Potential of Manure

Manure Type	BOD (mg/l)	Moisture (% w.b.)	Total Solids (%)	Volatile Solids (% of TS)	Biogas Production (ft³/AU)*
Dairy	18,500	86	14	85	42 - 85
Swine	36,500	87	13	77	43

* AU is “animal unit”, or 1000 lb of animal liveweight

Anaerobic Digestion Classifications

- AD are classified based on:
 - Operating phases:
 - Combined (mixed acidogenic + methanogenic)
 - Two phases (separated acidogenic and methanogenic)



Pix: Courtesy of Microgy, Inc. – Environmental Power Corporation

Ag Anaerobic Digestion Types

- Plug flow digesters
- Mixed plug flow digesters
- Complete mixed digesters
- Temperature-Phased Anaerobic Digesters
- Anaerobic sequencing batch reactor (ASBR)
- Fixed film digesters
- Covered lagoons
- Upflow anaerobic sludge bed (UASB)



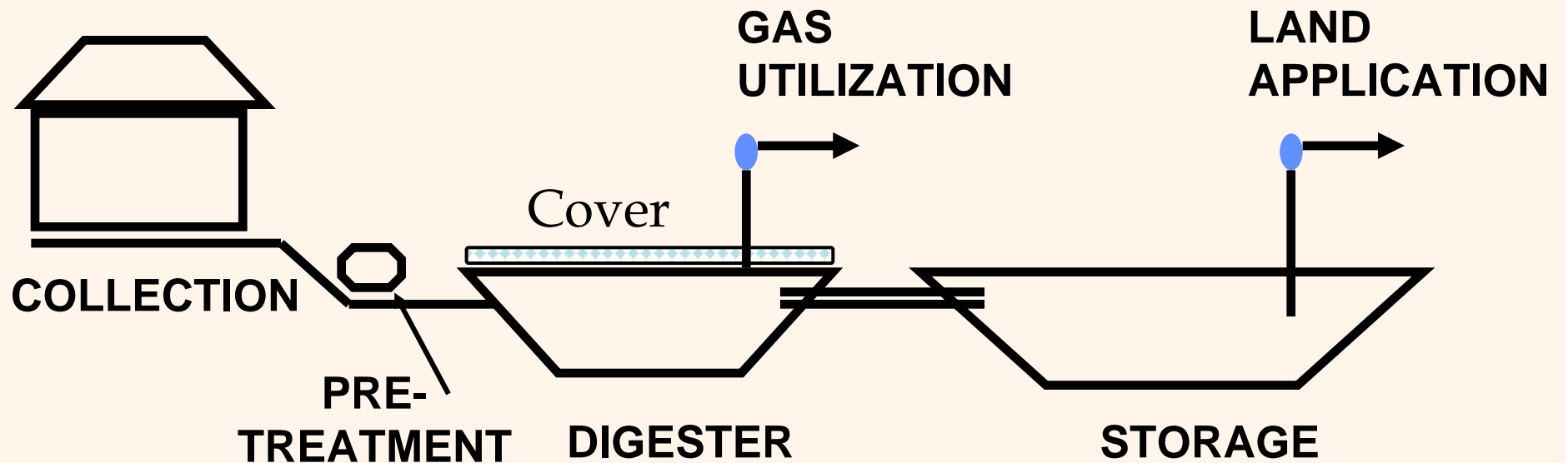
Anaerobic Digestion Classifications

- AD are classified based on:
 - Operating temperature range
 - Psychrophilic: $< 68^{\circ}\text{F}$ (20°C)
 - Mesophilic: 95° to 105°F (35 to 41°C)
 - Thermophilic: 125° to 135°F (52° to 57°C)



