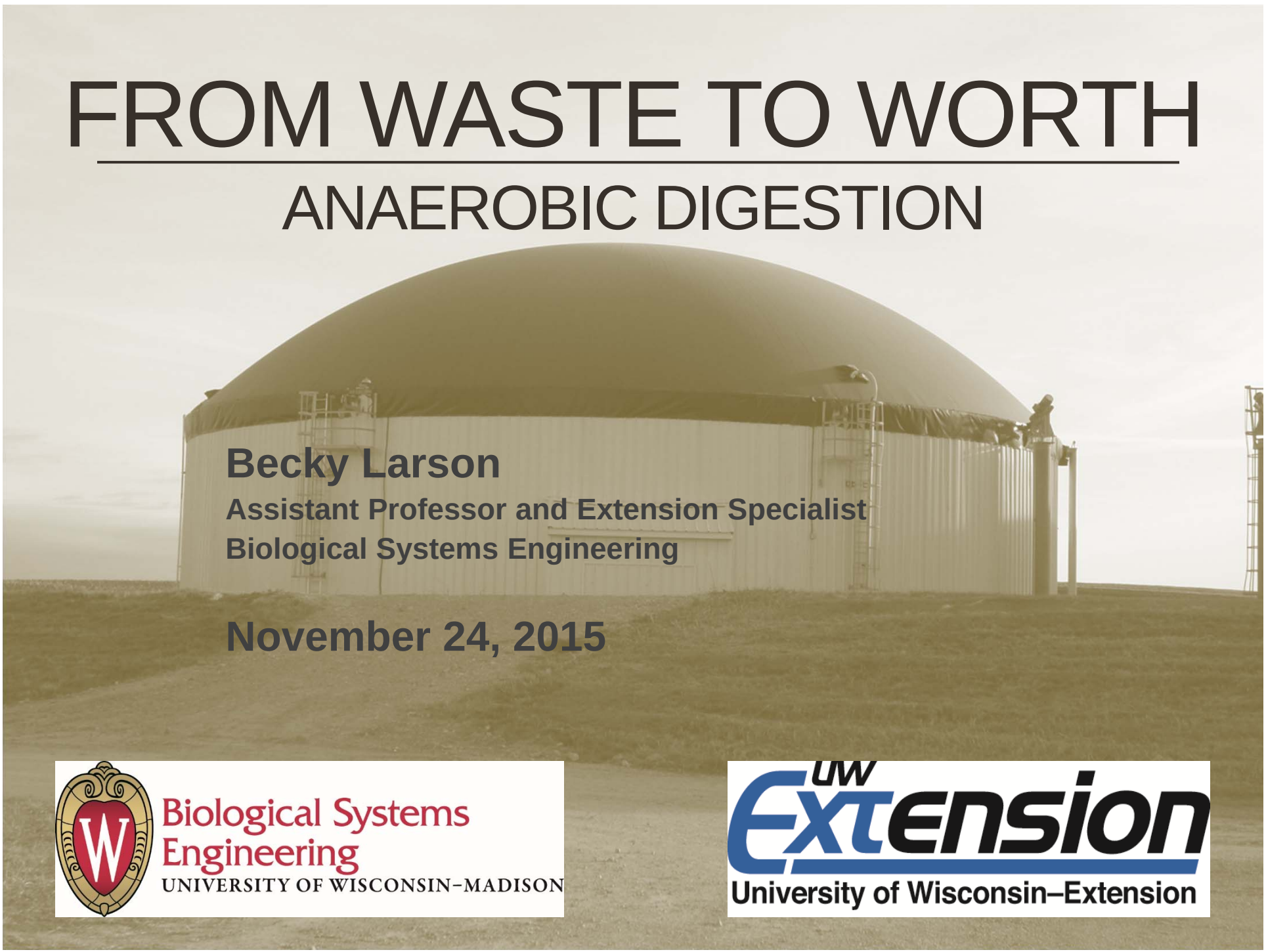
FROM WASTE TO WORTH

ANAEROBIC DIGESTION



Becky Larson
Assistant Professor and Extension Specialist
Biological Systems Engineering

November 24, 2015

Biological Systems Engineering
UNIVERSITY OF WISCONSIN-MADISON

UW Extension
University of Wisconsin–Extension

What is Anaerobic Digestion?

- Biological process
- Breakdown of organic materials (called feedstocks)
- Absence of oxygen (anaerobic conditions)
- Produced biogas - methane (CH_4) and carbon dioxide (CO_2)

Why install a digester?

- Energy independence
- Reductions in green house gases
- Flexibility in manure management
- Reduced odors & pathogens
- Reduction in other environmental impacts
- Potential for additional asset streams (?)
  - Bedding
  - Tipping fees
  - Environmental credits
- Profits?
- What can’t digesters do?

Anaerobic Digestion in the U.S.

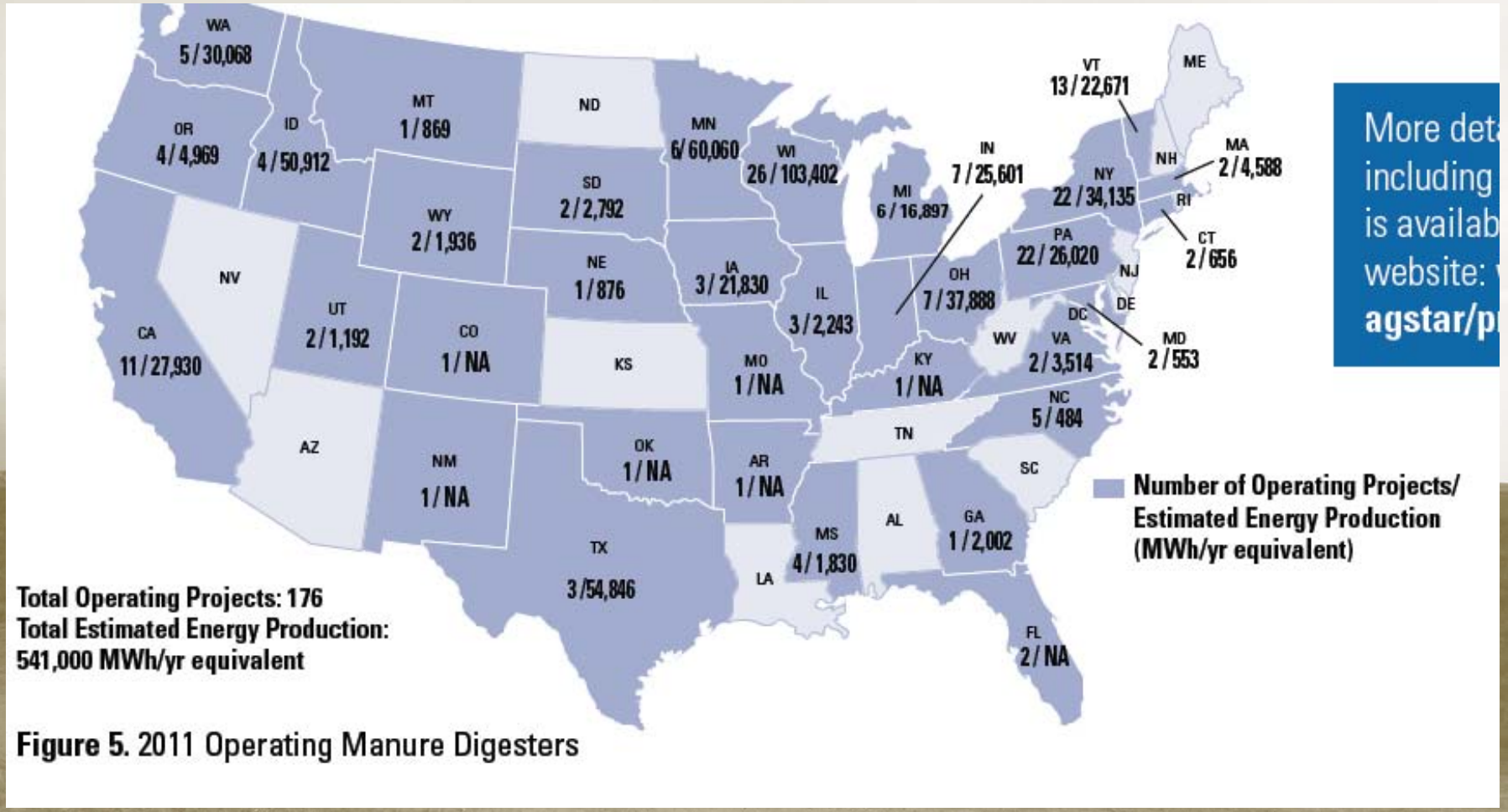


Figure 5. 2011 Operating Manure Digesters

USEPA AgSTAR, 2011

Anaerobic Digestion Livestock & Swine Operations

Animals	No. of Digesters Operational or in Construction	Methane Emissions Reductions (metric tons CO2-eq/year)	Shutdown Projects
All Livestock	261	3,480,955	52
Swine	39	1,491,718	10

- North Carolina has 10 swine digesters, others are scattered around country
- Operational from as far back as 1985
- From 1,200 to 1,200,000 million animals
- Completely mixed, covered lagoons, mixed plug flow designs
- Gas use in boilers, electricity, cogeneration, flares

USEPA AgSTAR, 2015

Currently Operational and Potential Biogas Systems in the United States				
	Livestock Manure	Landfill Gas	Water Resource Recovery Facilities	Total
Currently Operational Biogas Systems	239[xi]	636[xii]	1,241[xiii]	2,116
Total Potential Number of Biogas Systems	8,241[xiv]	1,086[xv]	3,681[xvi]	13,008

Figure 5 - Currently Operational and Potential Biogas Systems in the United States Creating Energy

Estimated Energy Potential from Biogas Sources in the United States[xvii]				
	Livestock Manure	Landfill Gas	Water Resource Recovery Facilities	Total
Biogas Production Potential (billion cubic feet/year)	257[xviii]	284[xix]	113[xx]	654
Annual Energy Production Potential (MMBTU/year)	142,000,000[xxi]	142,000,000[xxii]	67,000,000[xxiii]	351,000,000
Annual Electricity Potential (billion kWh/year)	13.1[xxiv]	22.5[xxv]	5.6[xxvi]	41.2
Equivalent Residential Electricity Use (1000 homes/year)[xxvii]	1,089	1,864	539	3,492
Potential Vehicle Fuel Gallons Displaced (million GGE)[xxviii]	1,031	1,028	441	2,499

