Introduction to Anaerobic Digestion (for Beginners)

Conference Co-Hosts:

EPA

Iowa State University
Bioeconomy Institute

IOWA
College of Engineering
Wastewater and Waste to Energy Research Program

Workshop Design:

Gnarly Tree Sustainability Institute

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AgSTAR

<u>Topics</u>
Digester Basics
Operational Fundamentals
AD Design and Technology
Benefits of AD
EPA AgSTAR Program
Economic and Financial Factors

Monday, November 6th
1:00 – 4:00 p.m.

Welcome from Daniel J. Robison
Dean of the College of Agriculture and Life Sciences

Daniel J. Robison is Dean and holder of the Endowed Dean's Chair of the College of Agriculture and Life Sciences at Iowa State University. He is also director of the Iowa Agriculture and Home Economics Experiment Station and serves on the Boards of several agriculture related organizations.

He has conducted research, taught, and trained graduate students in forest entomology and pest management, silviculture of natural hardwoods, biomass-bioenergy plantation systems, agroforestry and clonal forestry.

He was a Fellow of the American Council on Education 2007-2008 that included service at East Carolina University and University of Alaska-Fairbanks. He has received university level recognitions in teaching, public service, and diversity initiatives. A native of New Jersey, he and his wife Julie, a native of Wisconsin, have two grown daughters.

Introduction to Anaerobic Digestion (for Beginners)

Agenda:

1:00 pm – 1:15 pm: Welcome and Introductions	(Craig Just)
1:15 pm – 1:20 pm: Mentimeter Discussion	(Stephanie Richards)
1:20 pm – 1:40 pm: Digester Basics & Operational Fundamentals	(Craig Just)
1:40 pm – 2:00 pm: AD System Design and Technology	(Daniel Andersen)
2:00 pm – 2:05 pm: Mentimeter Discussion	(Stephanie Richards)
2:05 pm – 2:30 pm: Benefits of AD	(Daniel Andersen)
2:30 pm – 2:40 pm: Break	
2:40 pm – 2:45 pm: Mentimeter Discussion	(Stephanie Richards)
2:45 pm – 3:10 pm: AgSTAR Program	(Jake Dunton)
3:10 pm – 3:20 pm: Mentimeter Discussion	(Stephanie Richards)
3:20 pm – 3:35 pm: Economic and Financial Factors	(Craig Just)
3:35 pm – 3:50 pm: Mentimeter Discussion	(Stephanie Richards)
3:50 pm – 4:00 pm: Closing Remarks	(Craig Just)

Facilitators:

Craig Just, Associate Professor, Civil & Environmental Engineering, University of Iowa
Daniel Andersen, Associate Professor & Extension Specialist, Iowa State University
Jake Dunton, Program Manager, AgSTAR
Stephanie Hayes Richards, Managing Principal, Gnarly Tree Sustainability Institute

Digester Basics & Operational Fundamentals

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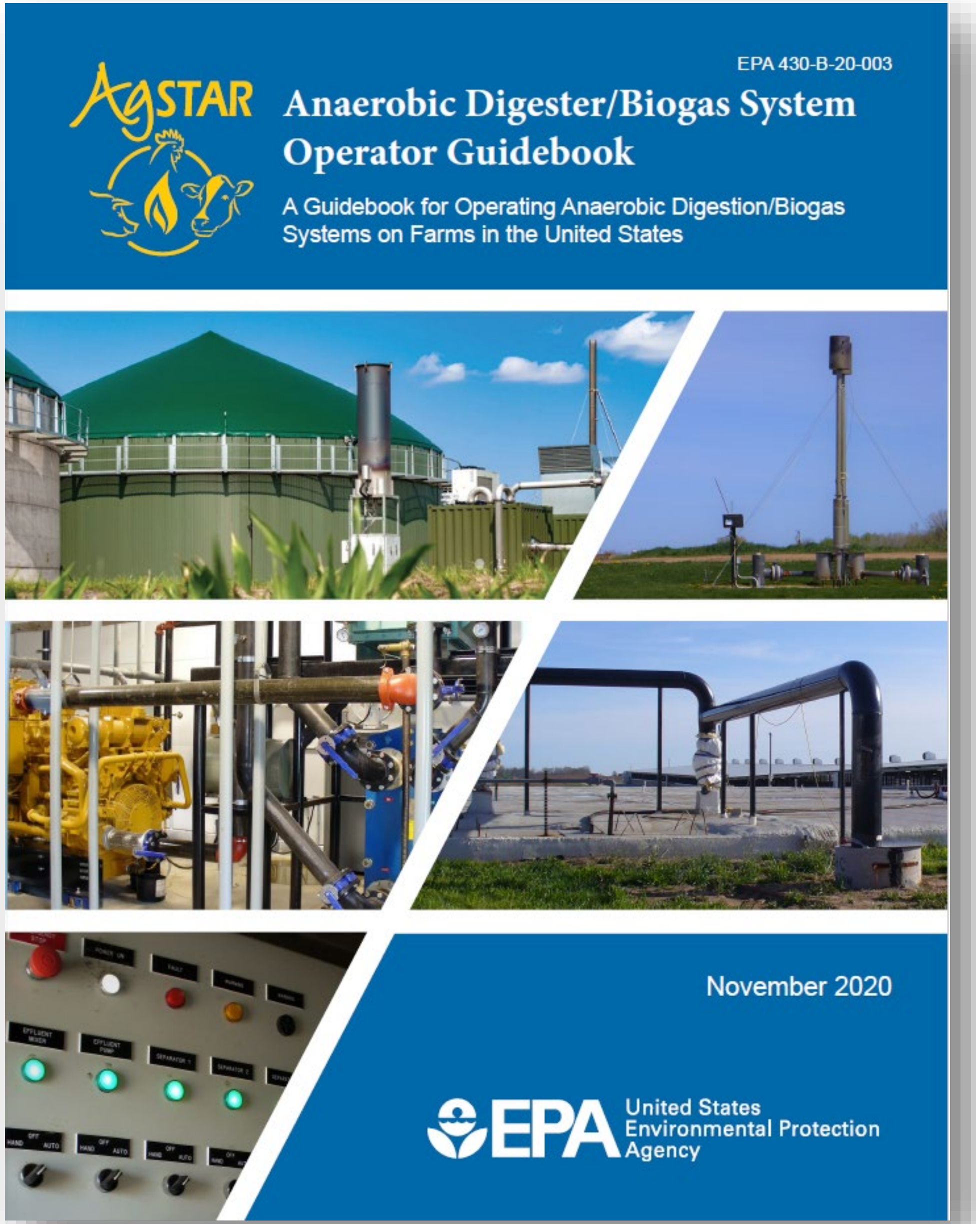
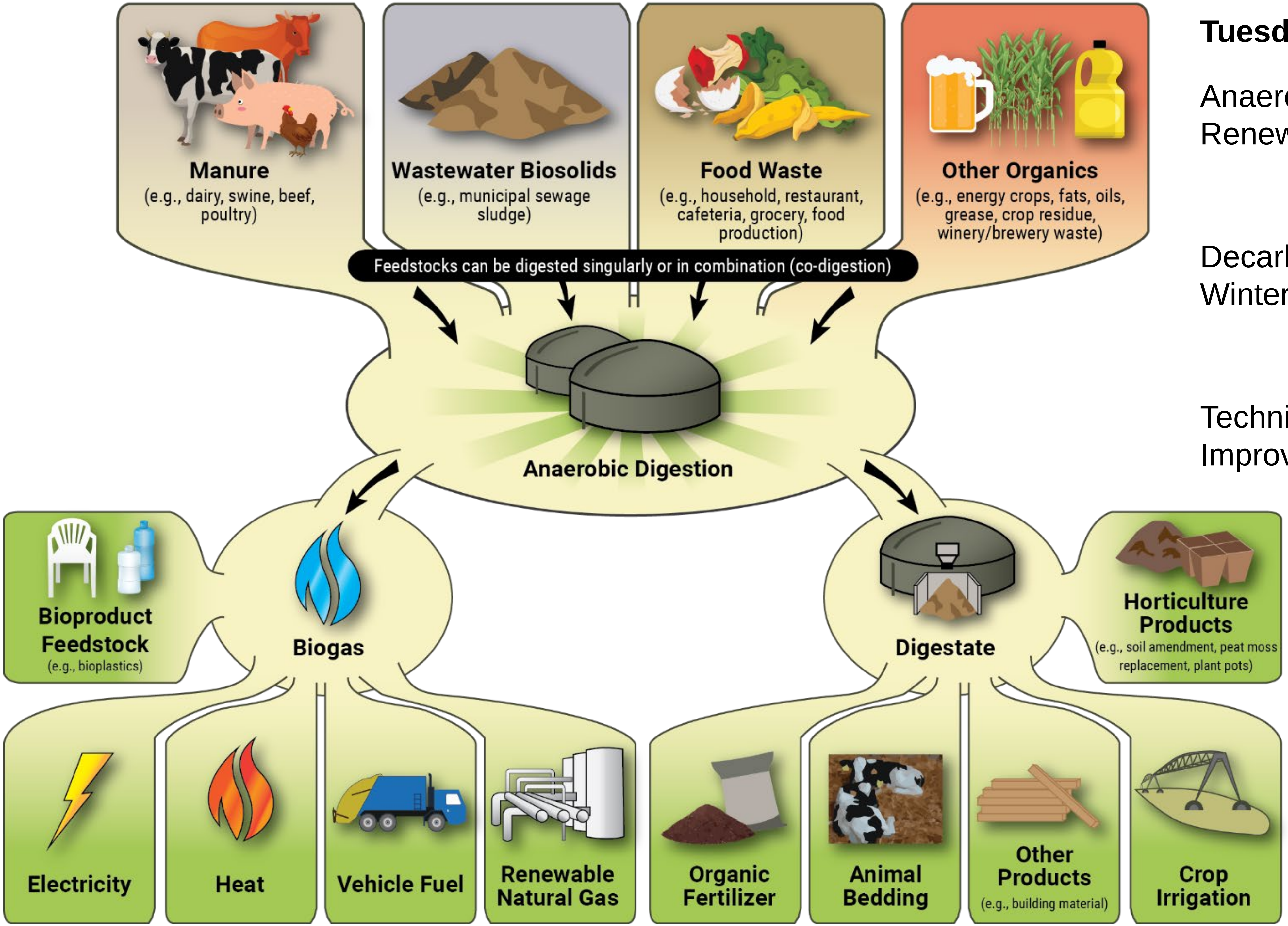