Pix: Courtesy of Microgy, Inc. – Environmental Power Corporation

Covered Lagoon



Lagoon typically $\frac{1}{2}$ -2% solids

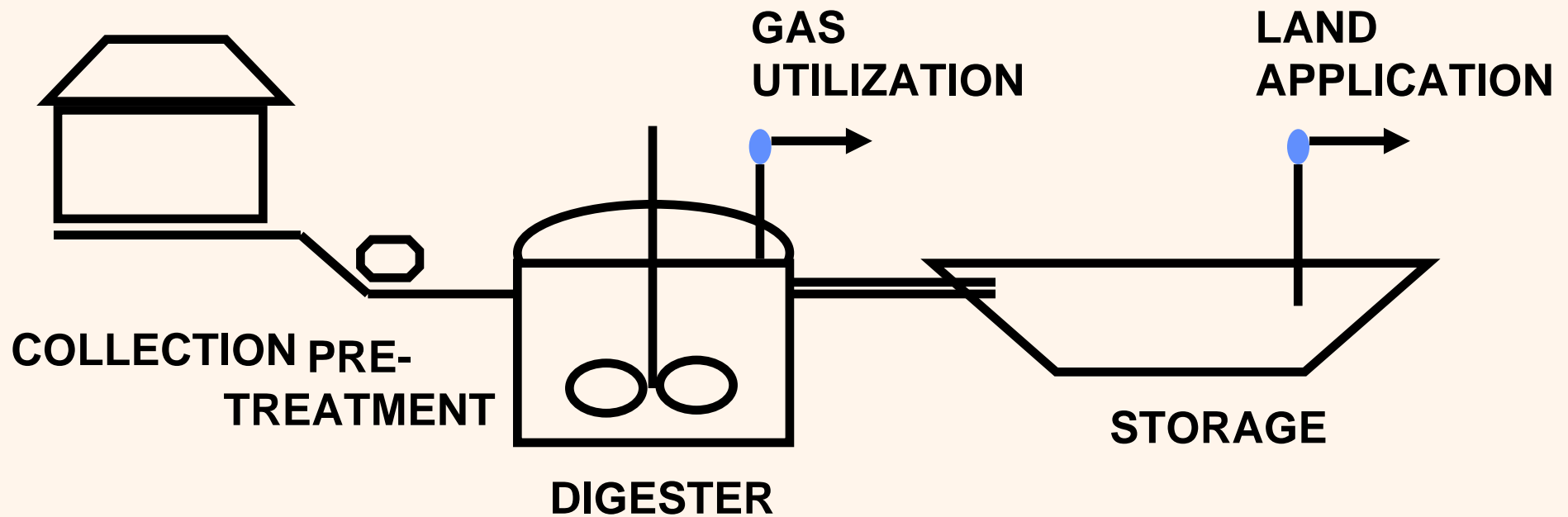
Source: EPA 2005

Covered Lagoon

- Advantages:
 - Relatively inexpensive to build
 - Adaptable to hydraulic flush removal of manure
 - Simple construction and management
- Limitations:
 - Limited to warm weather areas since digestion depends on temperature
 - Manure not completely digested, so some odor released when land applied
 - Lower methane yield than other digesters