Figure 6 - Energy Potential from Biogas Sources in the United States

Biogas Opportunities Roadmap

Voluntary Actions to Reduce Methane Emissions and Increase Energy Independence

U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Energy

August 2014

Traditional Anaerobic Digestion Process Flow

Biogas

Feedstock's

Slurry

Digestate

Filtrate (liquid)

Separator

Fiber (solid)

Anaerobic Digestion Feedstocks

Cheese Whey

Yard Clippings

Cattle Manure

Municipal Organics

Cucumber Waste

Food Processing Waste

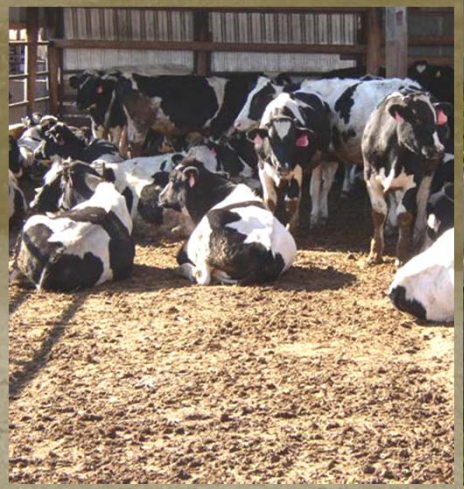
Dairy Manure

Human Waste

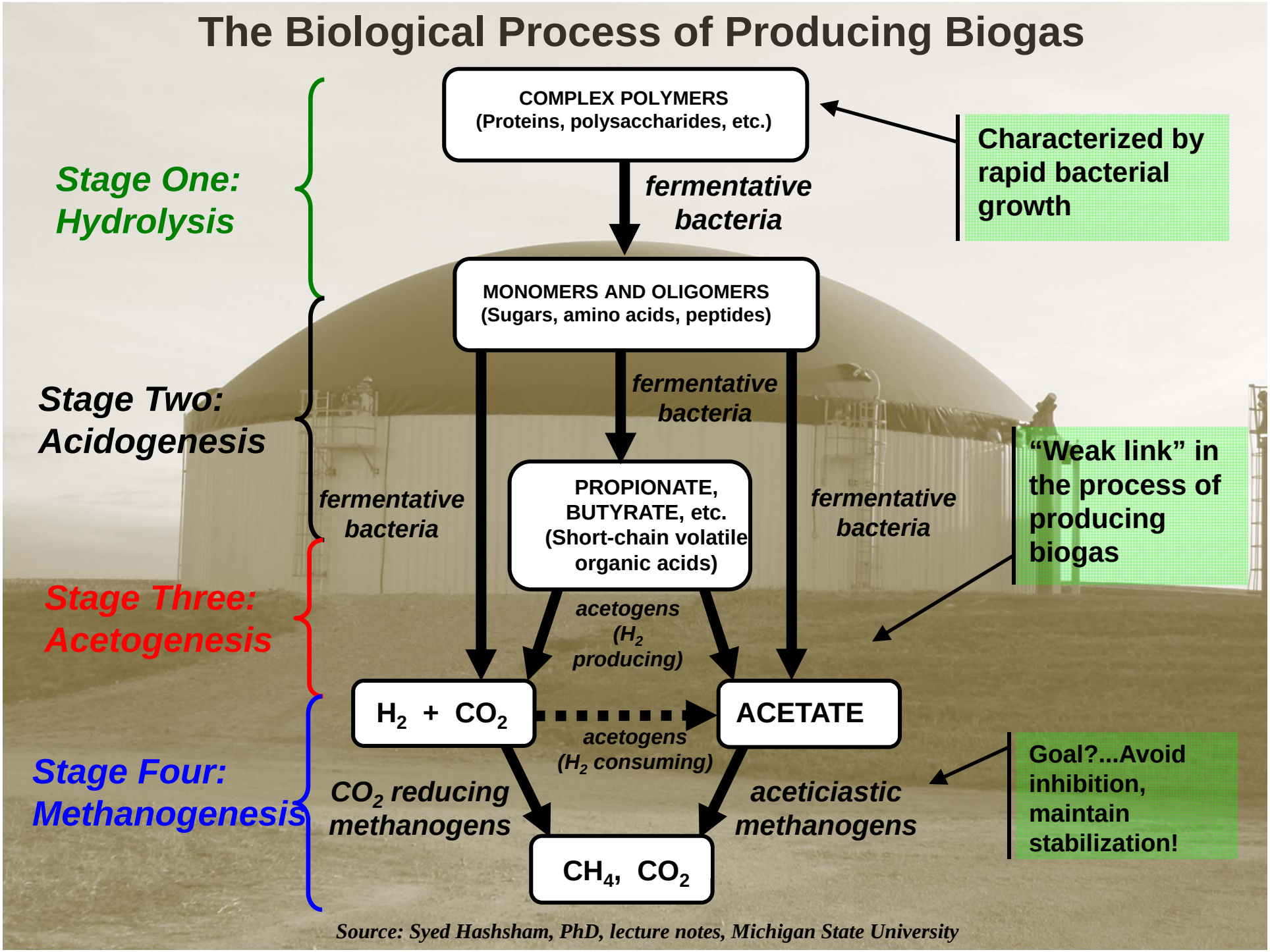
Grasses

Swine Manure

Vegetables

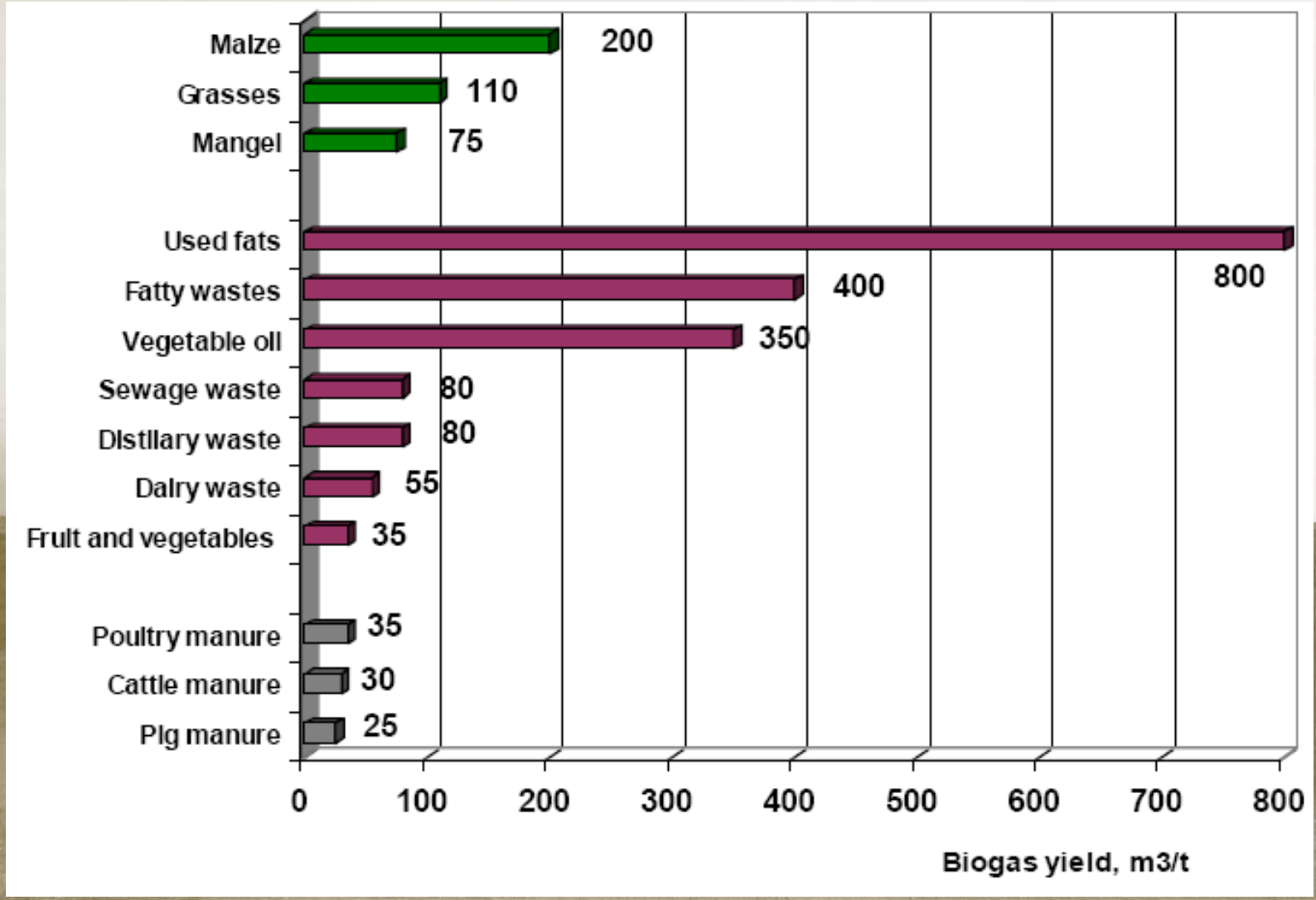


The Biological Process of Producing Biogas