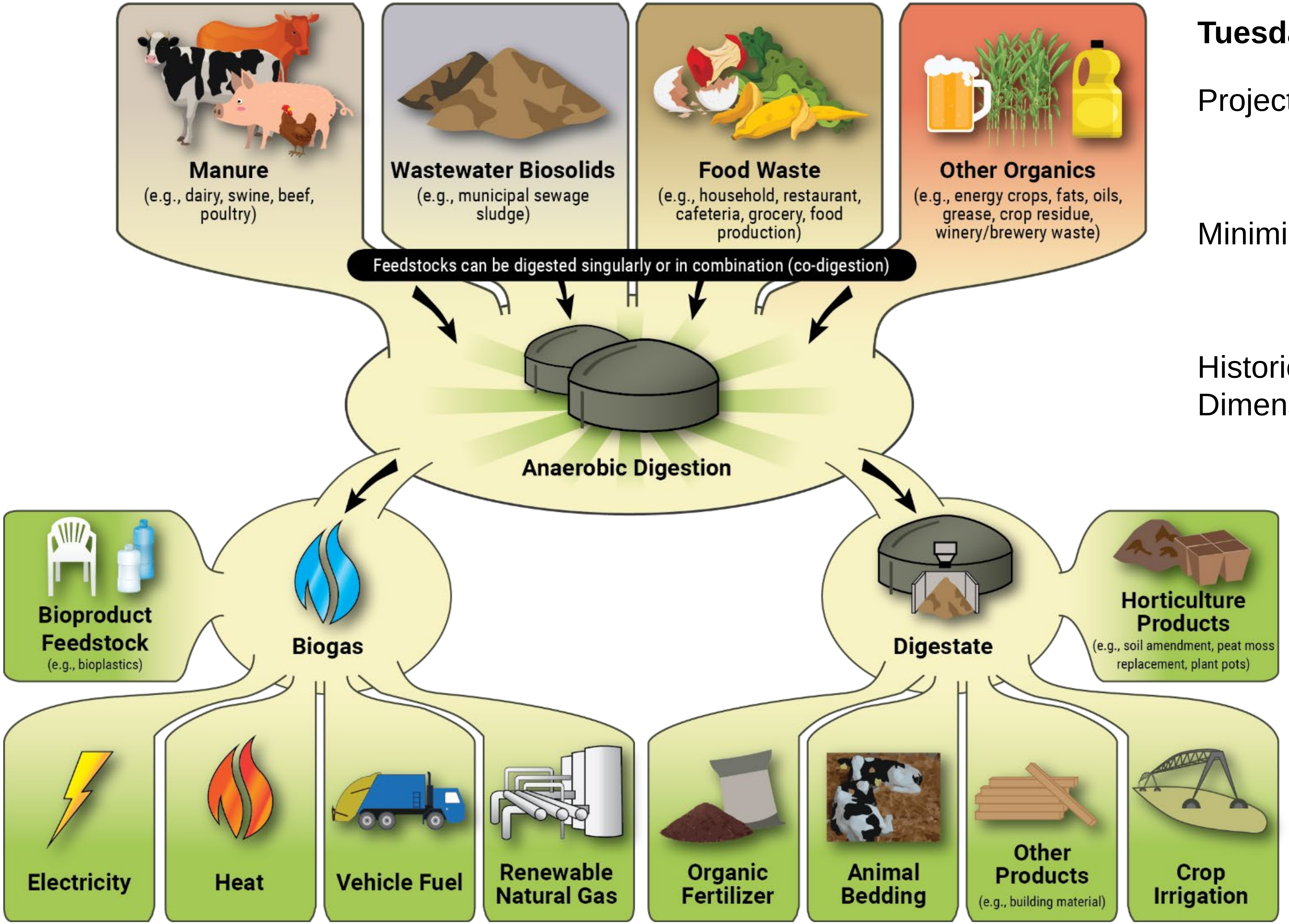


Tuesday: 10:45 – 12:30

Anaerobic Digestion and the Renewable Fuel Standard

Decarbonizing Agriculture with Winter Biomass Crops

Technical Innovations to Improve Anaerobic Digestion

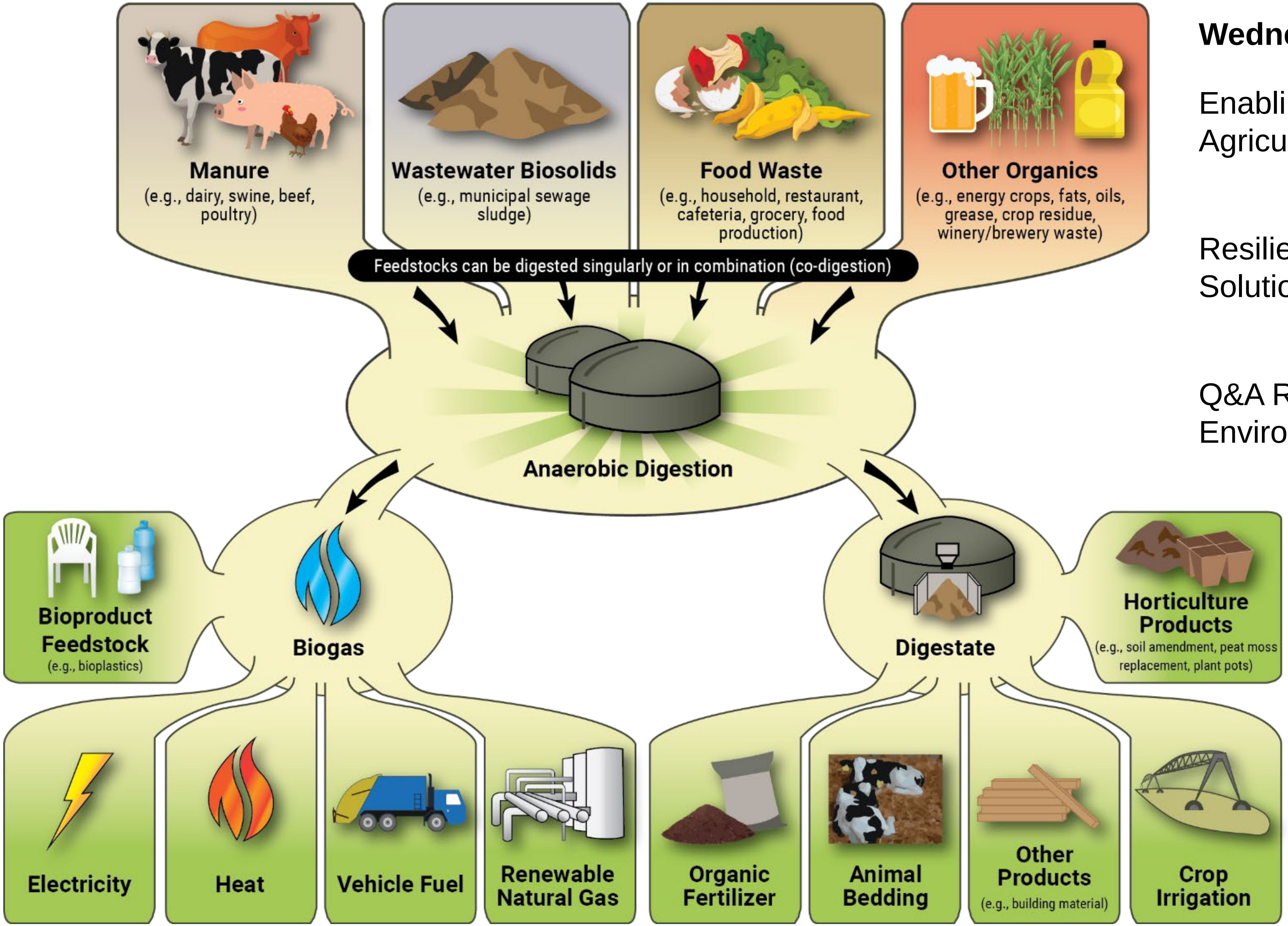


Tuesday: 2:00 – 3:45

Project Financing

Minimizing Emissions

Historical and Human Dimensions



Wednesday: 10:45 – 12:30

Enabling Circular Agricultural Systems

Resilient Infrastructure Solutions

Q&A Roundtable: Social and Environmental Concerns

EPA

Acronyms

AD	anaerobic digestion
ATA	anaerobic toxicity assays
BMP	biochemical methane potential
BOD	biochemical oxygen demand
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
COD	chemical oxygen demand
EPA	U.S. Environmental Protection Agency
H_2S	hydrogen sulfide
HRT	hydraulic retention time
HVAC	heating, ventilation, and air conditioning
IC	internal combustion
IDLH	Immediately Dangerous to Life and Health
kg	kilogram
L	liter
lb	pound
LEL	lower explosive limit
mg	milligram
NH_3	ammonia
O_2	atmospheric oxygen
O&M	operations and maintenance
OLR	organic loading rate
OSHA	Occupational Safety and Health Administration
ppm	parts per million = mg/L
PRV	pressure relief valve
PSA	pressure swing adsorption
RNG	renewable natural gas
SRT	solids retention time
TKN	total Kjeldahl nitrogen
TS	total solids
UEL	upper explosive limit
VFA	volatile fatty acid
VS	volatile solids

Digester Basics - What Does an Anaerobic Digester Do?

"In simplified terms, anaerobic microbes within the AD degrade or break down organic matter to obtain energy and nutrients for growth and reproduction."

"Biogas, a byproduct of this process, is composed primarily of CH_4."

"Biogas also includes carbon dioxide (CO_2), as well as trace amounts of hydrogen sulfide (H_2S) and ammonia (NH_3), which must be removed for certain biogas end uses."

"An engineered AD system creates a controlled environment that efficiently converts biodegradable organic materials (i.e., manure) into biogas and produces a stabilized residual effluent (digestate) that can be put to beneficial use."

AD Functions Include:

- Converting biodegradable organic matter into biogas, which can be sold as a fuel or combusted for on-farm energy use.
- Reducing biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
- Reducing odors.
- Converting organic nitrogen into more plant-available forms that can be used as fertilizer.
- Reducing pathogens.
- **Capturing CH_4 that otherwise would be released.**

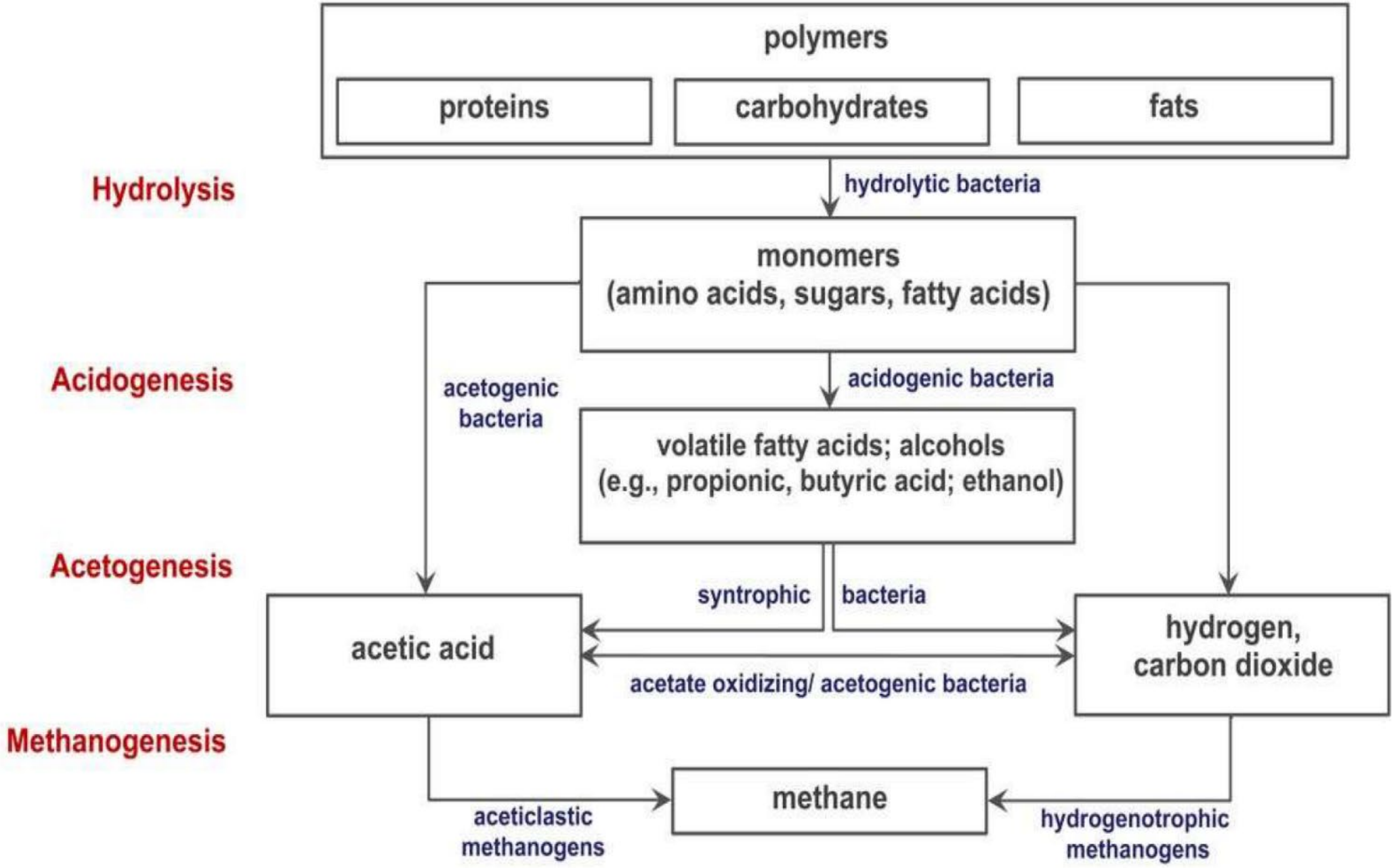
The AD process involves four steps:

Hydrolysis: Complex organics are broken down into simple organics. Specifically, hydrolytic microorganisms break down complex organic compounds such as proteins, carbohydrates, and fats.

Acidogenesis: Acidogenic microorganisms ferment the simple organics into short-chain fatty acids (also called volatile fatty acids [VFAs]), CO_2, and hydrogen gases.

Acetogenesis: Acetogenic microorganisms convert the mixture of short-chain fatty acids to acetic acid, with the release of more CO_2 and hydrogen gases.

Methanogenesis: CH_4-producing microorganisms called methanogens convert acetic acid and hydrogen to biogas. There are two classes of methanogens: one class primarily converts the acetic acid to CH_4, while the other class combines the hydrogen and CO_2 into CH_4; some unique methanogens can do both.

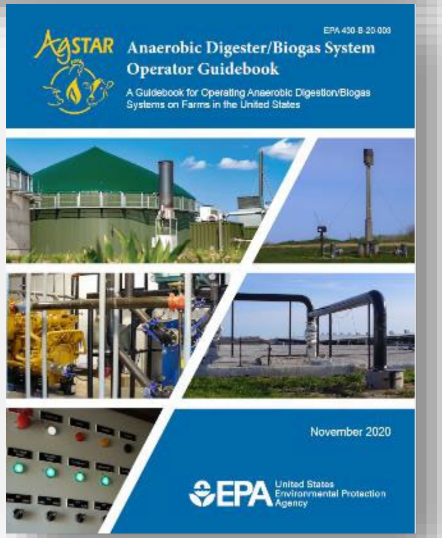


polymers
proteins
carbohydrates
fats
Hydrolysis
hydrolytic bacteria
monomers
(amino acids, sugars, fatty acids)
Acidogenesis
acetogenic bacteria
acidogenic bacteria
volatile fatty acids; alcohols
(e.g., propionic, butyric acid; ethanol)
Acetogenesis
syntrophic
bacteria
acetic acid
hydrogen, carbon dioxide
acetate oxidizing/ acetogenic bacteria
Methanogenesis
methane
aceticlastic methanogens
hydrogenotrophic methanogens

Text Box 3
Key AD/Biogas Parameters Required to Maintain Efficient Biogas Production

Several parameters determine the efficiency of converting organic materials to biogas:

- Retention time
- Organic loading rate (OLR)
- Temperature
- Characteristics of volatile solids (VS)[3]
- Inhibitors[4]



Solids retention time (SRT) is the average length of time the feedstock VS or COD remain in the digester's reactor and remain in contact with the microbes.

Hydraulic retention time (HRT) or hydraulic residence time is the average length of time the dissolved portion of the waste spends in the digester.

The organic loading rate (OLR) indicates the amount of VS that can be fed into the digester per day. OLR usually is expressed as pounds of VS added per cubic foot of digester volume per day.

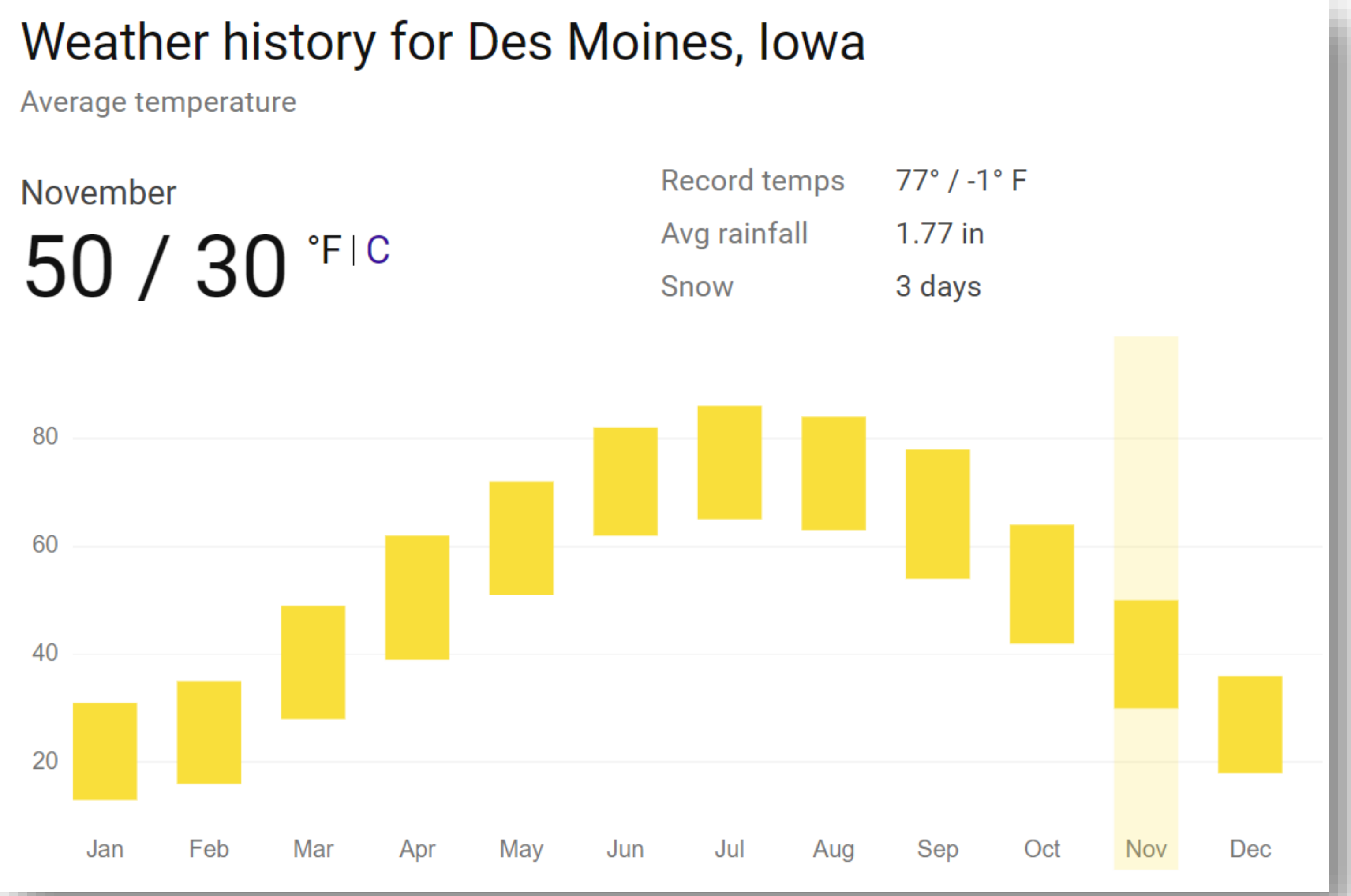
Temperature is typically mesophilic (86 °F to 104 °F) or thermophilic (122 °F to 140 °F).