Source: David Downing, Iowa Department of Natural Resources, 2002

Complete Mix Digester



Slurry typically 3-8% solids

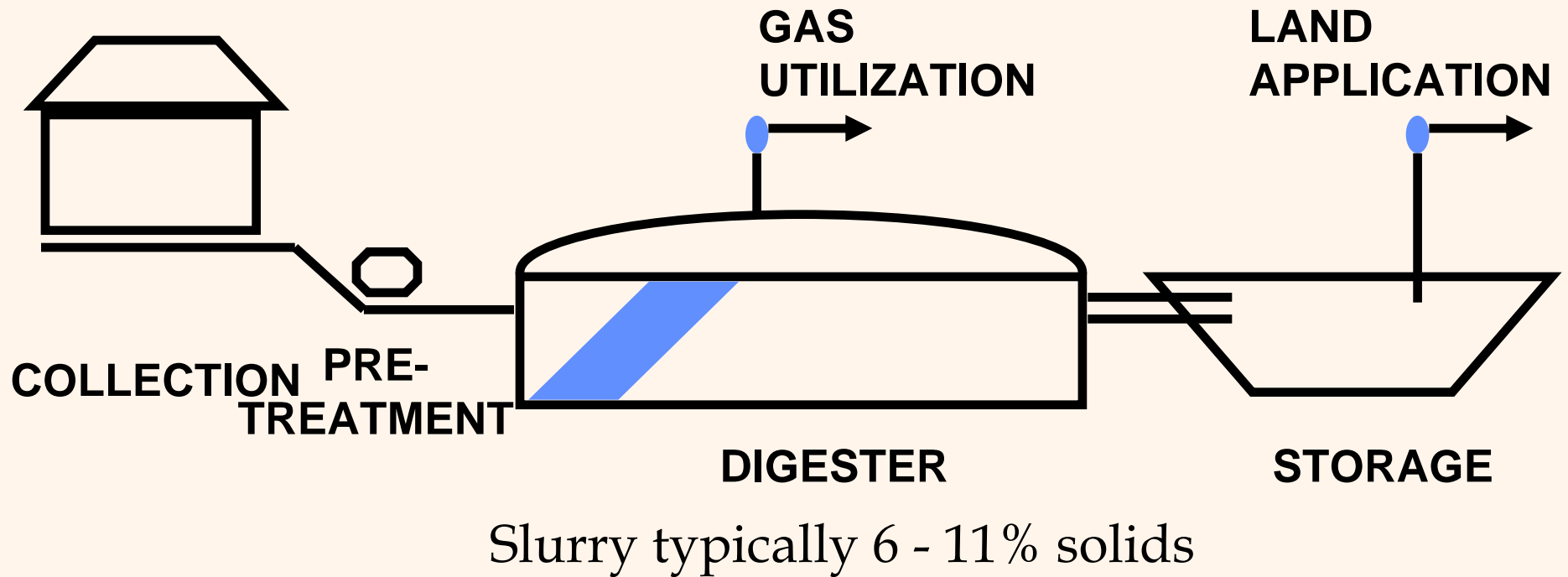
Source: EPA 2005

Complete Mix System

- Advantages:
 - Mechanical mixers prevent crust and keeps solids from collecting on the bottom of the digester tank, delaying cleaning
- Limitations:
 - Requires more maintenance
 - Requires more energy to operate

Source: David Downing, Iowa Department of Natural Resources, 2002

Plug Flow Digester



Source: EPA 2005

Plug Flow Digester

- Advantages:
 - Medium cost range
 - Simpler design that “complete mix”
 - Less labor/management intensive to operate
- Limitations:
 - Most compatible with daily scrape manure systems
 - Requires pre-mix tank ahead of digester

Source: David Downing, Iowa Department of Natural Resources, 2002

Fixed-film Anaerobic Filter

- Upflow digester with porous media
- Bacteria grows on media and feeds on organics passing by
- Wastewater passes thru in 4-6 days but slow-growing bacteria remain in digester – much smaller digester
- Low Food:Mass ratio makes system stable

Economic Benefits of Methane Generation

- Revenue from sale or use of bioenergy
- Reduced solid content in digested waste makes it easier to handle
- Less odor when digested waste is stored and land applied
- Methane capture and utilization reduces methane emissions - a greenhouse gas
- Most weed seeds and pathogens are killed

Reference: Mike Casper, Microgy, Inc.

Performance Difficulties

- Inadequate heat to digester due to engine trouble or maintenance, especially during start-up
- Water pipe break
- Anti-freeze leak in barn killed digester bacteria
- Sanitizing footbath drained to digester killer bacteria
- Mastitis and increase somatic cell counts from recycled bedding
- Problems mainly due to inexperienced and inadequate management/ design issues