Source: Syed Hashsham, PhD, lecture notes, Michigan State University

Biogas Yield



Kestutis Navickas. 2007. Bioplin Tehnologija in Okolje,

Anaerobic Digester
Completely Mixed and Plug Flow

AD System Types

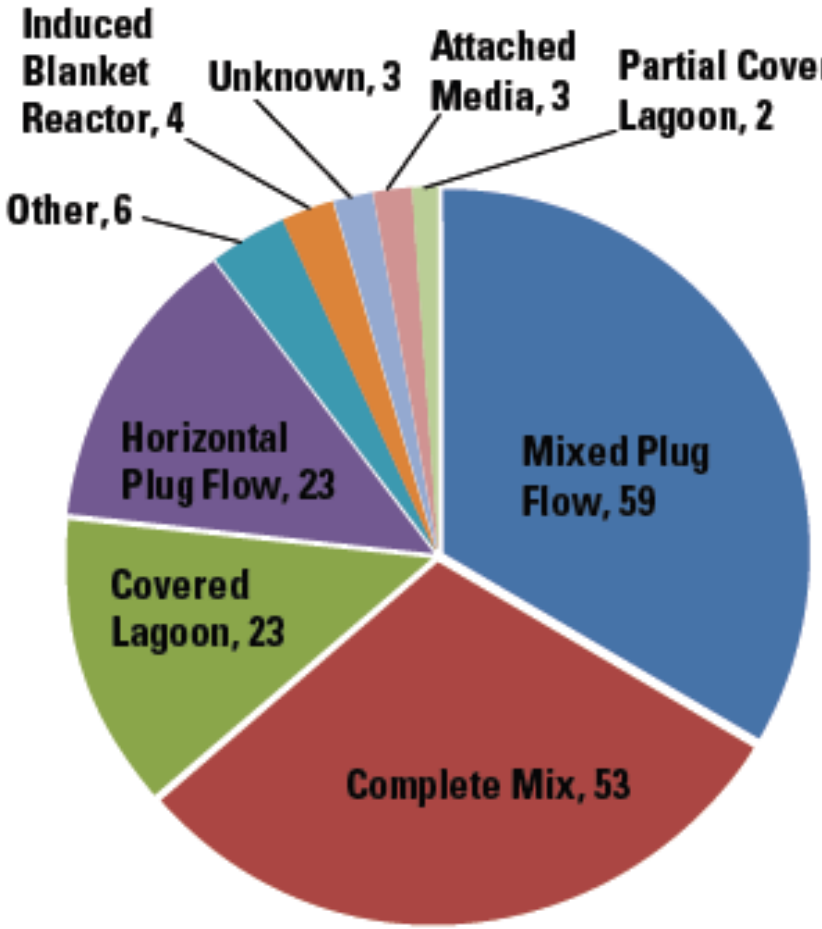


Figure 4. Number of Currently Operating U.S. Digesters by Technology (Dec 2011)

Covered storage

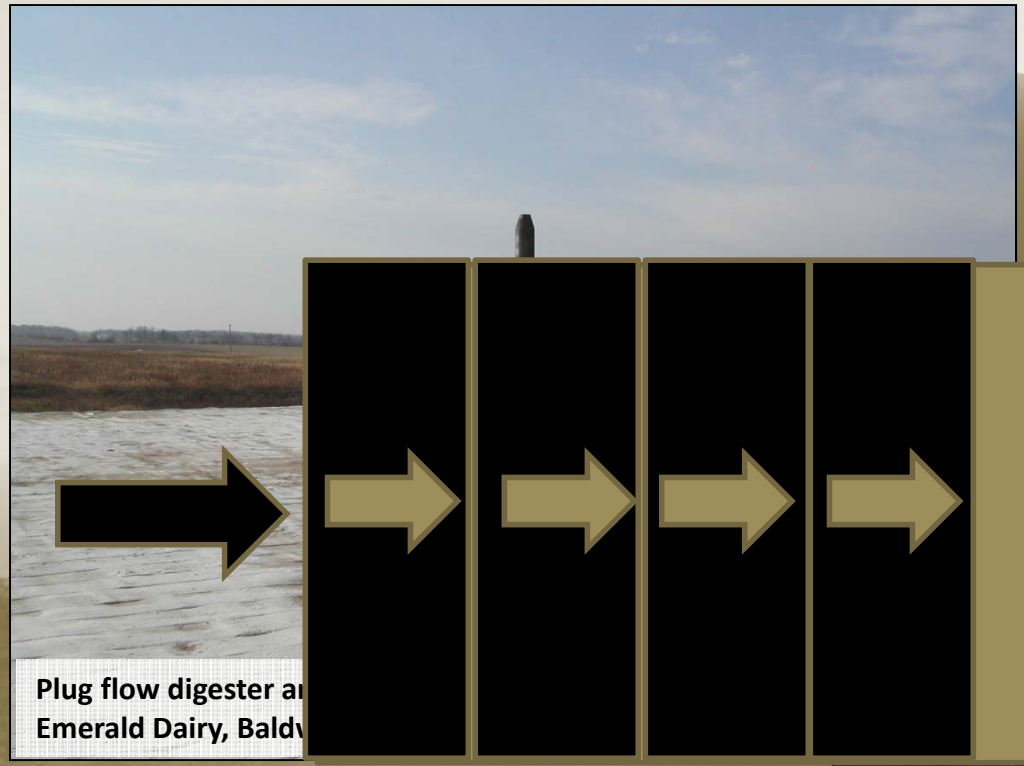
Advantages included odor control, low cost, integrated manure storage and minimal operational costs

Disadvantage include seasonal biogas production in cold climates and difficulties with sludge removal

Covered Lagoon Digester and Flare
Baldwin Dairy, Baldwin, WI

Covered Lagoon at a Swine Farm
Olivia, MN

Plug flow & mixed plug flow



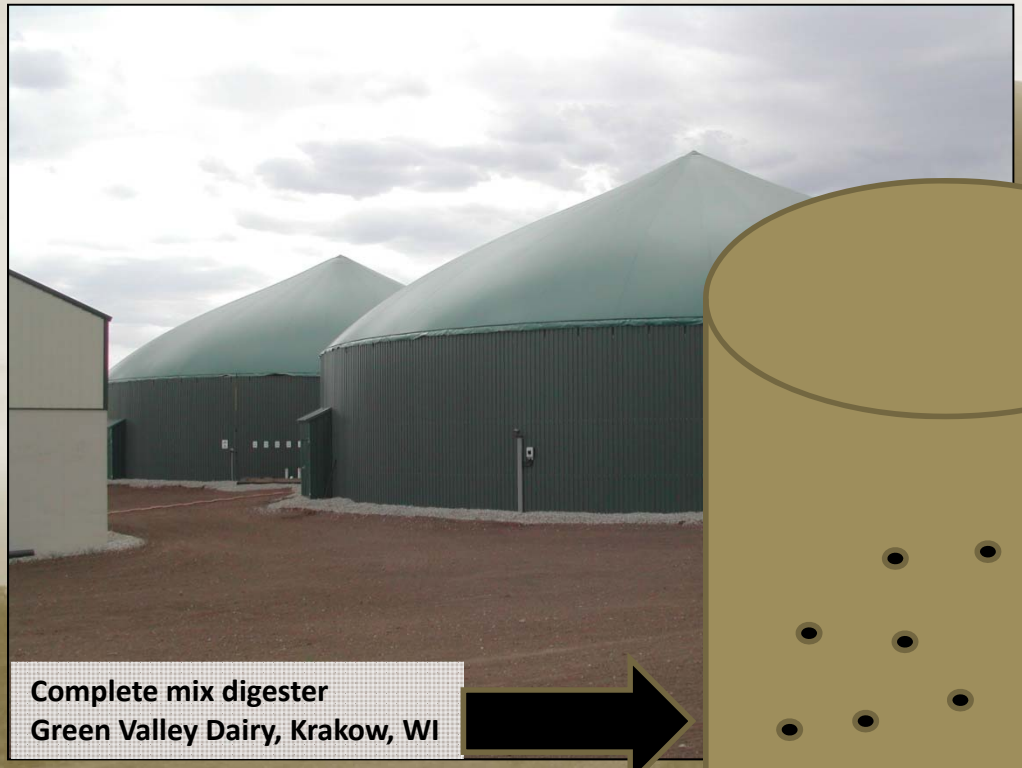
Plug flow digester ar
Emerald Dairy, Baldv