Volatile solids are the fraction of TS that are combustible. Manure is composed of VS and minerals (commonly referred to as fixed solids or ash). While all organic matter is ultimately biodegradable, its various components degrade at different rates.

Inhibitors are toxic compounds that are most commonly introduced when another waste, such as food processing waste, is co-digested in AD (ACoD)

Peer Challenge!

"Temperature is typically mesophilic (86 °F to 104 °F) or thermophilic (122 °F to 140 °F)."



Discuss: How can AD projects work in Iowa with this temperature requirement?

Anaerobic Digestion System Design and Technology for Livestock Manures and Crop Residues

Dr. Daniel Andersen

Iowa State University
Extension and Outreach

Manure Management

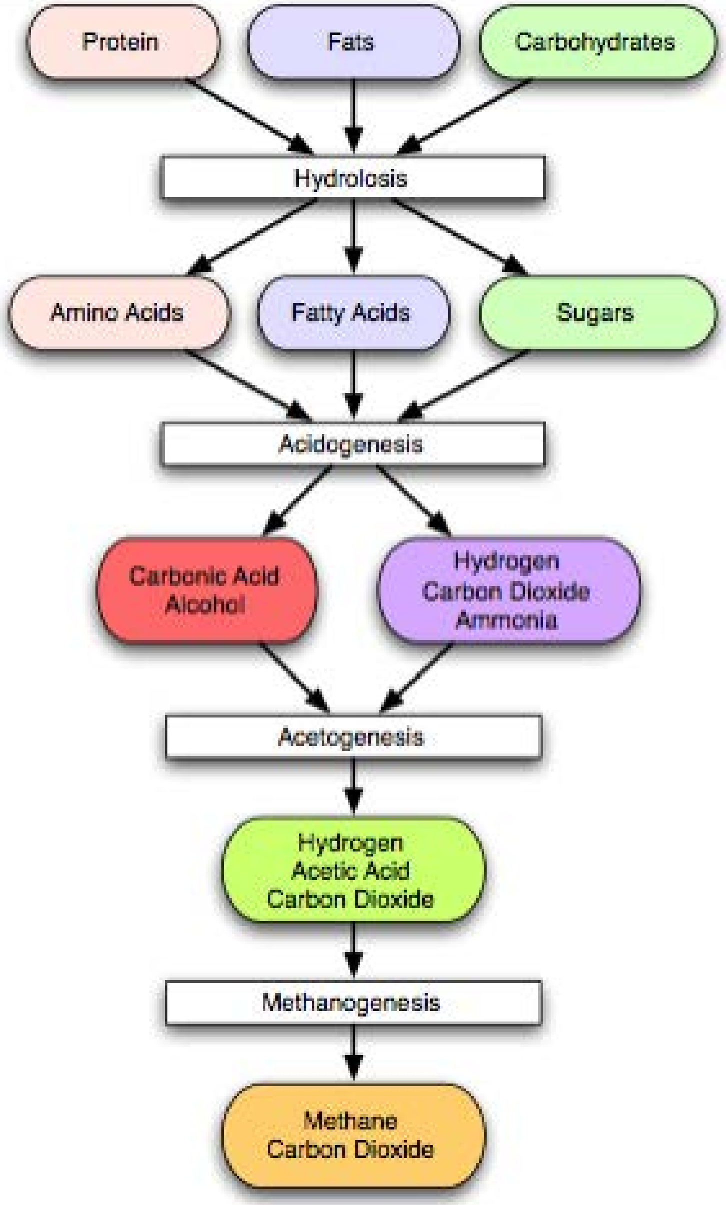
- Digesters should:
  - Reducing odor (onsite and down wind)
  - Maximizing fertilizer power
  - Increased reactive nitrogen retention
  - Reduced greenhouse gas emissions

Agricultural Residues

- Digesters should:
  - Improve circularity
  - Generate energy
  - Increase farm productivity and revenue
  - Encourage cropping innovation

Methane Generation

1. Manure volatile solids
2. Volatile solids biodegradability
3. Storage conditions
4. Storage length
5. Temperature



Processing Advantages

- Non-sterile reaction vessels
- Automatic product separation
- Relatively simple equipment and operations

Disadvantages of AD

- Slow reaction rates
- Low methane yields
- Microbial reduction of sulfur to hydrogen sulfide

Approximate HRTs

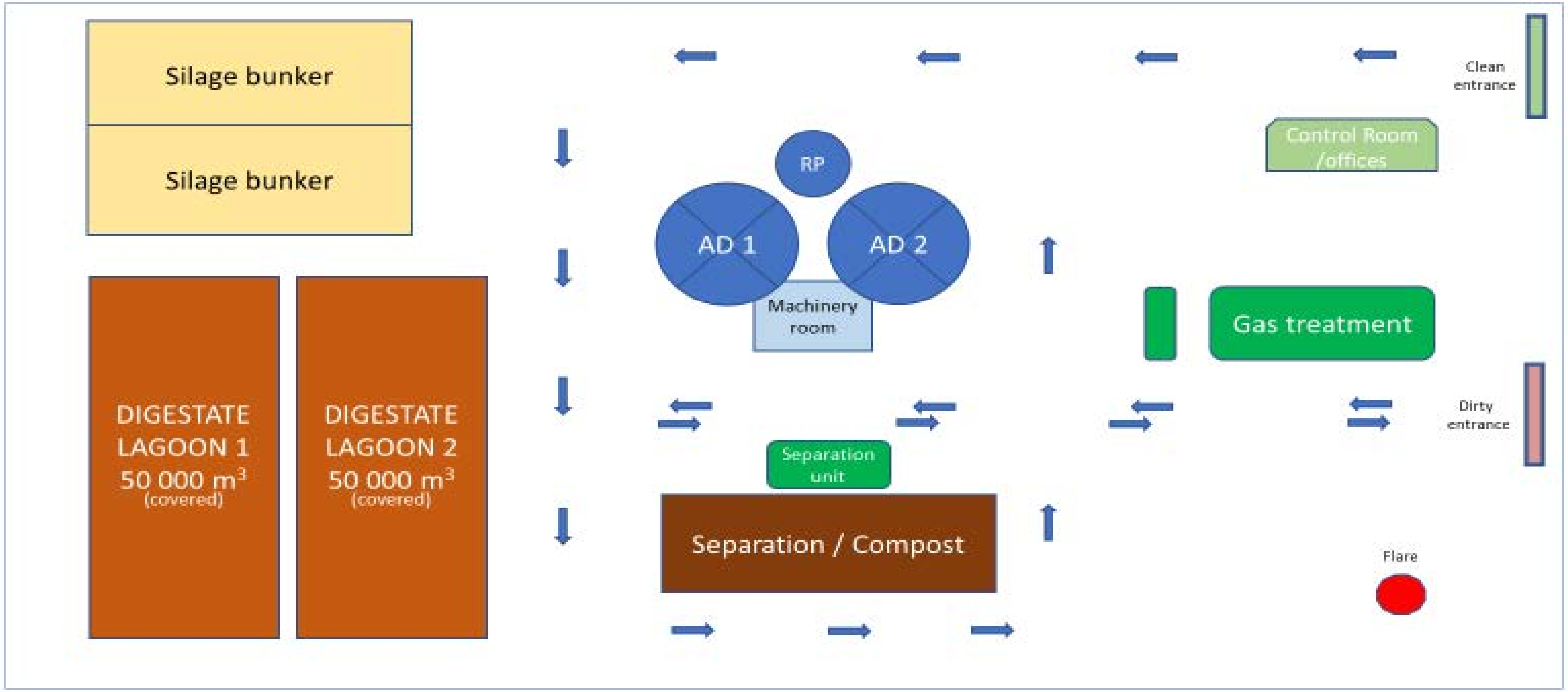
- Commercial EtOH fermentations: ~48 h
- Commercial biodiesel transesterification: ~2 h

  1 – 2 order of magnitude reductions with ultrasound
- Anaerobic digestion
  - Sugary wastewaters: ~8 h
  - Lignocellulosic feedstocks: 20 – 100 d
  - Pretreated LC feedstocks?

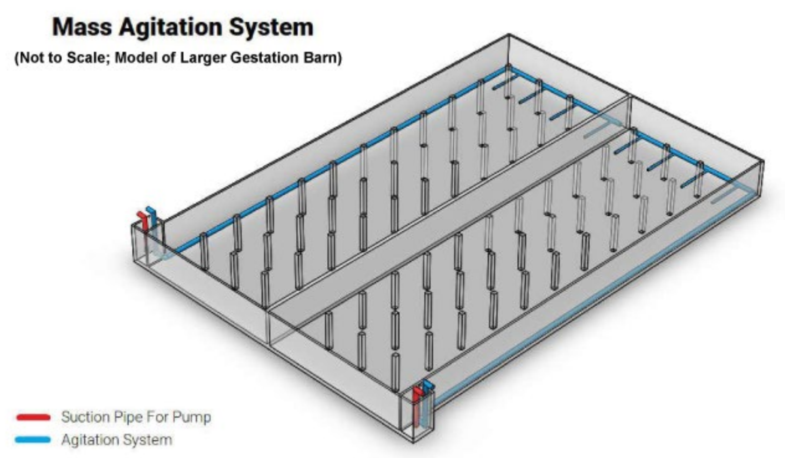
AD Systems

- Feedstock Storage
- Feedstock Preparation and Pretreatment
- Digestion Tanks and Reactors
- Biogas Collection and Storage
- Digestate Handling and Utilization

General AD System Layout



Feedstock Harvest and Storage



What has made manure and municipal projects more favorable than biomass projects?

- Group of 4-5, identify 2 opportunities or advantages of each manure/municipal, and one to two reason biomass could be important.

Feedstock Preparation and Pretreatment

- Physical
  - Particle sizing
  - Hydration
- Biological
  - Ensiling
  - Enzyme
- Chemical
  - Hydrolysis

Digestate Handling and Utilization






Digestion System Technology Horizons

- Horizon 0: Impermeable cover storage
- Horizon 1: Heated Digesters
- Horizon 2: Heated Digesters with Biomass added
- Horizon 3: Heated Digesters with Biomass added and liquid recycling to increase biomass addition
- Horizon 4: Heated Digesters with Biomass added, liquid recycling to increase biomass addition, nutrient removal from effluent
- Horizon : Adding CO2 Capture

Digestion System Technology Horizons

- H0: Impermeable covers
- H1: Heated Digesters
- H2: Digesters/Biomass
- H3: Digesters/Biomass&Recycle
- H4: Digesters/Biomass,Recycle,EffluentTreat
- H5: Adding CO2 Capture

- Group of 4-5, identify technology readiness level, challenge, and opportunity

Covered Lagoon

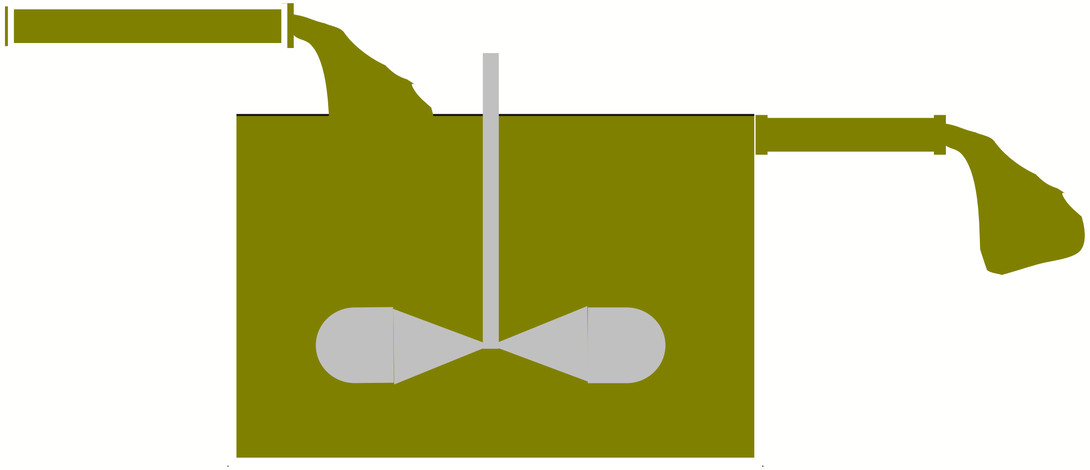
Advantages

- Low Cost
- Existing Infrastructure
- High HRT/SRT

Disadvantages

- Slow conversion
- Not uniform production
- Climate matters

Completely Mixed Digester



Advantages

- High level of industrial experience
- Works over wide range of influent TS

+ Can be used with scrape or flush systems

+ Can be used with swine or dairy systems

Disadvantages

- Poor biomass immobilization (HRT=SRT)
- Mechanical mixing requirement

Plug Flow Digester

Advantages

- Good track record
- Works well with scrape systems

Disadvantages

- Requires high solids manure (11 - 14 %)
- Not compatible with sand bedding

Digester Efficacy

- Complete Mix and Plug Flow ~ 70-85% Efficient

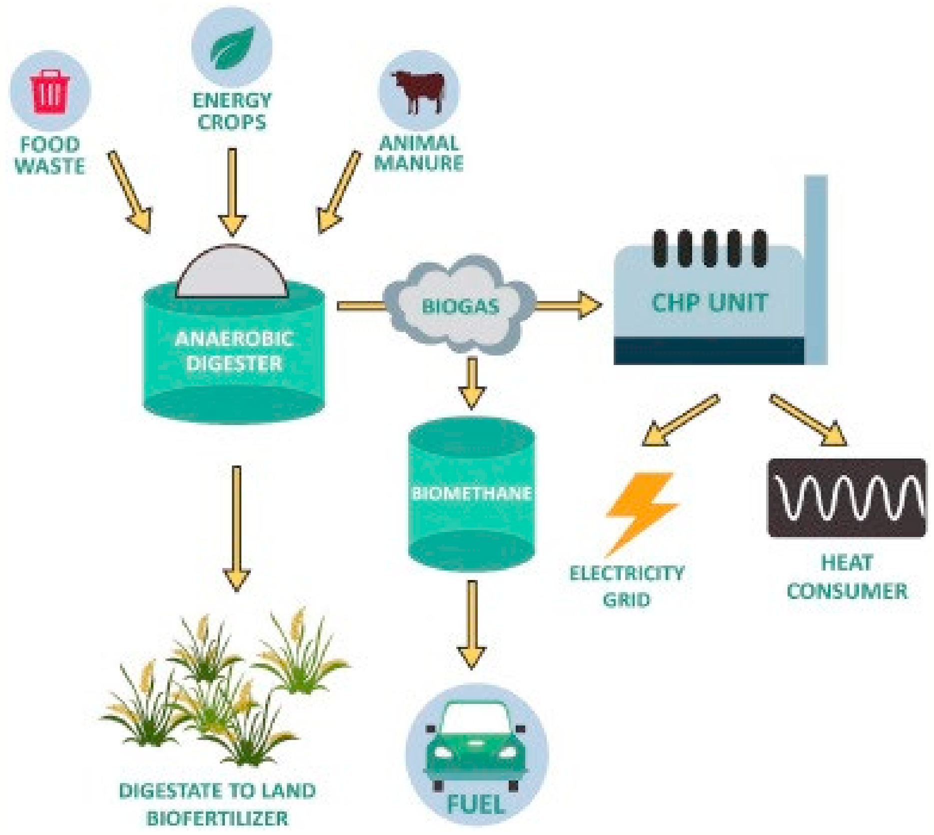
Digester Style for a Project

- Group of 4-5, choose a project type (4 minutes in group, 2 minutes report)

- Example: Deep pit swine manure mixed with baled corn stover and cover crop silage

- What digester style and why?
- Digestate management strategy and why?