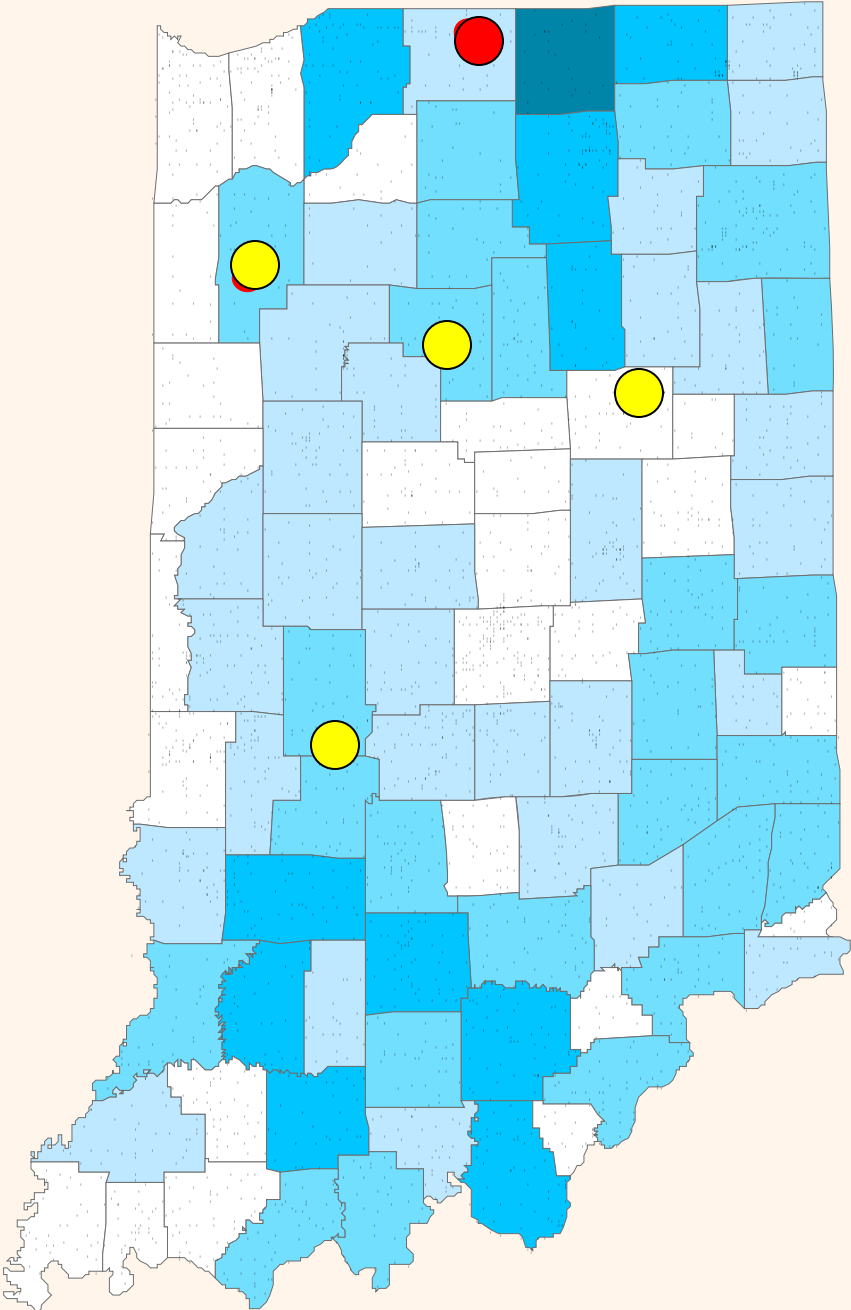
Indiana

Cattle Concentration



Ethanol Plants

- Existing
- Under Construction



Potential Daily Energy Production

	# Livestock	MMBTU CH ₄	MW Electricity
	5000	54.7	16.0
	50001-10000	54.7 - 109.4	16.0 - 32.0
	10001-20000	109.4 - 218.8	32.0 - 64.1
	20001-40000	218.8 - 437.5	64.1 - 128.2
	> 40000	> 437.5	> 128.2