Inside a plug flow digester under construction
Baldwin Dairy, Baldwin, WI

Advantages include low cost of construction and ease of daily operation

Disadvantage include the limited range of feedstock TS concentration

Completely mixed



Complete mix digester
Green Valley Dairy, Krakow, WI

Complete mix digester
Five Star Dairy, Elk Mound, WI

Inside a completely mixed AD

Slow speed agitator fixed to the digester floor

Submersible mix mounted to a mast

Inside a complete mix digester under construction
Westfalia, Germany

Fixed film

Fixed film digester
ROPA, Regensburg, DE

Fixed film digester media
J.J. Farber Farm, East Jewett, NY

Advantages include low cost of construction and ease of daily operation

Disadvantage include the limited range of feedstock TS concentration

Dry Digestion

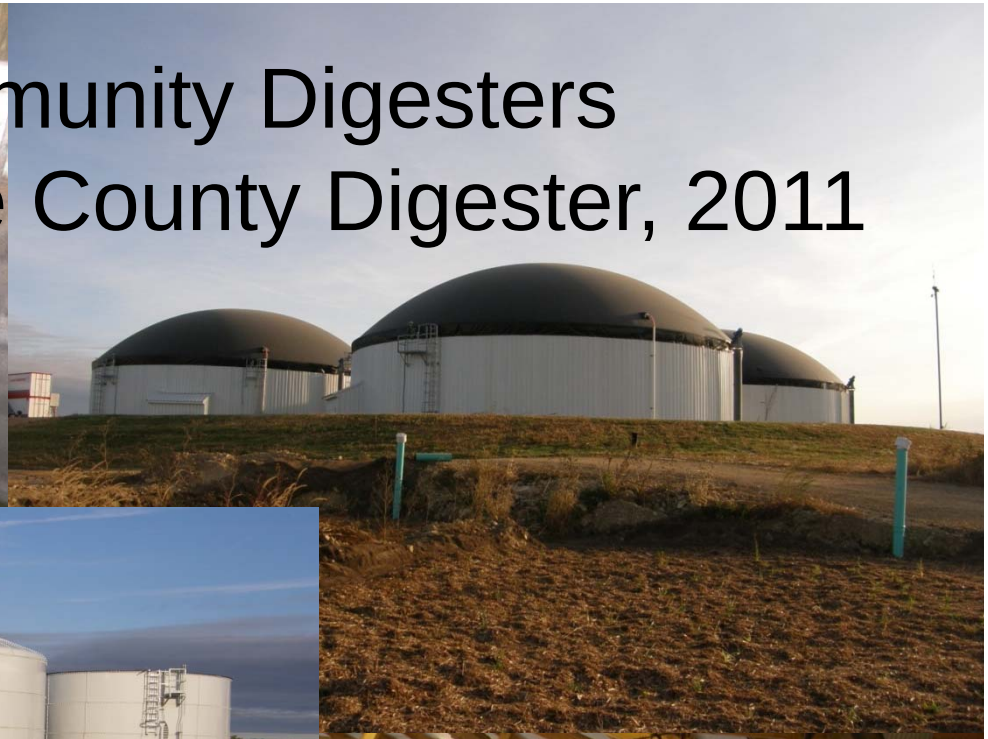
OshKosh Dry Digester, BIOFerm

Small Scale Digesters

Small Scale Digestion

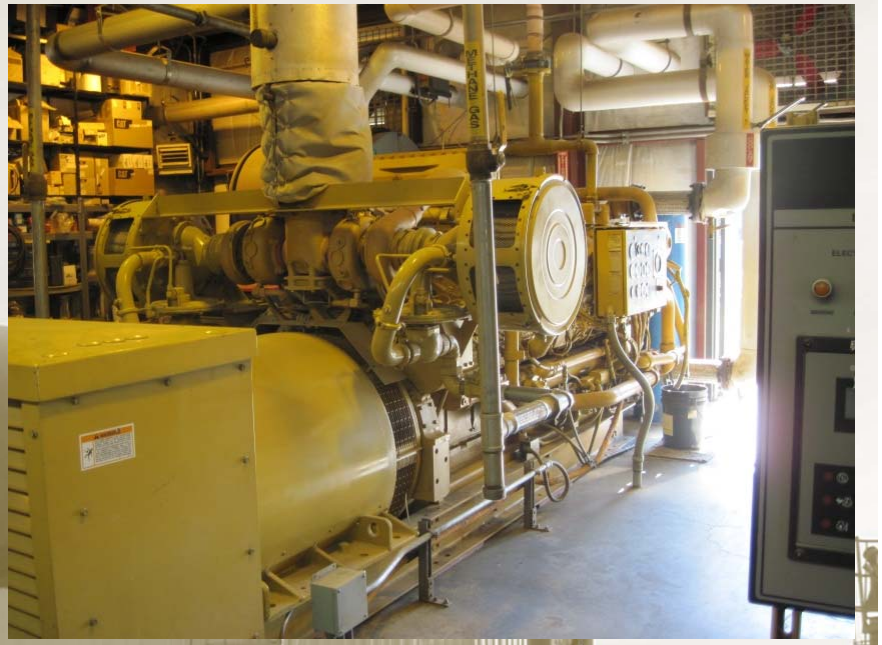
Ecofys bag digester, ecofys.com

Community Digesters
Dane County Digester, 2011



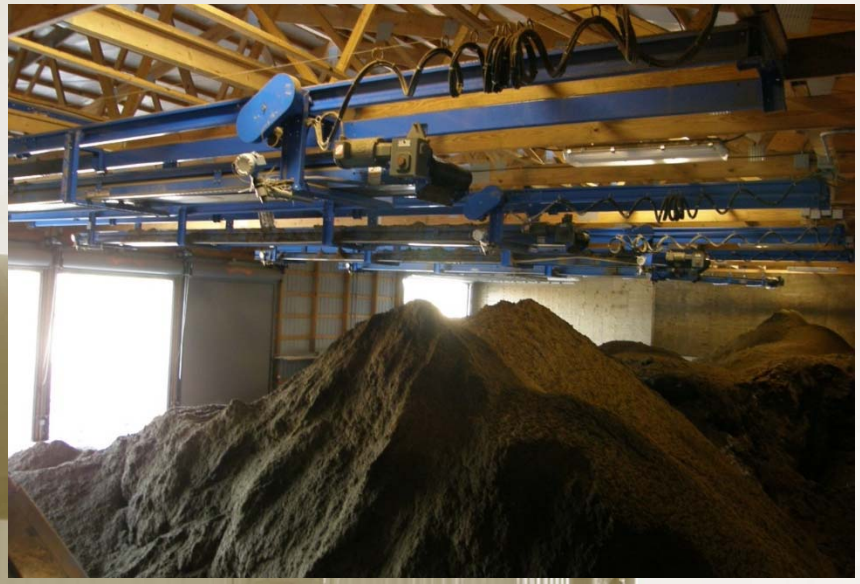
Biogas

- Biogas Components
  - CH_4 (50 – 65%)
  - CO_2 (40 – 50%)
  - H_2S (<1%)
  - Other Trace Elements (?)
- Generator (CHP) – electricity production
  - Most common (ease of use)
  - High cost
  - Requires pretreatment or specially designed equipment
- Compressed Biogas
  - High cost of clean-up
  - Requires design
  - High revenue
- Biogas Treatment
  - High cost systems
  - Multi-phase approach

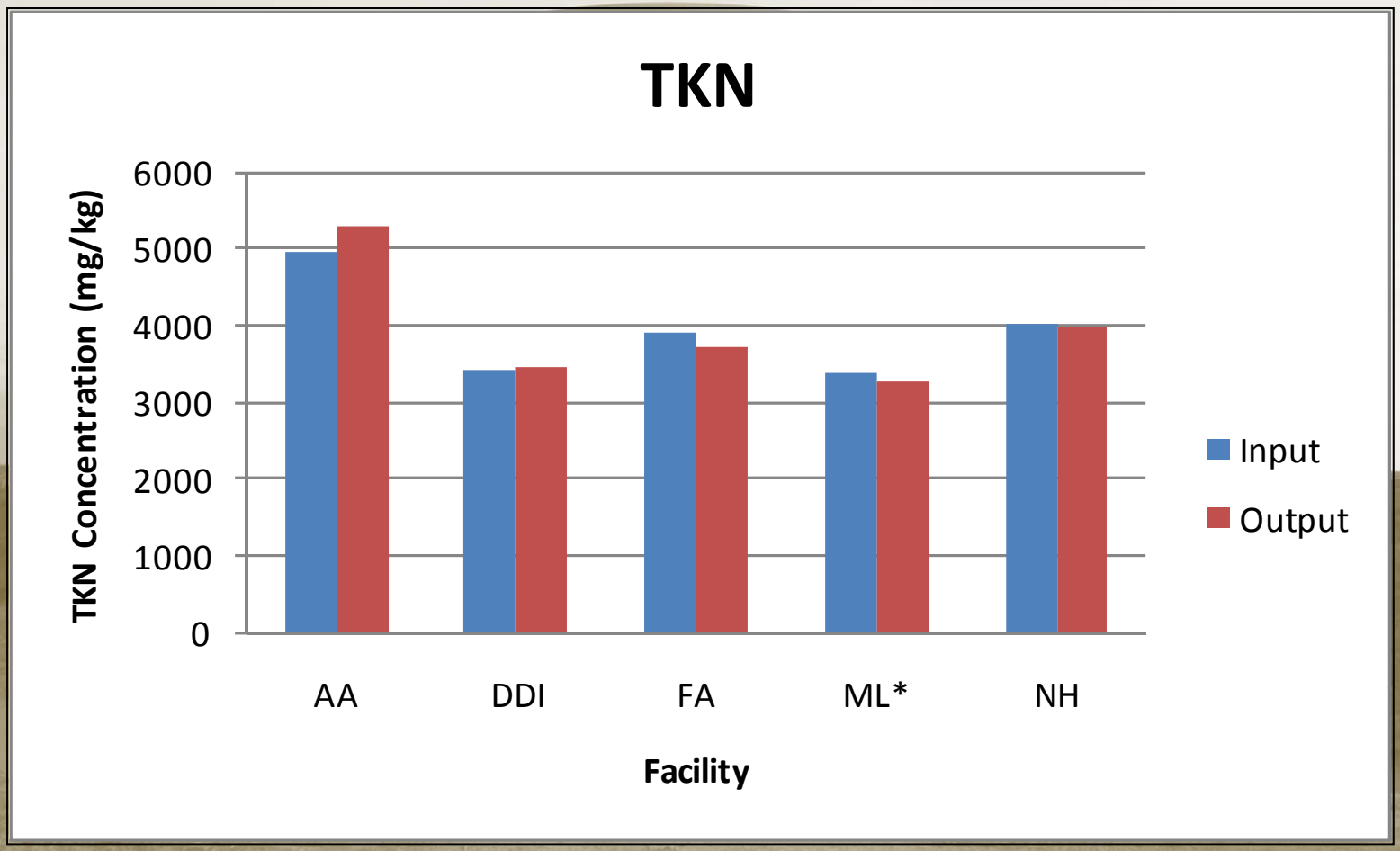


Digestate

- Must be disposed
- Liquid and solid commonly used for fertilizer
- Solids potential for higher value products
- AD results in:
  - nutrient mineralization
  - odor reduction
  - pathogen reduction
  - antibiotic degradation