Unlocking Sustainable Agriculture: Anaerobic Digestion Benefits for Livestock Manures and Ag Residues

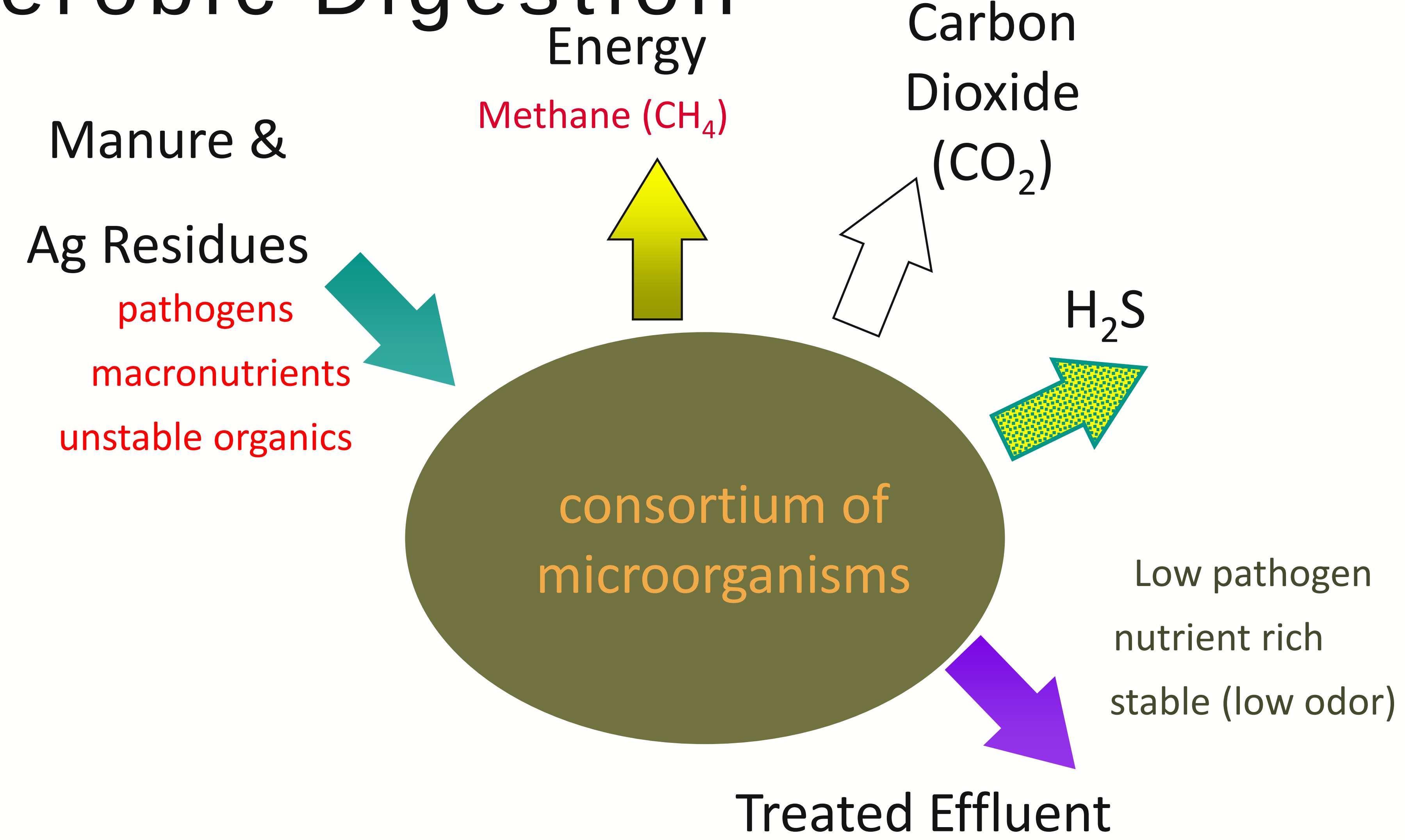


Dr. Daniel Andersen

Introduction

- What is sustainable
- Importance of sustainability
- Role of organic waste management

Anaerobic Digestion



Manures and Ag Residues

- Livestock Manures
  - Solid Manure
  - Liquid Manure
- Crop Residues
- Energy Crops
- Food & Grain Processing

Small Group Activity

- Livestock Manures
  - Solid Manure
  - Liquid Manure
- Crop Residues
  - Corn Stover
  - Cover Crop
- Energy Crops
  - Miscanthus
  - Switch Grass
- Food & Grain Processing
  - Brewery waste
  - Food Processing Waste

- Group of 4-5, identify 2 opportunities or advantages of each material, and two challenges related to that material.
- 3 minutes group, 2 minute report back

Farm Odors

- **Nuisance to Neighbors**
- **Complaints and Legal Actions**
- **Where do odors come from?**
  - **Livestock:** 0.5 OU/pig-s (0.4-24 O.U./pig-s)
  - **Manure:** 0.5 OU/m^2-s (1-17 O.U./m^2-s) (about 3 m^3 per pig)
  - **Biomass - ???**

Odor Control

Iowa State Air Management Practices Assessment Tool

Manure Storage and Handling

	Ammonia	H2S	Odor	Dust & Particles	VOC	GHG	Cost
Acidification	Green	Red	Red	Yellow	Blank	Yellow	$
Aeration	Yellow	Yellow	Green	Blank	Blank	Blank	$$
Anaerobic Digestion	Red	Red	Green	Red	Green	Green	$$$-$$$$
Composting	Red	Yellow	Yellow	Red	Red	Yellow	$-$$
Diet Manipulation	Yellow	Yellow	Yellow	Green	Blank	Blank	$
Impermeable Covers	Green	Green	Green	Blank	Blank	Blank	$$
Landscaping	Yellow	Blank	Yellow	Yellow	Blank	Blank	$
Manure Additives	Red	Red	Red	Blank	Red	Red	[illegible]
Permeable Covers	Yellow	Green	Yellow	Blank	Blank	[illegible]	[illegible]
Siting	Red	Red	Green	Red	Red	[illegible]	[illegible]
Solids Separation	Red	Red	Red	Blank	Blank	[illegible]	[illegible]
Urine / Feces Segregation	Green	Green	Green	Blank	Blank	Green	[illegible]

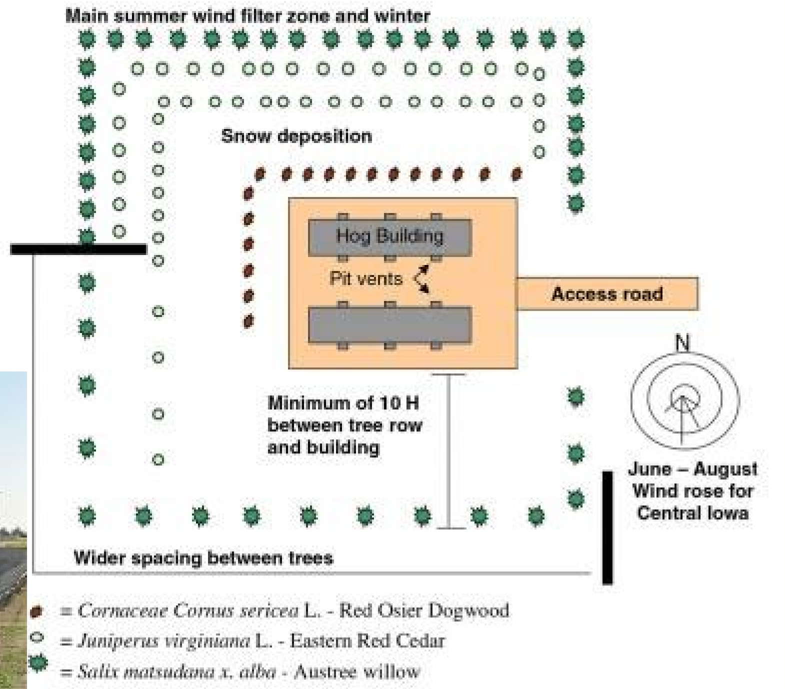
H2S = Hydrogen Sulfide; VOC = Volatile Organic Compounds; GHG = Greenhouse Gases

Red = low impact

Yellow = medium impact

Green = high impact

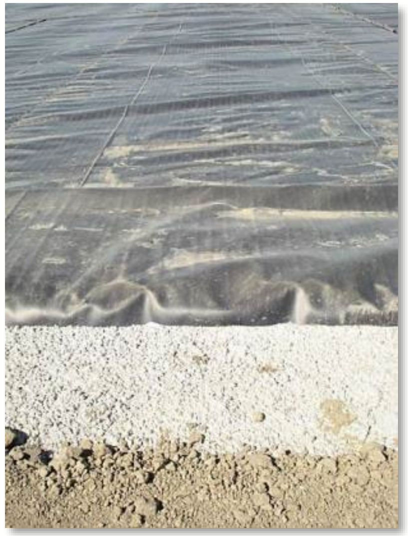
Blank = insufficient data



How Does AD Reduce Odor?

Anaerobic Digestion

- Increases NH_4 and H_2S
- Reduces volatile organic C by shifting to CO_2 and CH_4

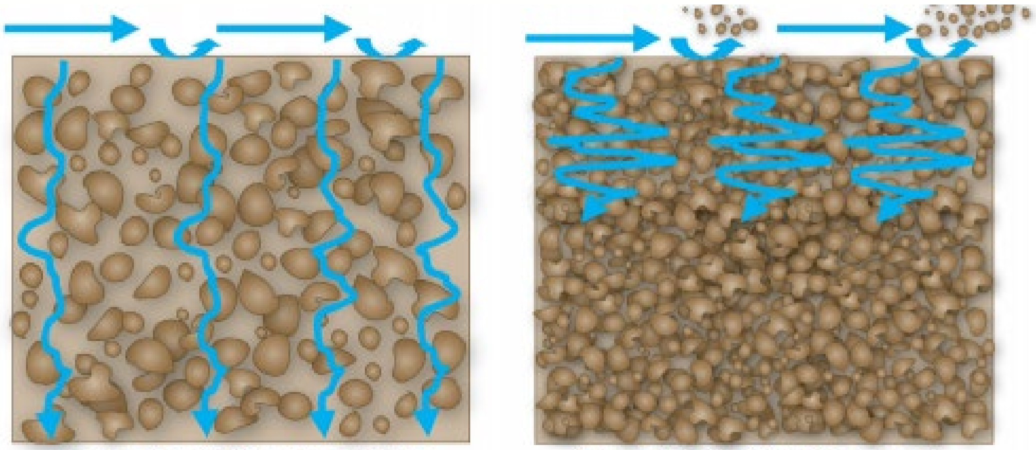


Impermeable Cover

- Both digester and effluent storage
- Reduces odor transfer

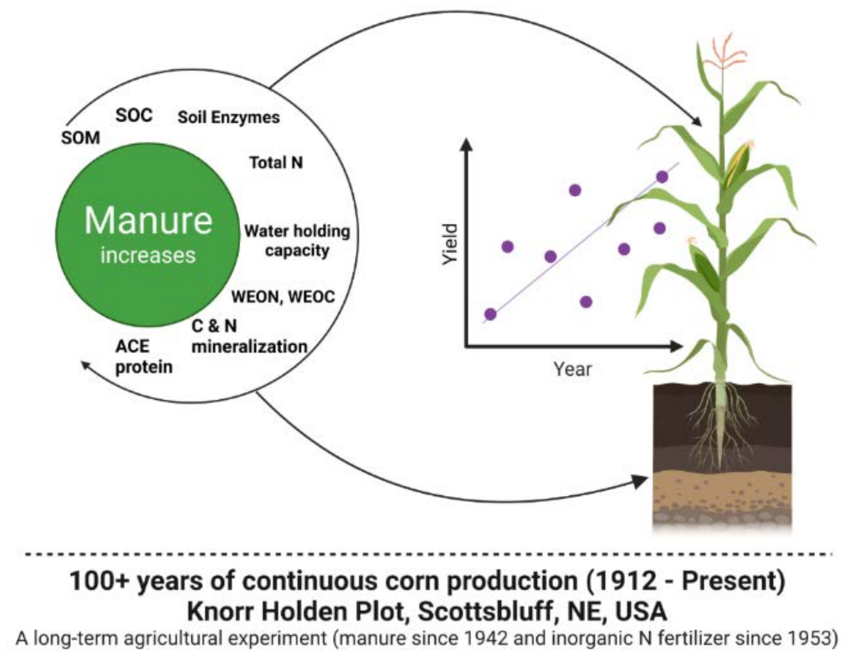
Soil Health Improvement

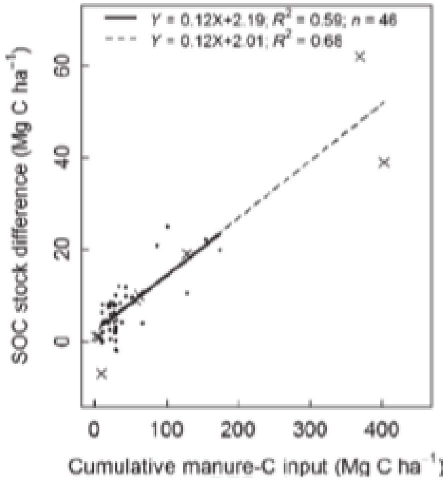
- Importance of soil health
- Soil Organic Matter
- How does the use of biomass influence carbon flows?



Uncompacted soil with stable aggregates

Compacted soil with surface crust and unstable aggregates





How do digesters influence soil health?

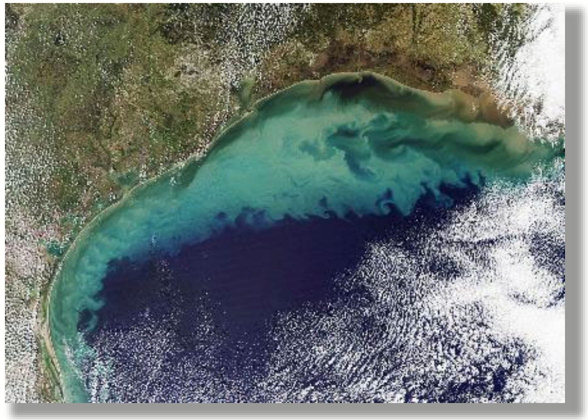
- Role of digesters on soil health
  - Crop rotation
  - Biomass crops
  - Biomass removal
  - Effluent application

- Group of 4-5, pick 1 topic and discuss in group how carbon flow is impacted. What role on soils.