Indiana

Hog Concentration

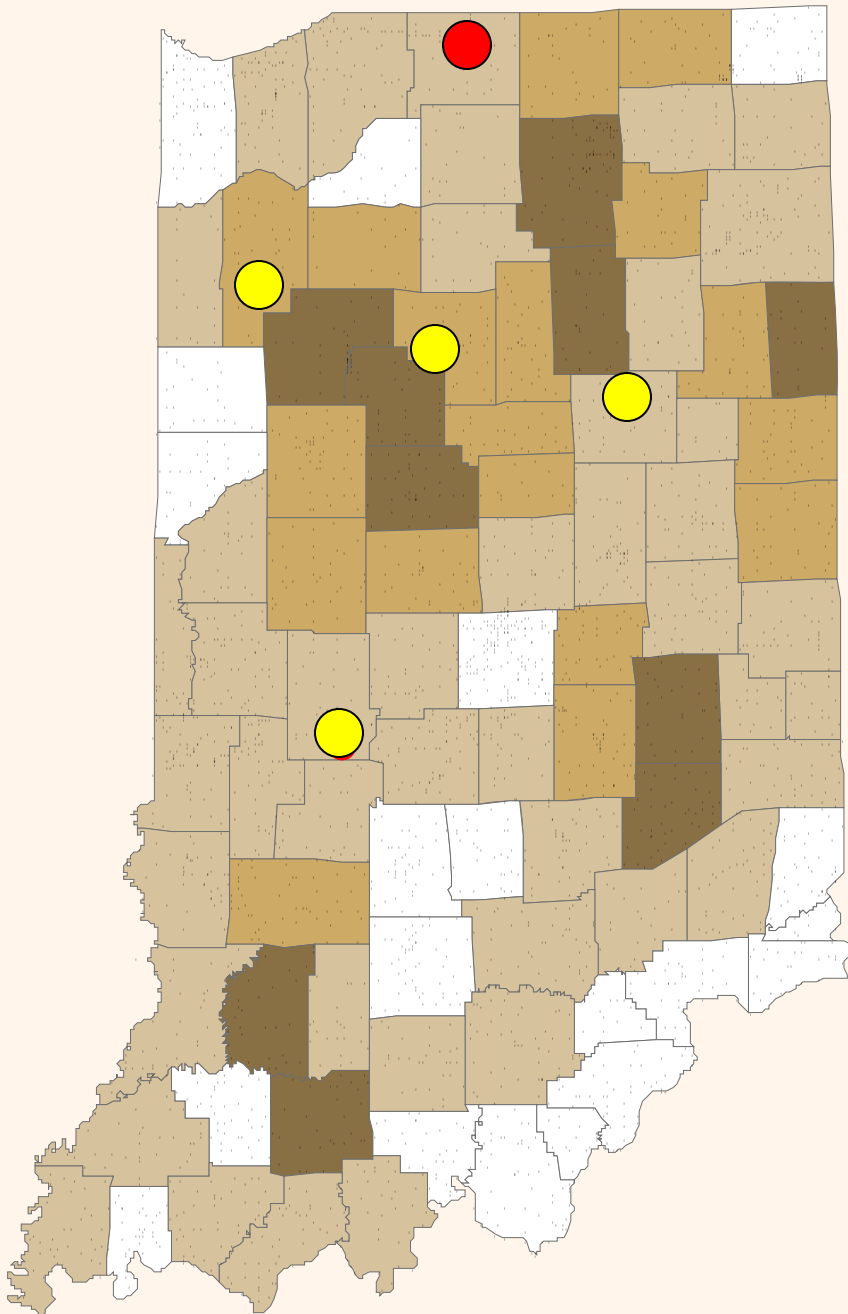


Ethanol Plants

- Existing
- Under Construction

Potential Daily Energy Production

	# Livestock	MMBTU CH ₄	MW Electricity
	< 10000	22.5	6.6
	10001-50000	22.5 – 112.5	6.6 – 32.9
	50001-100000	112.5 – 224.9	32.9 – 65.9
	> 100000	> 224.9	> 65.9



Why has methane production not been successful in the US?

- Industry still in infancy
- High capital costs
- Low wholesale electricity prices
- Government has not promoted investment in energy generation
- Lack of support industry
- Lack of knowledge and long-term data needed to run successful on-farm methane digester

Promoting On-farm Energy Generation: What Government must do?

- Need grants for capital investments PLUS develop market incentives and price support mechanisms to grow the industry
- Indiana has no Renewable Portfolio Standards (RPS)



U.S. Environmental Protection Agency

The AgSTAR Program



The AgSTAR Program is a voluntary effort jointly sponsored by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture, and the U.S. Department of Energy. The program encourages the use of methane recovery (biogas) technologies at the confined animal feeding operations that manage manure as liquids or slurries. These technologies reduce methane emissions while achieving other environmental benefits.

Web site: <http://www.epa.gov/agstar/>



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