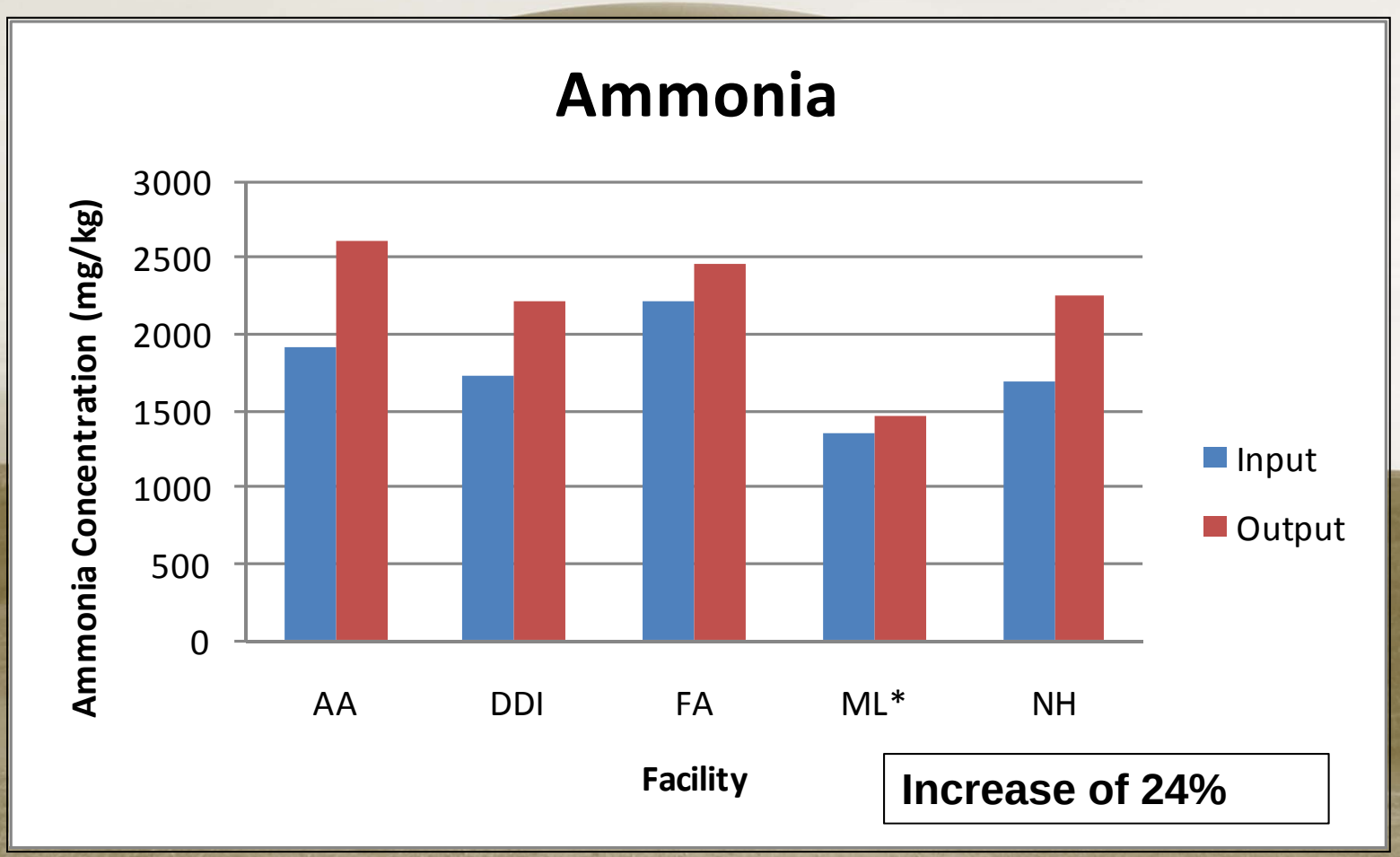


Nutrients & Anaerobic Digestion



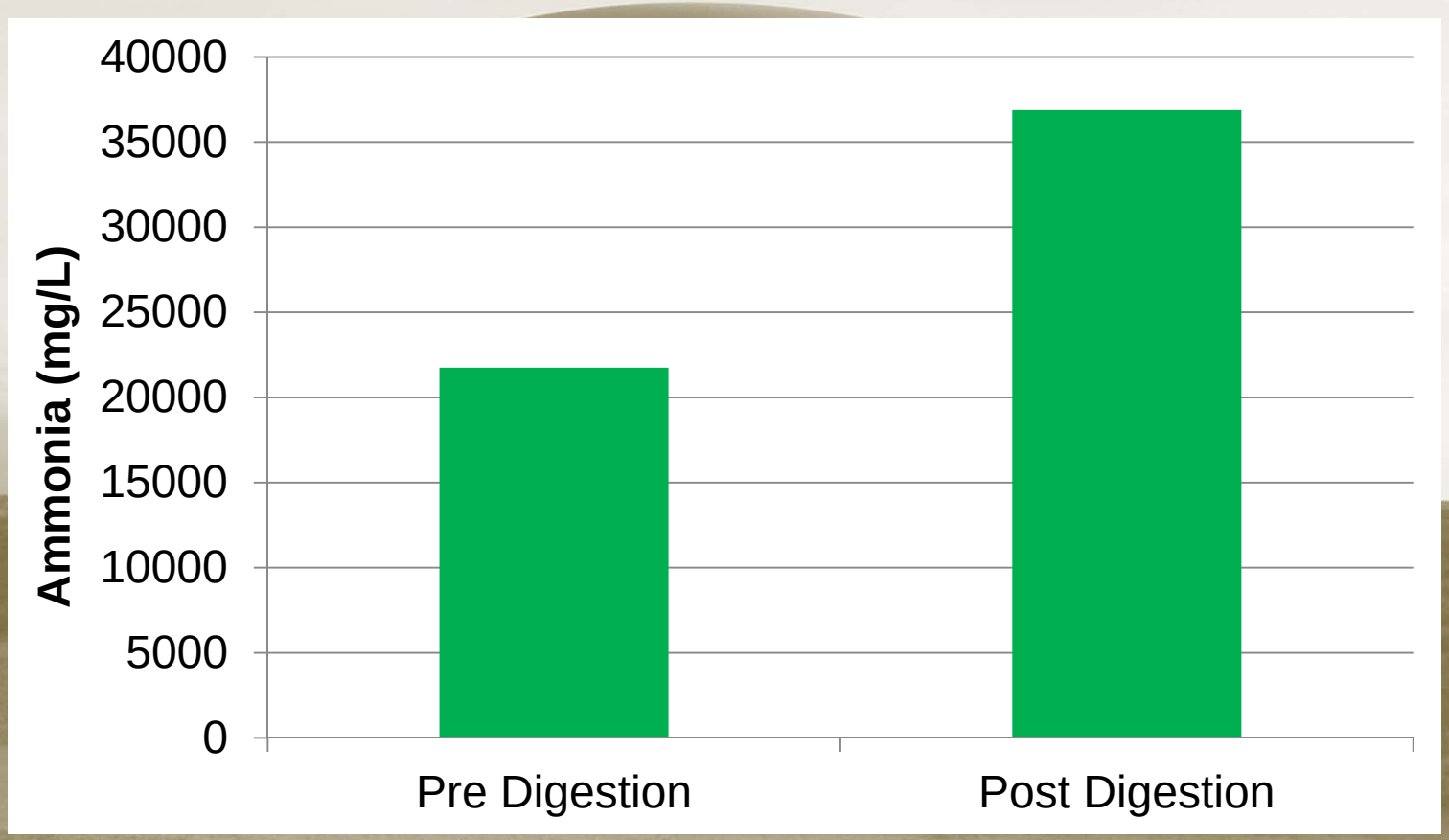
Wright, et al. 2004. Preliminary Comparison of Five Anaerobic Digestion Systems on Dairy Farms in New York State

Nutrients & Anaerobic Digestion

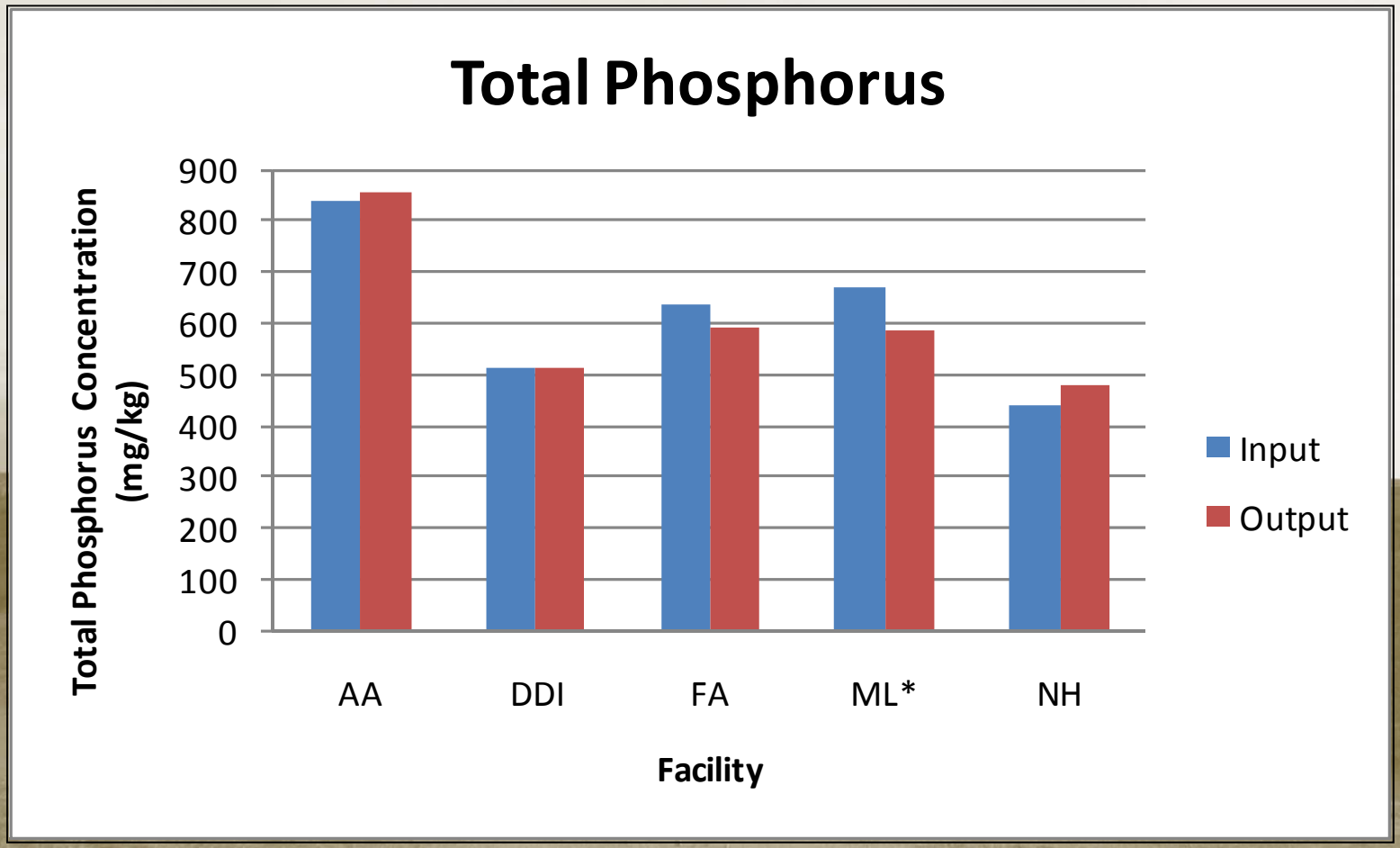


Wright, et al. 2004. Preliminary Comparison of Five Anaerobic Digestion Systems on Dairy Farms in New York State