- 3 minutes group, 2 minute report back

Challenges of Corn Belt Agriculture

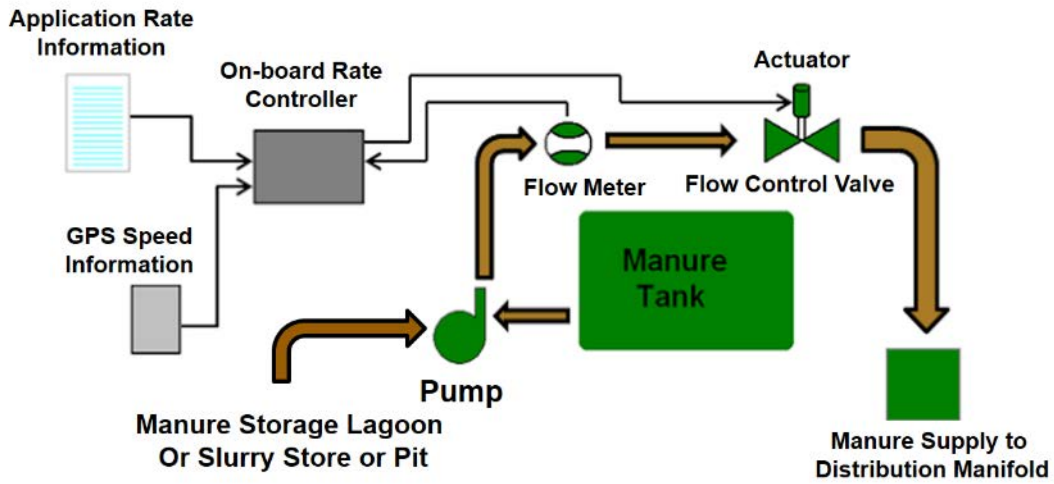
- Row crop monoculture with <u>long fallow periods</u>
- <u>Soil and nutrient losses</u>
- Drinking water contamination
- Eutrophication
- Dead zones
- Land degradation
- Scalable solutions needed for improvement of local and downstream water quality – cover crops?



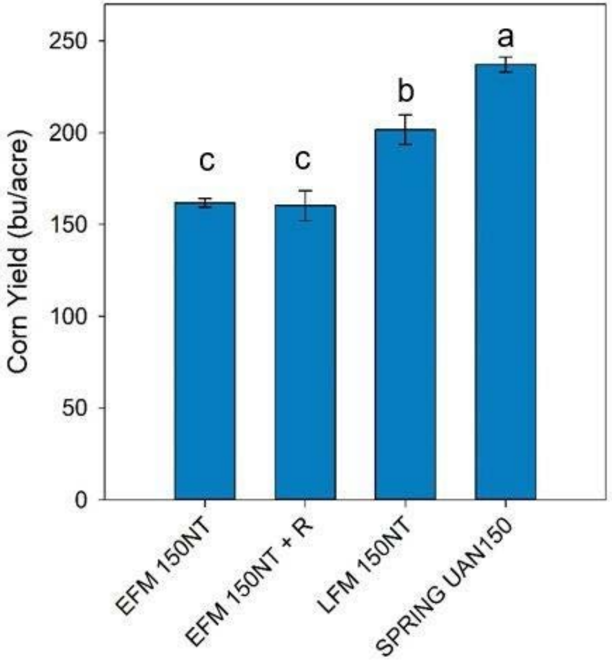
USGS

U.S. Fish and Wildlife Service

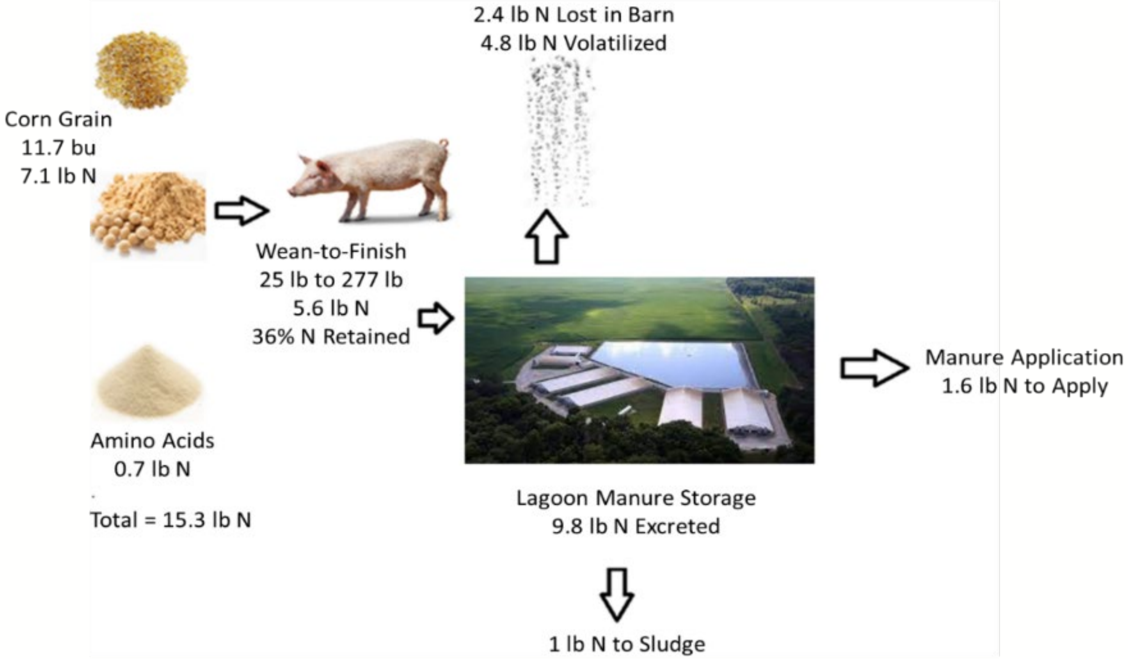
Nutrient Management Impacts

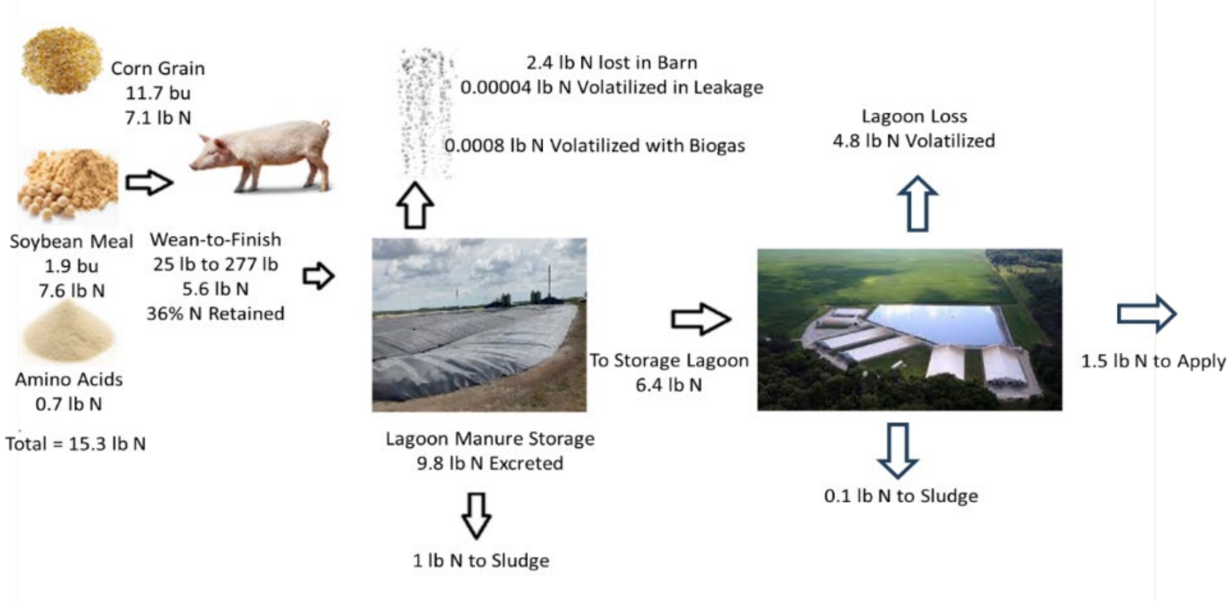


Manure/Effluent is a complete fertilizer, but not a balanced fertilizer (may not be complete based on digester recipe)
Digestion increases N availability
More P may settle in storage.
Reduces solids and bacteria in the manure.



Nitrogen Retention Example





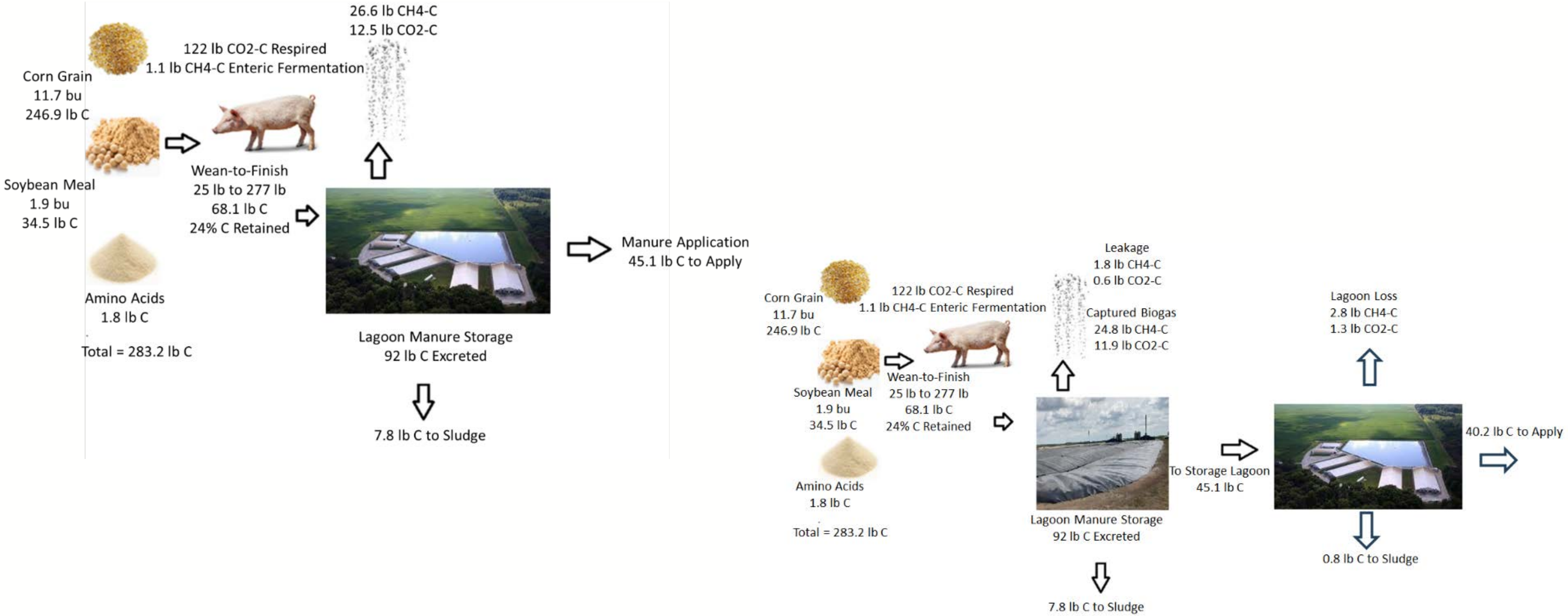
Reduced Carbon Footprint

- Livestock Globally
  - Responsible for 15% of anthropogenic greenhouse gas emissions
  - 5% resulting from manure management
- Carbon Reduction Pledges – Production and Processing
  - Smithfield Foods: 30% reduction by 2030
  - JBS Foods: 30% by 2030, net zero by 2040
  - Nestle: 20% by 2025, 50% by 2030, net zero by 2050

Carbon Footprint

System	CH_4 kg/hd-yr	N_2O kg/hd-yr	$CO_{2,eq}$ kg/hd-yr
Lagoon	22.6	0.2	625
Deep-pit	7.3	0.2	242
Deep-pit (revised)	12.2	0.2	365
Bedded Pack	0.9	0.7	231

Carbon Reduction Example



Making Digesters Pay

- Direct sale of energy
- Sale of digitate products?
- Tipping fees?
- Carbon Credits
  - RINS, LCFS (CI), eRINs
- Flaring vs Electricity vs Compress Natural Gas
- Economy of Scale

Question and Comments

Daniel Andersen, PhD, EIT
Associate Professor
Ag. and Biosystems Engineering
Manure Management and Water Quality
Iowa State University
515-294-4210
dsa@iastate.edu
@DrManure
themanurescoop.blogspot.com

Status of AD in the United States and the AgSTAR Program

AD on the Farm Pre-Conference Workshop – 6 November 2023

WHAT WE'LL COVER TODAY

1. Introduction to the AgSTAR Program
2. Benefits of AD
3. State of AD in the United States
4. Opportunities for AD in the United States
5. Overview of AgSTAR resources & tools

The AgSTAR Program

PARTNERSHIP PROGRAM

Collaborative program sponsored by EPA and USDA.

1. **Promote Anaerobic Digestion**
   Advancing economically and environmentally sound livestock manure management.

2. **Strong Ties**
   Working with industry, government, NGOs and university stakeholders.

3. **Helping Hand**
   Assisting those who enable, purchase, or implement farm anaerobic digestion projects.

Resources for Sustainable Manure Management

www.epa.gov/agstar

Market Trends

- National data for anaerobic digester projects
- Market Opportunities Report

Success Stories

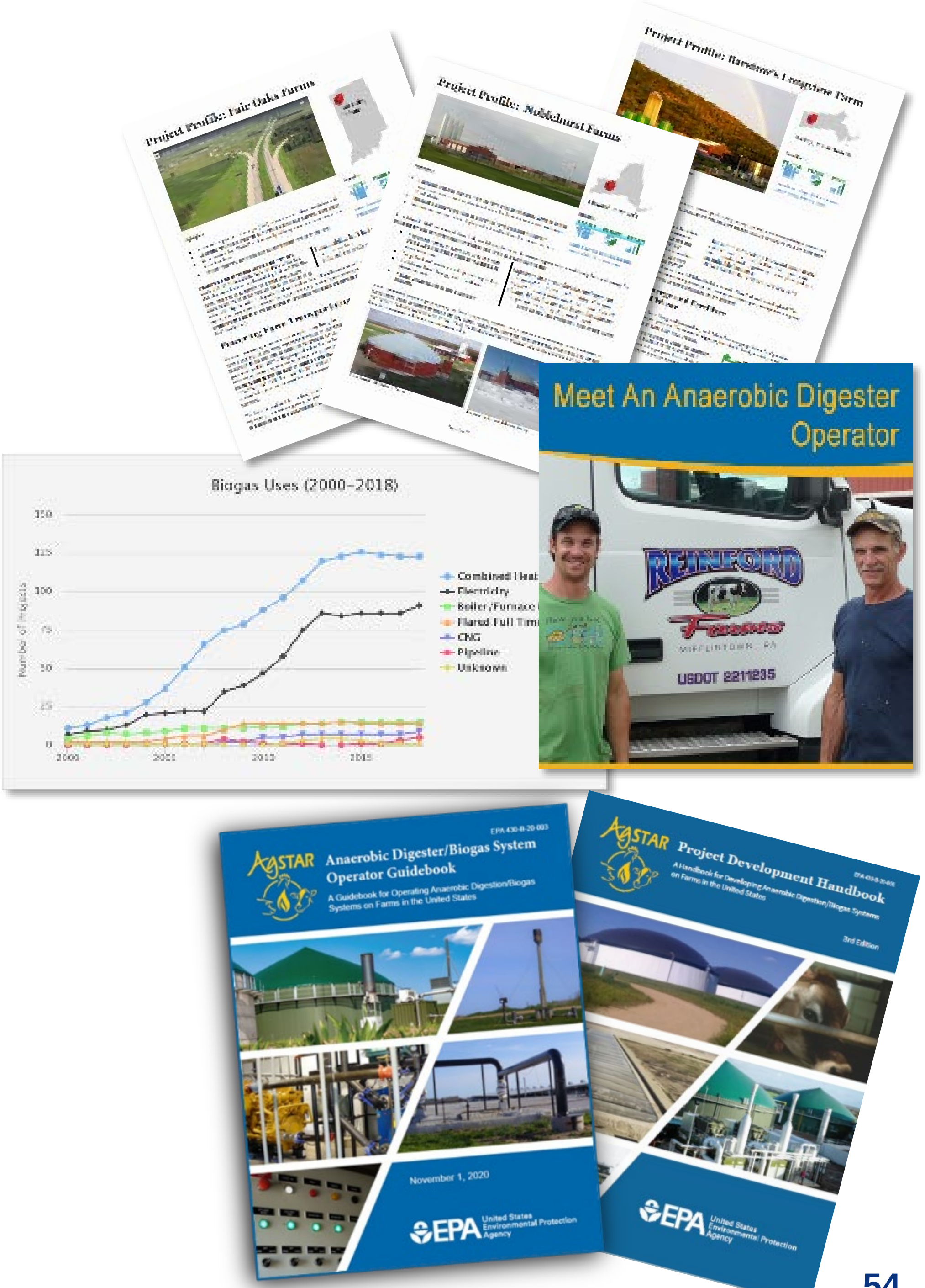
- Project profiles
- Interviews with operators