Ammonia

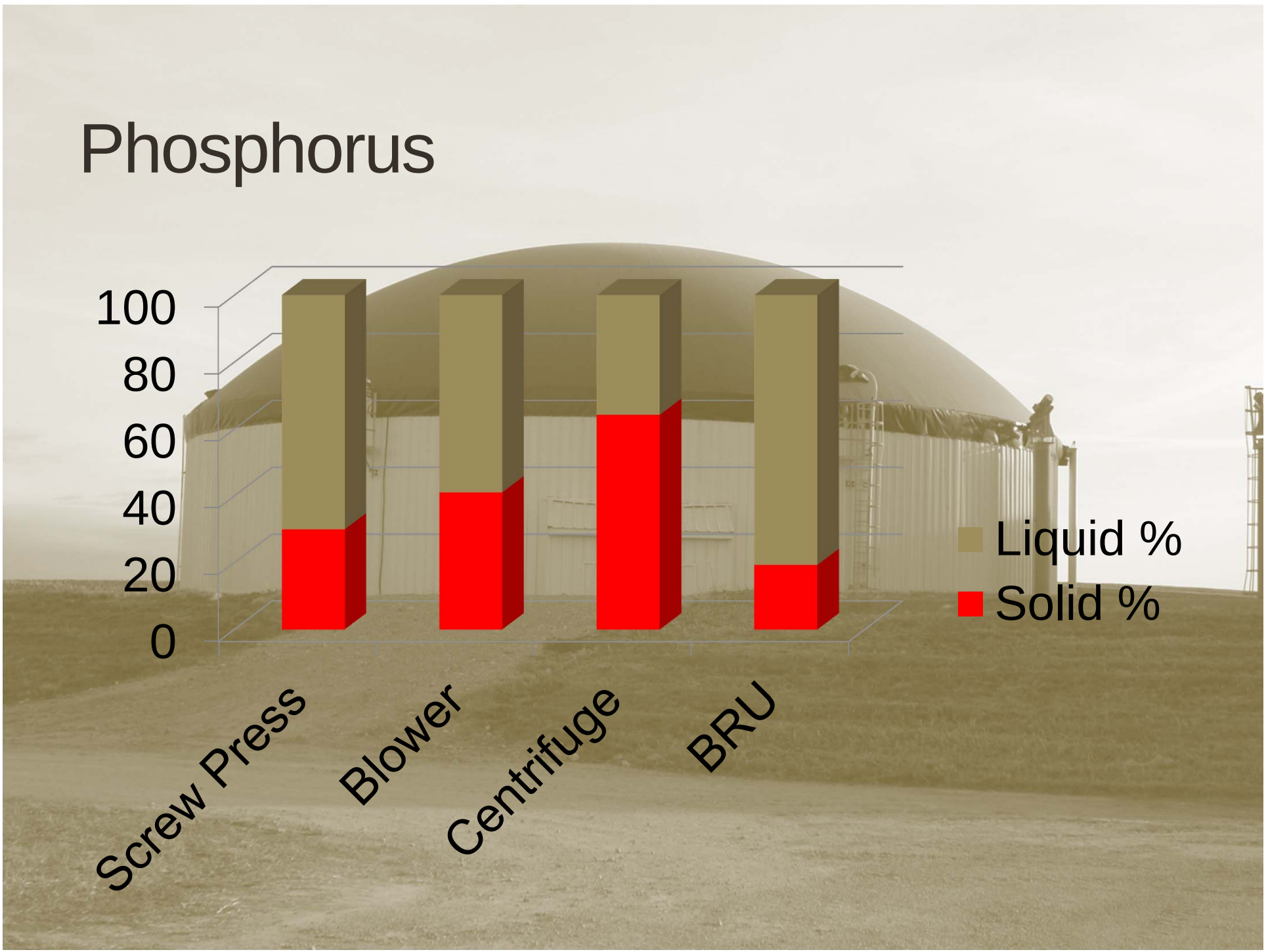

Ammonia (mg/L)
40000
35000
30000
25000
20000
15000
10000
5000
0
Pre Digestion
Post Digestion

Nutrients & Anaerobic Digestion



Wright, et al. 2004. Preliminary Comparison of Five Anaerobic Digestion Systems on Dairy Farms in New York State

Phosphorus


100
80
60
40
20
0
Screw Press
Blower
Centrifuge
BRU
Liquid %
Solid %

N-P-K

Concentration	N (g/kg)	P_2O_5 (g/kg)	K_2O (g/kg)
Manure	50	18	41
Liquid	101	27	75
Solid	15	14	8

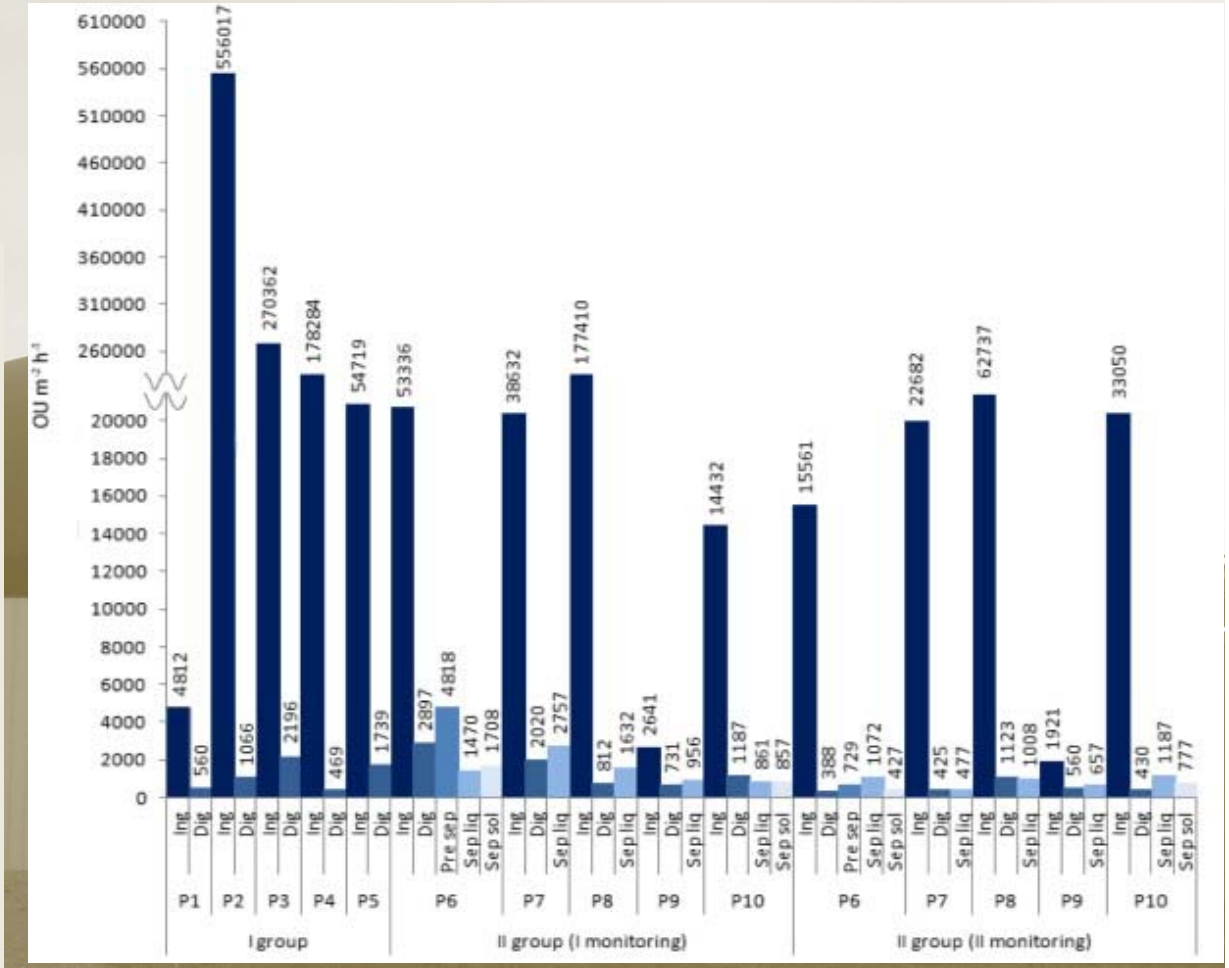
Ratio	N	P_2O_5	K_2O
Manure	3	1	2
Liquid	4	1	3
Solid	2	2	1