Technical Information

- Biogas Toolkit
- AD Risk Analysis Checklist
- AD Project Development Handbook
- AD Operator Guidebook
- Sector Factsheets – Dairy, Swine & Poultry

Collaboration

- Webinars
- Industry events & trainings



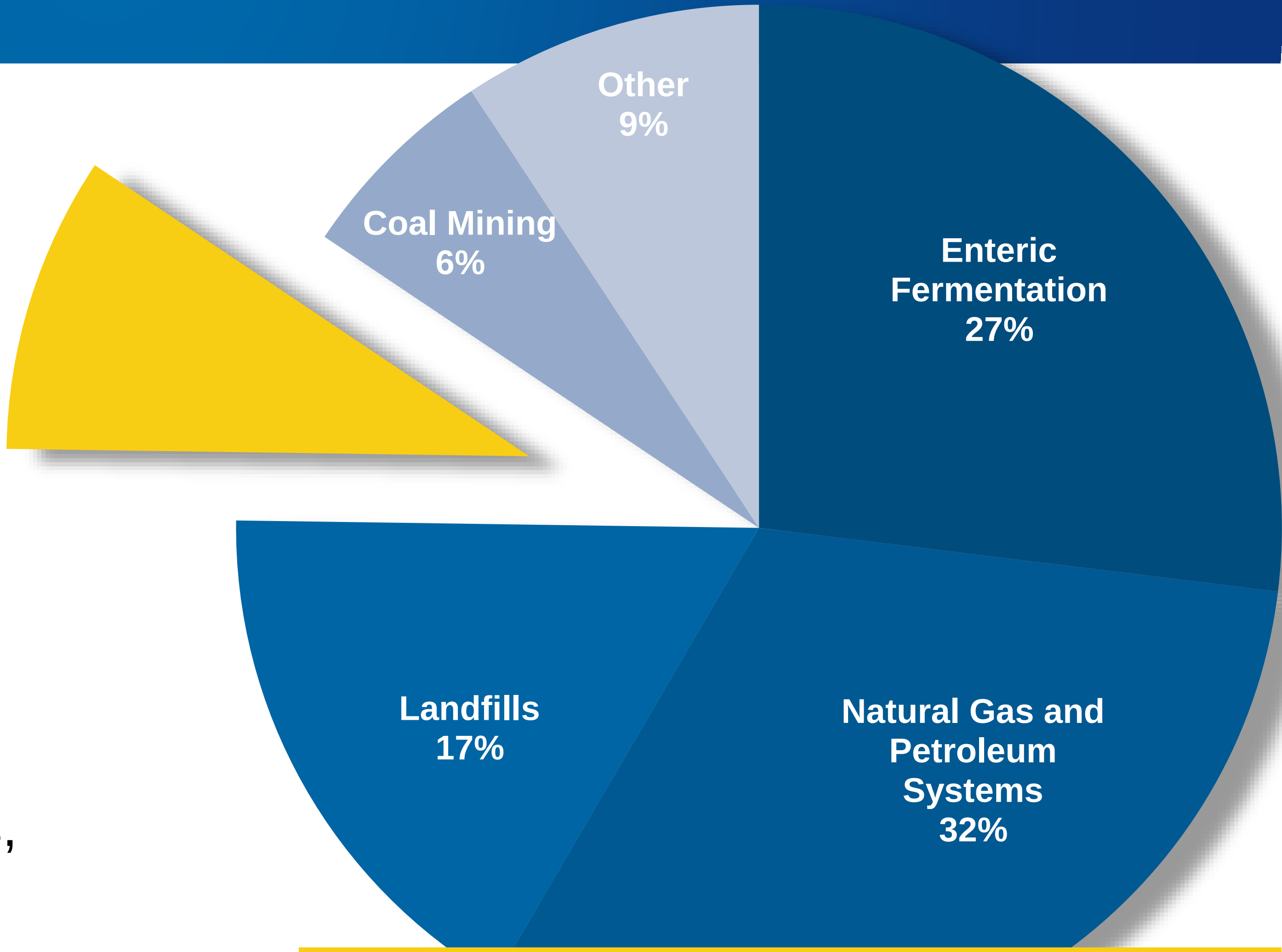
Benefits of Anaerobic Digester Systems

Anaerobic digesters are a tool to manage manure sustainably

- ## Environmental
  - **Air Quality:** reduced methane emissions, a powerful GHG and source of ground-level ozone; reduced odors
  - **Water Quality:** reduced pathogens and excess nutrients from leaching into surface and groundwaters
  - **Soil Health:** land application of digestate recycles nutrients and is shown to increase crop yields
- ## Energy
  - Renewable energy production; energy independence; and displacement of fossil fuels
- ## Economic
  - Diversified farm revenue through sale of energy and co-products; opportunity to create new local jobs; partnerships with local businesses

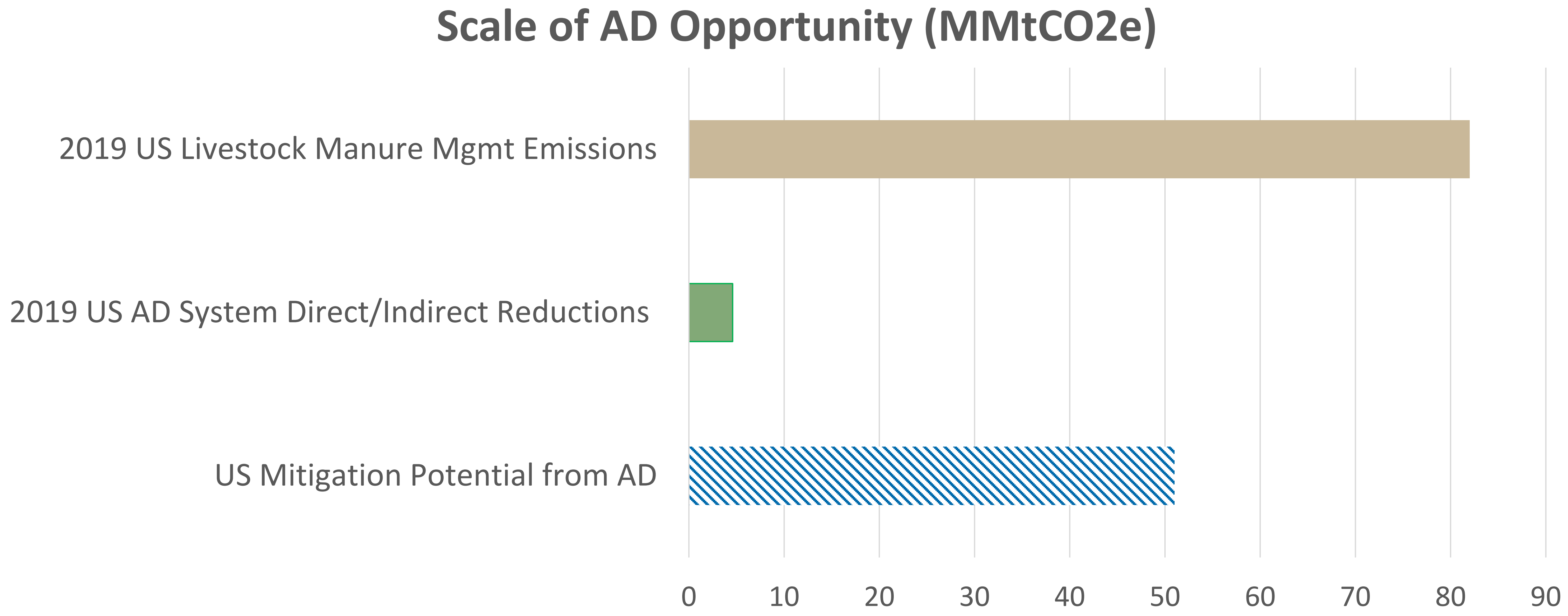
Scale of Potential AD/ Biogas Systems in U.S.

- Livestock (dairy, beef, swine, poultry) manure contributes ~9% of US methane emissions, or 59.6 MMTCO2e
- US methane emissions from livestock manure increased 71% between 1990 to 2020
- AgSTAR's Market Opportunities Report estimates that **over 8,000 systems are feasible*** on farms
  - Opportunities to incorporate organics, diversion from landfills
    - Based on farm size – 500 cows, or 2000 swine



U.S. METHANE EMISSIONS 2020, BY SOURCE
1990-2020 U.S. GHG INVENTORY – PUBLIC REVIEW ESTIMATES

Potential GHG Emission Reductions from AD Systems



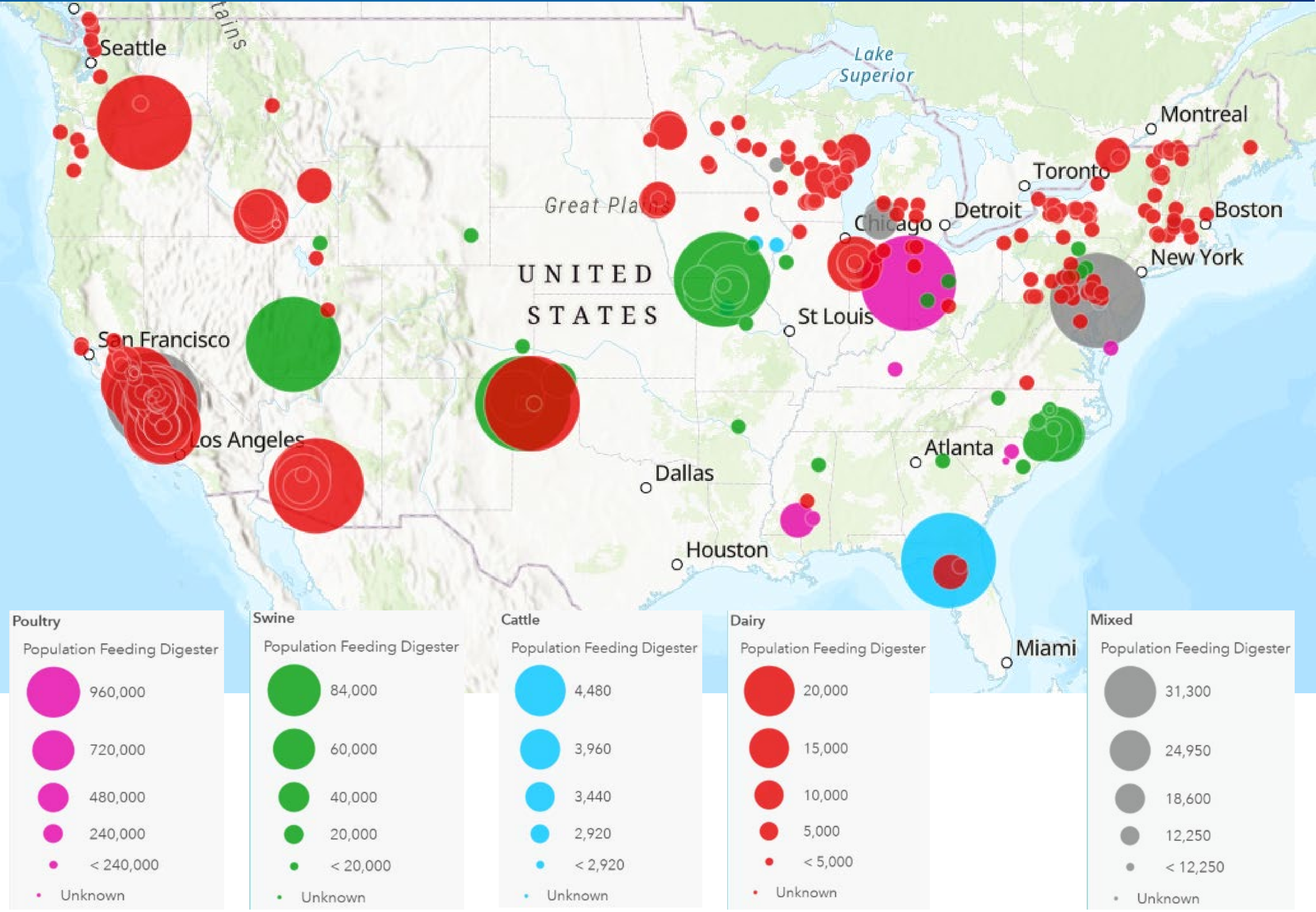
Sources: 2019 Manure Management – GHGRP, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 – Main Text" page 2- 9 Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019 ; 2030 Economic Potential: Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation: 2015-2050. October 2019; 2019 Direct & Indirect Emission Reductions, AgSTAR Livestock Anaerobic Digester Database

Where are digesters currently found?

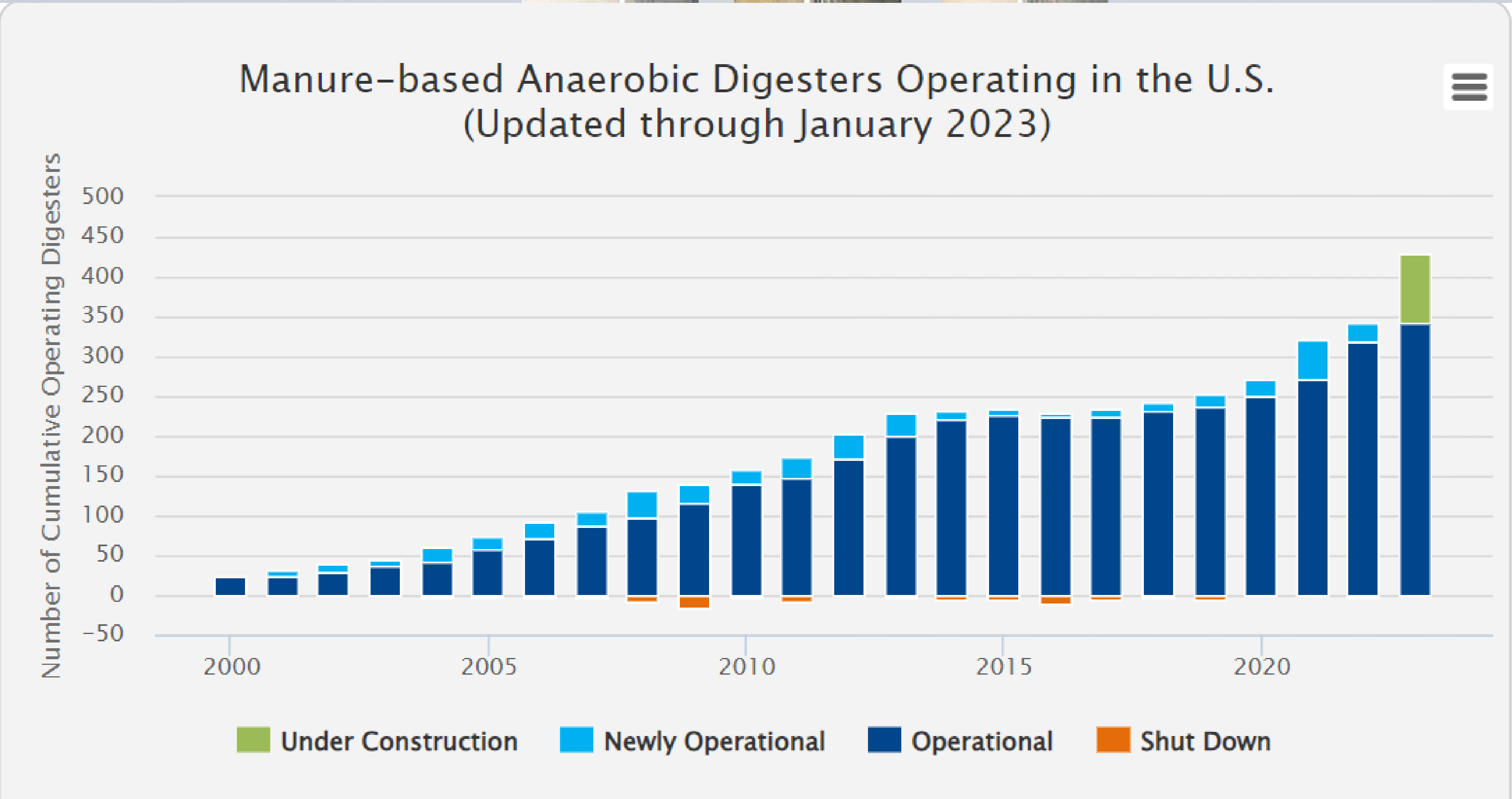
- **343 active digesters in the U.S.**
  - ➢ **290 Dairy**
  - ➢ **46 Hog**
  - ➢ **8 Poultry**
  - ➢ **9 Beef**

Note: Total exceeds 343 because some systems accept manure from more than one animal type.

- **104 (~30%) digesters combine manure with other feedstocks such as:**
  - ➢ **Brewery/distillery spent grain**
  - ➢ **Dairy processing wastes (e.g., whey)**
  - ➢ **Food waste**
  - ➢ **Agricultural residues**



Farm Digester Market Growth



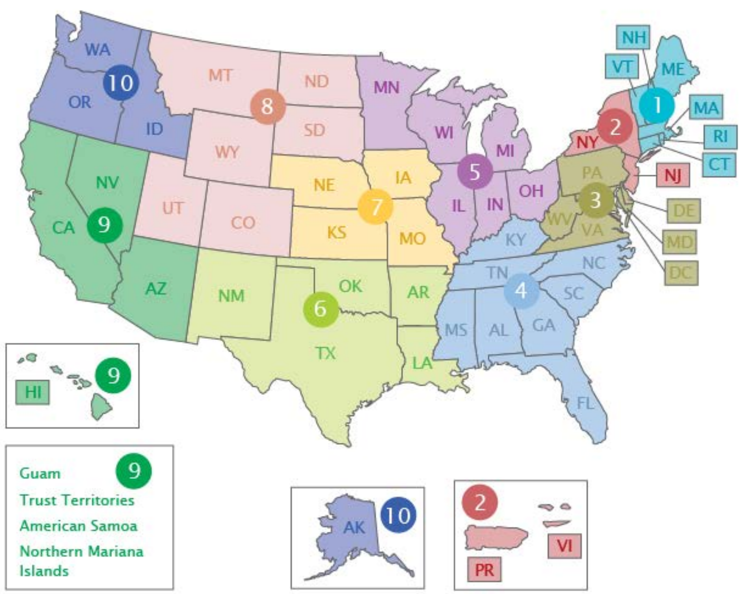
343 Current Digesters

Growth projected to exceed 500 digesters in next 3 years

Potential for over 8,000* digesters on farms in U.S.

Source: AgSTAR Digester Database

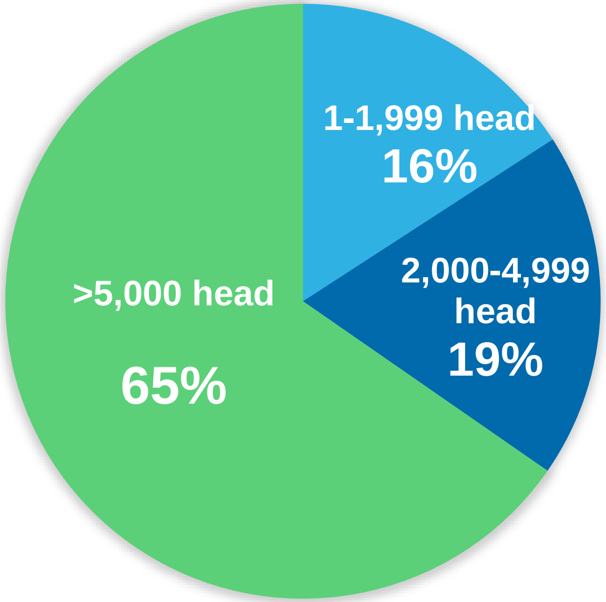
Region 7 AD Market Growth Potential



Region 7 includes Iowa, Kansas, Missouri, Nebraska and Nine Tribal Nations

Market Opportunities to Generate Electricity with Anaerobic Digestion in EPA Region 7	
Total number of swine operations	14,996
Total number of mature swine (000 head)	27,550
Number of feasible swine operations	2,408
Number of mature swine at feasible operations (000 head)	19,661
Methane emission reduction potential (tons/year)	384
Methane production potential (billion cubic ft/year)	31
Electricity generation potential (000 MWh/yr)	2,601

Region 7 Swine Farm Size



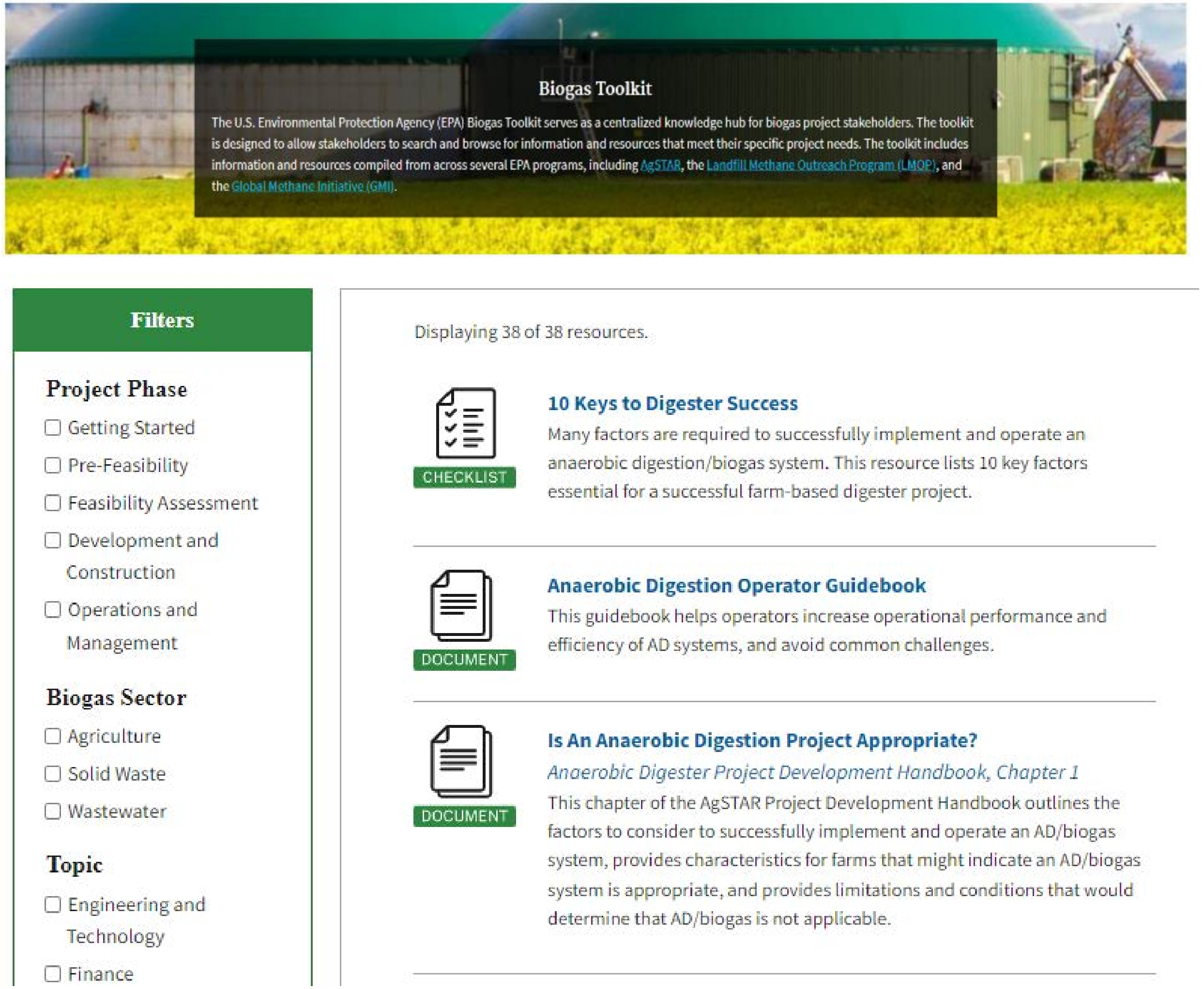
Source: AgSTAR Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities

Foundational Resources for AD/ Biogas Systems

- **Biogas Toolkit:**
  - A web-based toolkit with 38 tools and resources to facilitate biogas project development.
- **Project Development Handbook (3rd Edition):**
  - A comprehensive compilation of the latest knowledge in the industry on best practices for anaerobic digestion (AD)/ biogas systems.
- **Operator Guidebook (1st Edition):**
  - A guide for AD/ biogas systems operators to ensure safe and efficient operations of the systems they manage.
- **AD Risk Analysis Checklist:**
  - A checklist of best practices to help users determine technical & financial feasibility of AD/ biogas projects.
- **AD Screening Tool:**
  - A Microsoft Excel-based screening tool to assess the potential feasibility of AD projects in the U.S. and globally.

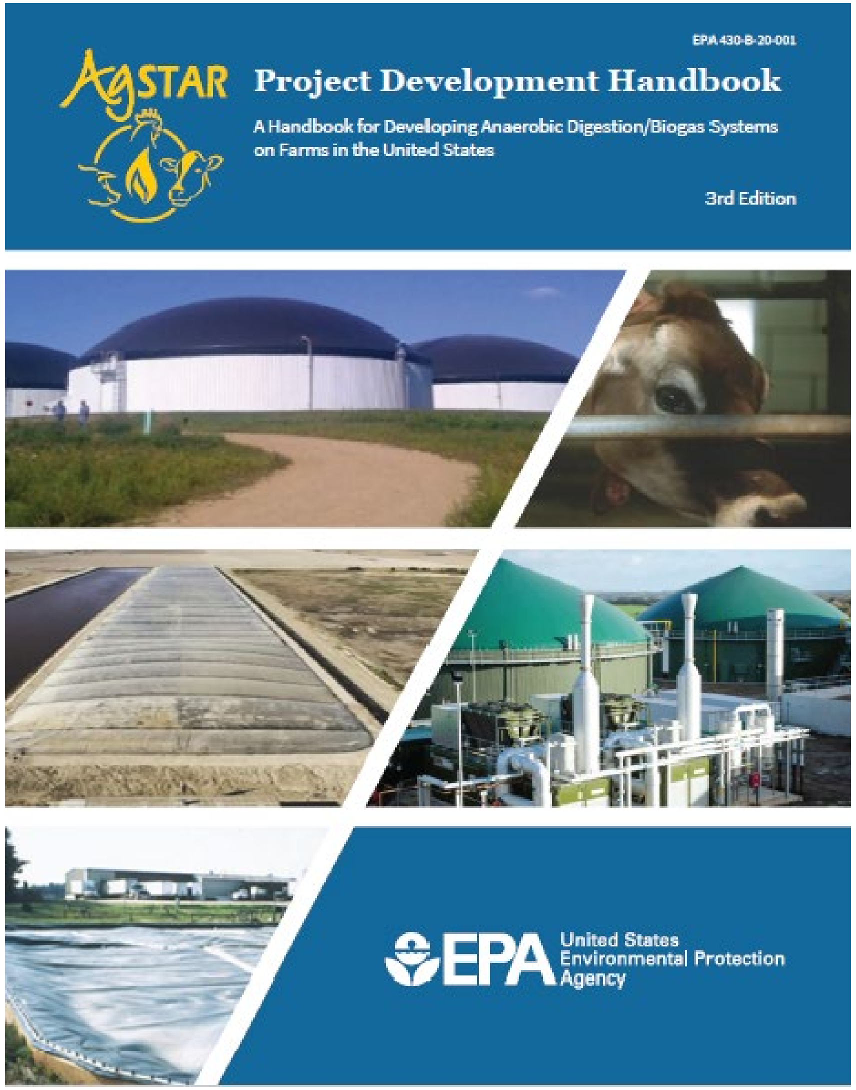
EPA Biogas Toolkit

- EPA Biogas Toolkit includes **38 tools and resources** to facilitate biogas project development.
- **Roadmap for planning and implementing biogas projects** and quantifying economic and environmental impacts
- **Audience:** Project implementers, developers, financiers, and policymakers.



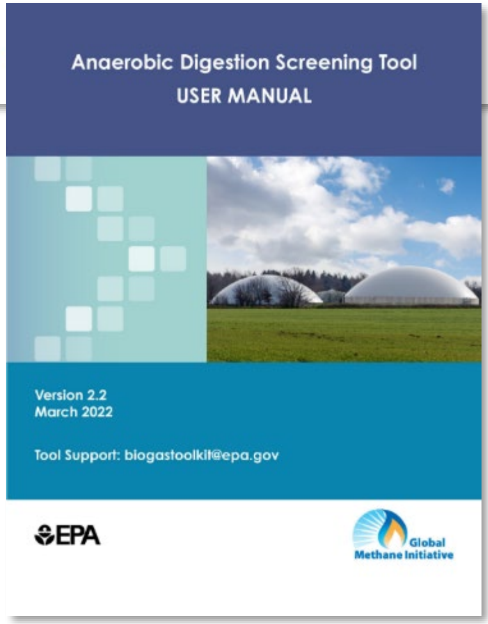
AD Project Development Handbook

- The latest knowledge in the industry on best practices for anaerobic digestion (AD)/ biogas systems.
- **Goal**: ensure long-term success for AD/ biogas systems by providing a framework for project development.
- **Primary audience**: Anyone interested in AD/biogas systems as a farm manure management option
  - Policy makers
  - Farmers
  - Financiers/ investors
  - Private Developers



Anaerobic Digestion (AD) Screening Tool

- **Excel-based screening tool** to assess potential feasibility of an anaerobic digestion project. The tool outputs include:
  - Annual biogas and digestate generation
  - Methane emissions reductions projections
  - Potential end uses of biogas
- **Primary audience:**
  - Project proponents to understand the biogas potential of a proposed project
  - Lending institutions/banks to determine if a project application is feasible



Visit GMI's Tools and Resources Library to download the tool: https://www.globalmethane.org/resources

Organics Economics (OrganEcs)

- **Two Excel-based tools** to estimate the financials of organic waste management projects:
  - Composting
  - Anaerobic digestion
- **Primary audience:**
  - Local governments
  - Waste professionals
  - Policymakers
  - Facility operators
  - Project developers

Visit GMI's Tools and Resources Library to download the tool: https://www.globalmethane.org/resources

Register for our Upcoming Webinar!