Odor

Swine Manure

Hansen et al. 2006, Applied Engineering in Agriculture

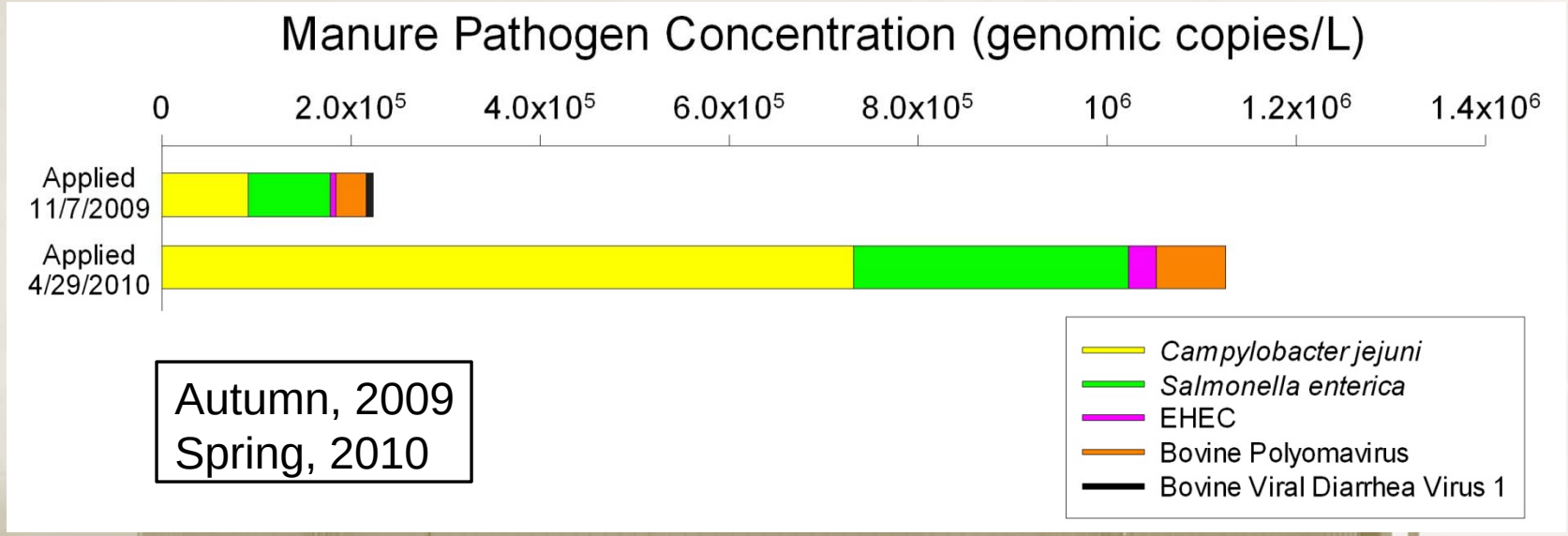
- Slurry concentrations of malodorous VFA were reduced 79-97% from AD
- Odor concentration above undisturbed slurry store reduced (higher odors after mixing)
- Land application odor reductions:
  - 17% anaerobic digestion
  - 50% anaerobic digestion and solid liquid separation

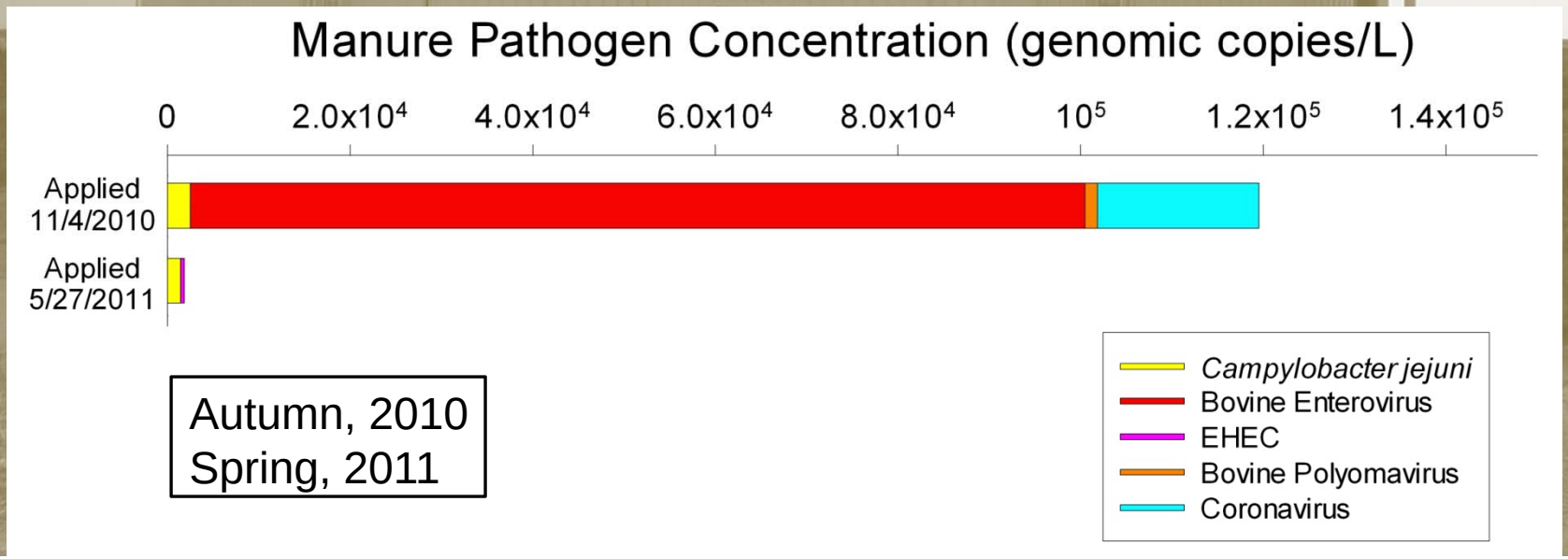


Orzi et al., 2015, Science of the Total Environment

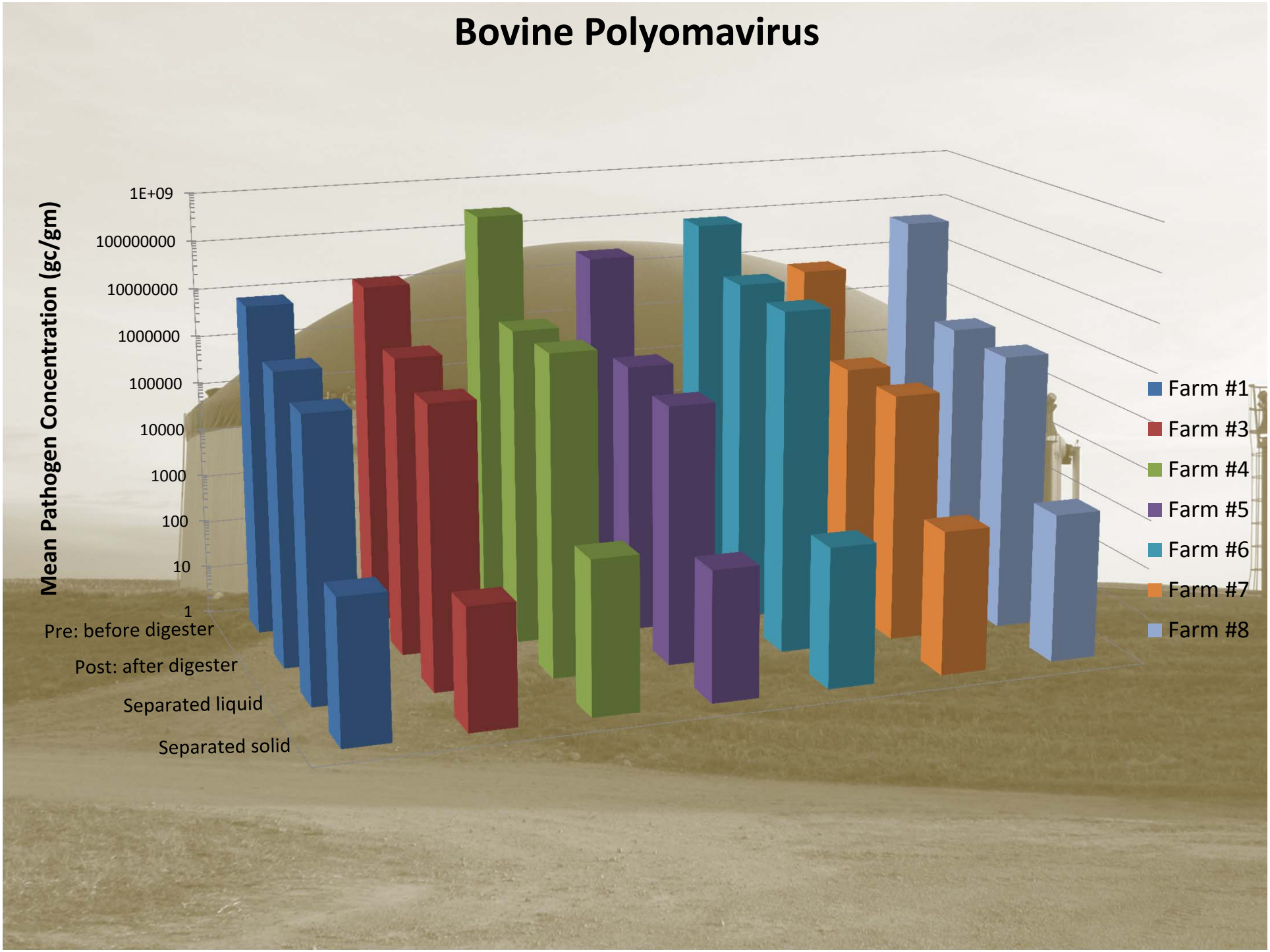
- Odors reduced 98%
- P2-P6 are pig slurries
- VFA destruction related to measured odor reductions

Pathogens in manure from a single farm by year and season



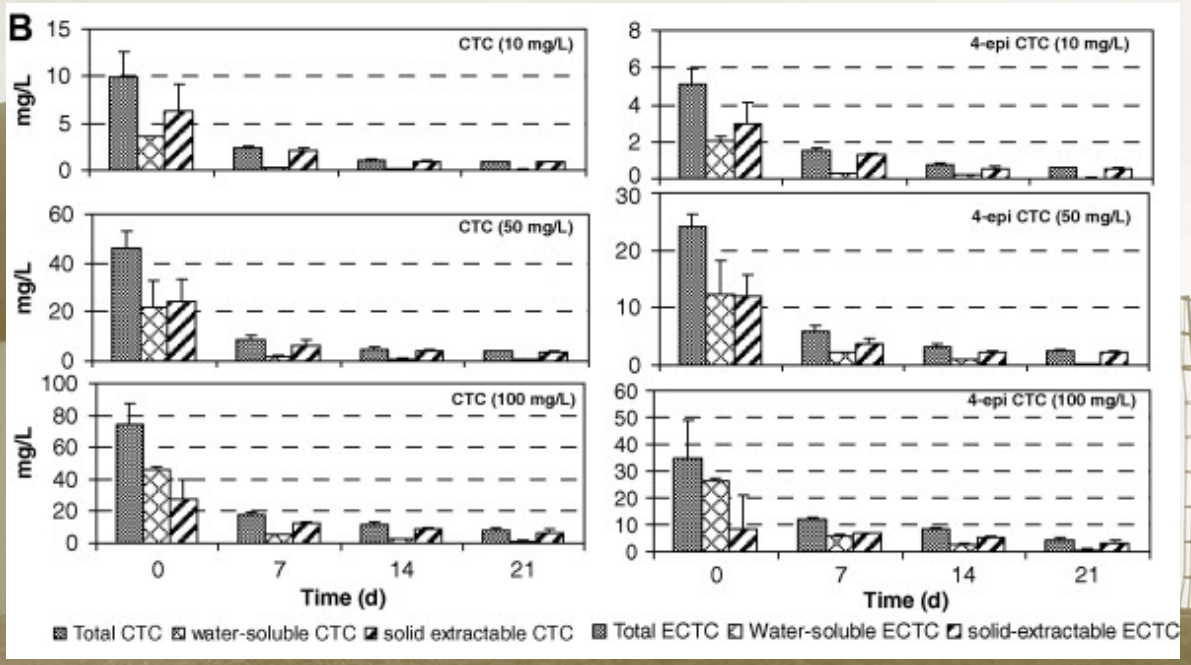


Bovine Polyomavirus



Antibiotic Degradation

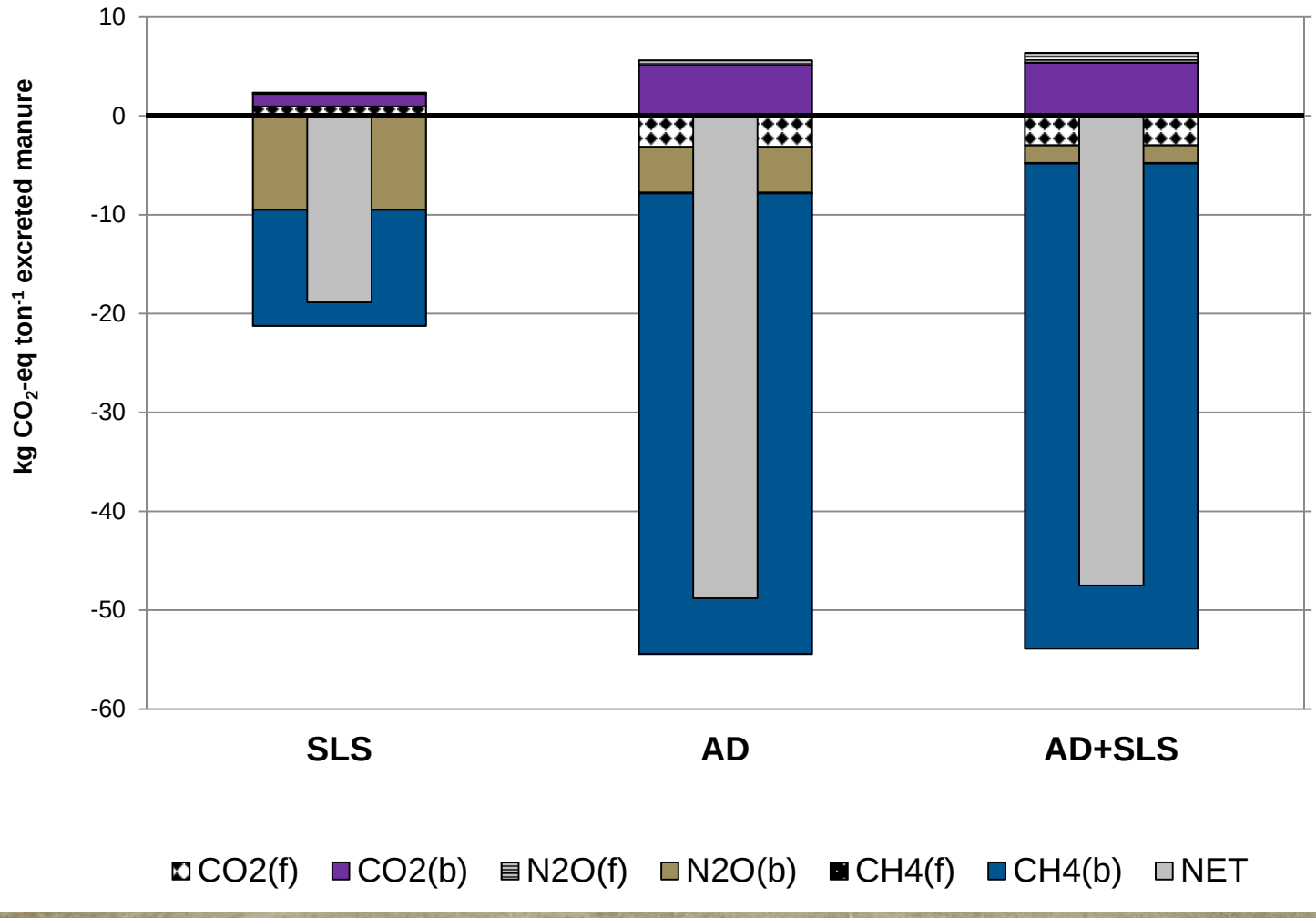
- Many antibiotics to be tested
- Not many studies to date
- May increase intermediates
- Beef manure studies by Arikan (2006, 2007, 2008) found some degradation in initial component, increases in some intermediaries



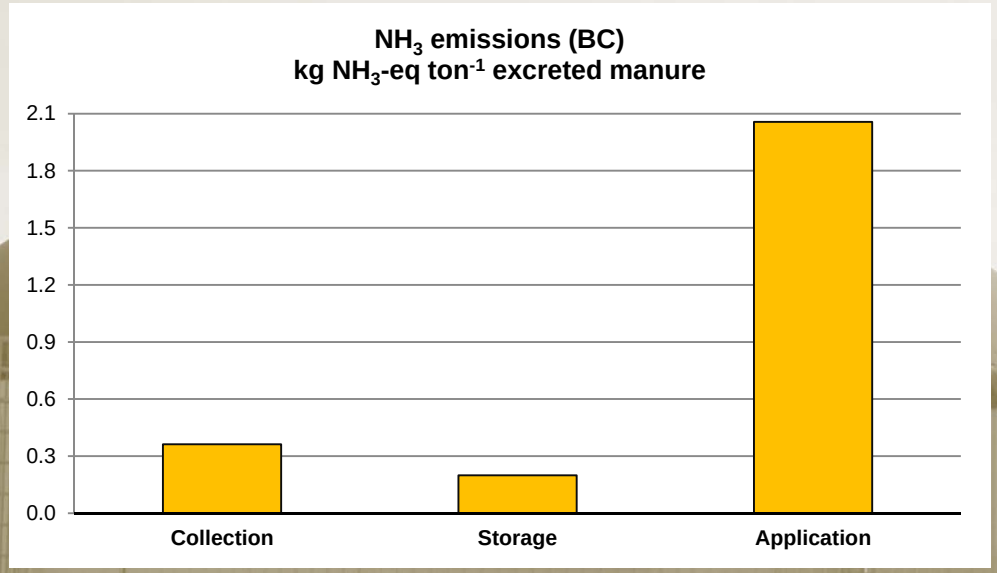
Alvarez et al., 2010, Bioresource Technology

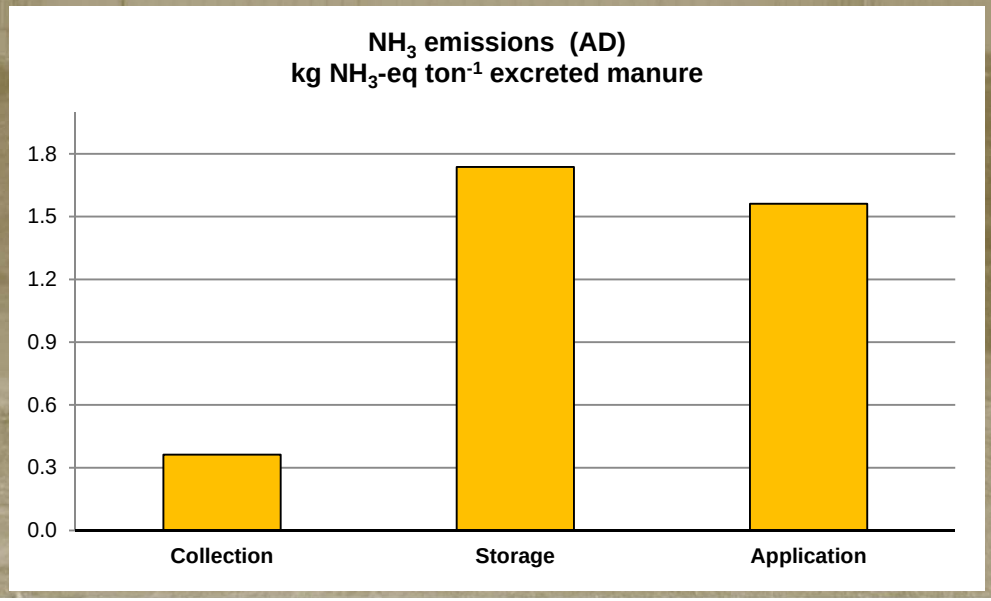
- Fate of antibiotics in pig manure in AD
- oxytetracycline (OTC) and chlortetracycline (CTC)
- Reduction in antibiotics over time, as well as methane production
- Antibiotics adsorbed to solids increasing duration for destruction

Global Warming Potential



Ammonia Emissions





Limitations to Adoption

- Lack of Awareness of Biogas Benefits.
- Unpredictable Biogas Market Conditions
- Lack of Market Maturity.
- Lack of Full Valuation
- Inconsistencies across Federal, State, and Local Governments.
- Lack of Technical and Applied Research & Development

Biogas Opportunities Roadmap
Voluntary Actions to Reduce Methane Emissions and Increase Energy Independence
U.S. Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Energy
August 2014

- Capital cost
- Operating cost
- Energy use
- Energy value
- By-product Revenue

Thank You!

Becky Larson

ralarson2@wisc.edu

(608) 890-3171