December 5, 2023
1:00 – 2:00 PM EST
Registration link:

AgSTAR Tools and Resources:

Understanding the Financial and Environmental Benefits of Anerobic Digestion

Presenters from the U.S. Environmental Protection Agency (EPA) will introduce the AgSTAR Program and provide an overview of tools and resources available to support anaerobic digestion (AD) projects. Attendees will learn how to estimate the economic feasibility and environmental benefits of AD using the Anaerobic Digestion Screening Tool and Organics Economics (OrganEcs).

Contact:

Jake Dunton
dunton.jake@epa.gov

Nick Elger
elger.nicholas@epa.gov

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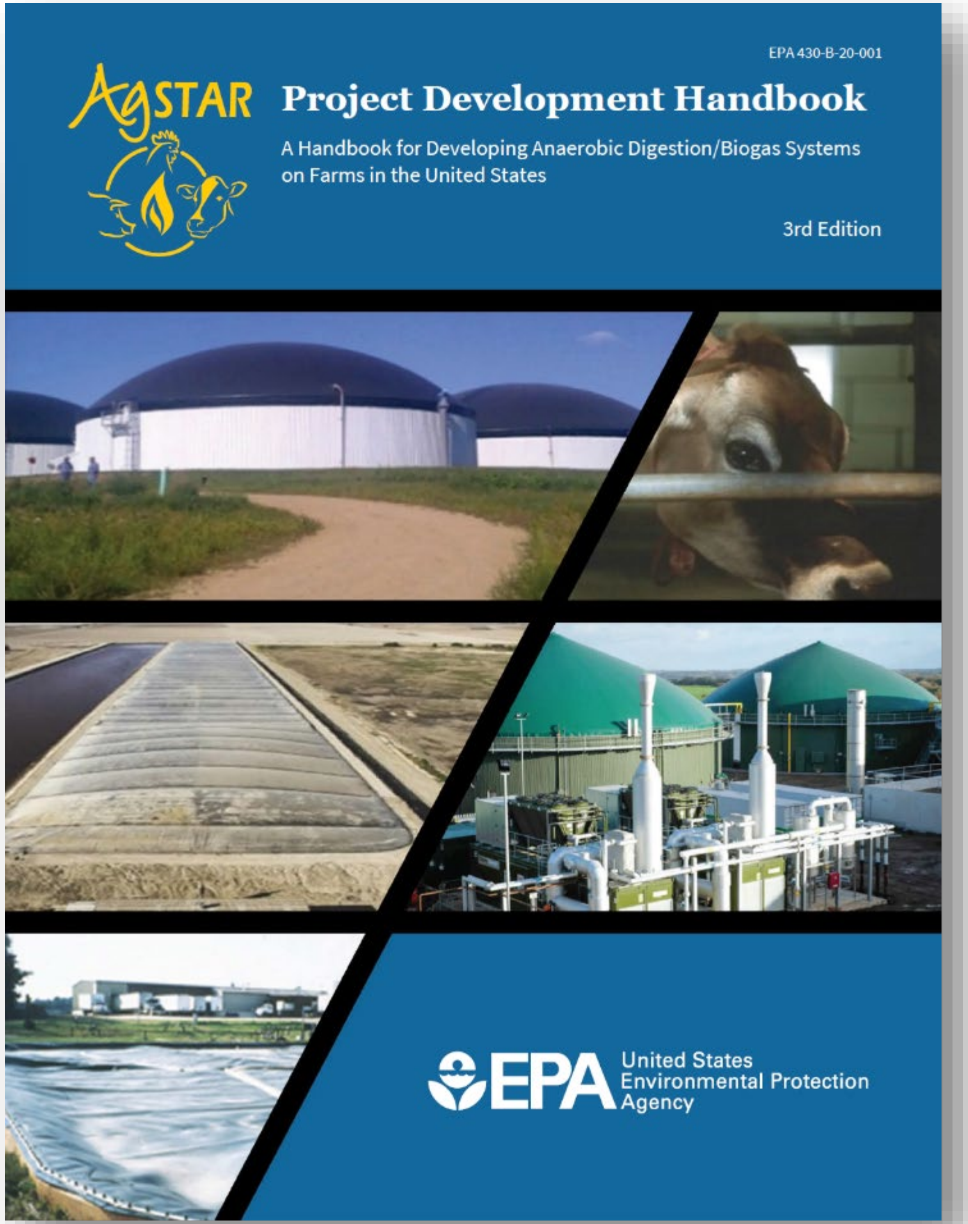
Economic and Financial Factors

6.0 Economic and Financial Factors ....
6.1 Capital Investment ....
6.2 Operating Expenses..................................
6.3 Project Revenues....................................
6.4 Owner and Operator Models..........................
6.5 Project Finance......................................
6.6 Financial Assistance for Agricultural Projects



Capital Investment

Some of the capital costs associated with building an AD/biogas system may include:

Table 6.1. Capital Budget Example

	Construction Budget Items
	Digester Turnkey Cost
+	Engineering and Permits
+	Construction Insurance
+	Interconnection Costs
+	Filtrate Storage System
+	Developer's Fee
=	**Construction Budget Total**

	Owner's Budget Items
	Working Capital
+	Financing Costs
+	Contingency
=	**Owner's Budget Total**

Operating Expenses

Table 6.2. Examples of Operating Expenses

Expense	Units
Daily Labor, if needed	$/hour
Engine O&M	¢/kWh
AD/Biogas System O&M	$/day
H_2S Removal	$/year
Insurance	$/year
Outside Engineering & Other Services	$/year
Filtrate Management	¢/gallon

Daily operating labor is commonly assumed to be a farm employee task.

Operational labor is frequently underestimated.

A farm-based digester generally requires at least one operator, close to full time.

Operating Expenses

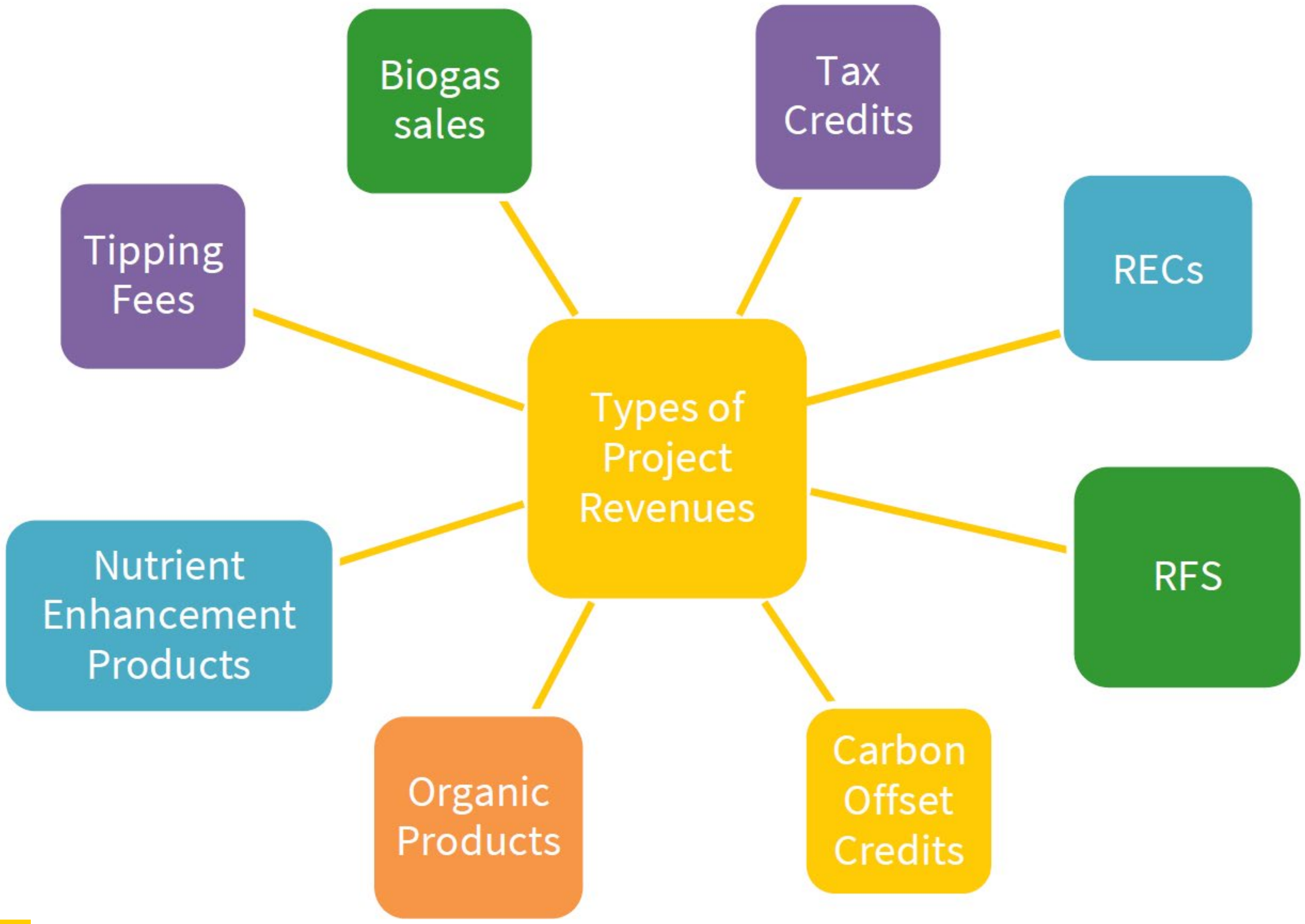
Daily labor includes checking mechanical & electrical systems, assuring proper control system functions, routine engine maintenance, checking proper operation of biogas and other meters, digester pH and temperature, and assembling data.

Biogas-fueled engines require routine oil, filter, and sparkplug replacement. Depending on the engine's duty-cycle, oil changes might be done between 500 to 1,500 hours of operation. After about 20,000 hours, a top end rebuild of the engine may be necessary.

Depending on the AD/biogas project ownership structure, daily labor may be provided by the farm. Because the farm's primary purpose is to generate a product, evidence shows that digester O&M becomes secondary.

Project Revenues

Figure 6.2. Types of Project Revenues



Project Revenues

Biogas sales

Biogas can be used for CHP to offset the farm's electricity and heating costs and excess electricity can be sold at wholesale rates.

In states with incentives for biogas-generated electricity, it may be better to sell to the grid and use the CHP heat on-farm. In this case, electricity is purchased on a per kWh basis.

Varying on-peak/off-peak rates is a possibility. Generation and storage is sized to maximize biogas utilization during on-peak periods. Downtime for maintenance is scheduled for off-peak hours.

If producing RNG, can be used on site or for pipeline injection. If the goal is use as transportation fuel, compression is required (onsite or offsite). Generally, the project will be generating revenue from RNG sales and from transportation sector credits.

Project Revenues

Tax Credits

Federal Electricity Production Credit/Investment Tax Credit

Tuesday: 2:00 – 3:45 Project Financing Session

RECs

Renewable Energy Certificates: RECs are tradable, non-tangible energy commodities representing proof that electricity was generated from a qualified renewable energy resource. Sometimes electric utilities fund an AD/biogas project in return for the RECs generated.

RFS

Renewable Fuel Standard/Renewable Identification Number: The RFS, established by the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007, provides financial incentives for RNG that is used as a vehicle fuel. California and Oregon also have LCFS and Clean Fuels incentive programs, respectively.

Tuesday: 10:45 – 12:30 Anaerobic Digestion and the Renewable Fuel Standard Session

Project Revenues

Carbon Offset Credits

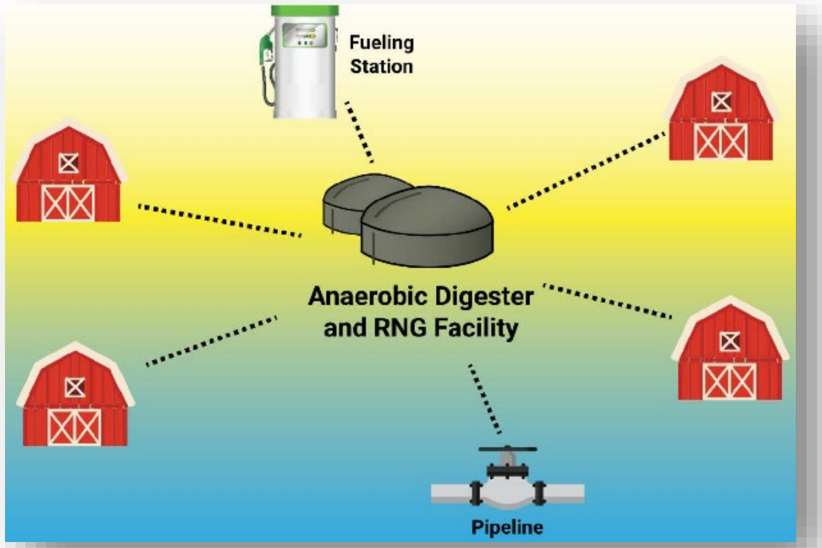
Carbon Offset Credits may be earned by reducing GHG emissions, such as the CH_4 recovered from an AD/biogas system. These credits have an economic value and can be bought and sold on commodity exchanges, through private transactions, or through credit aggregators.

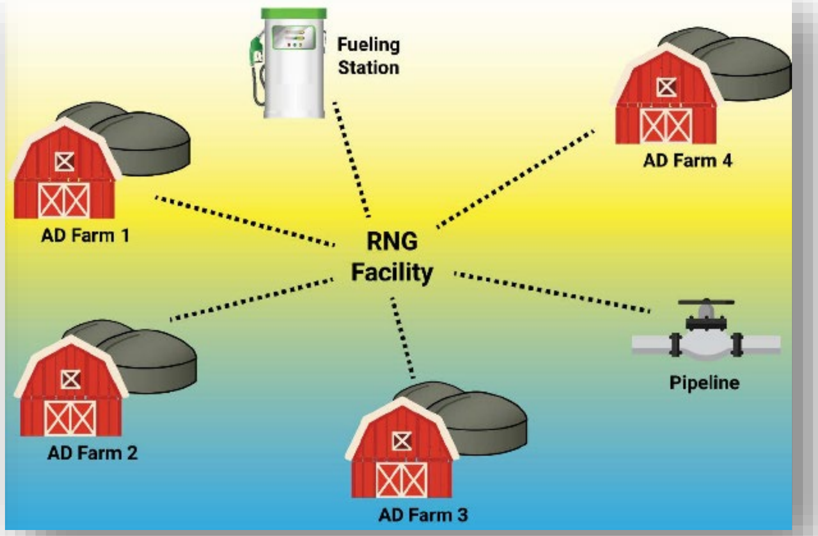
Tipping Fees

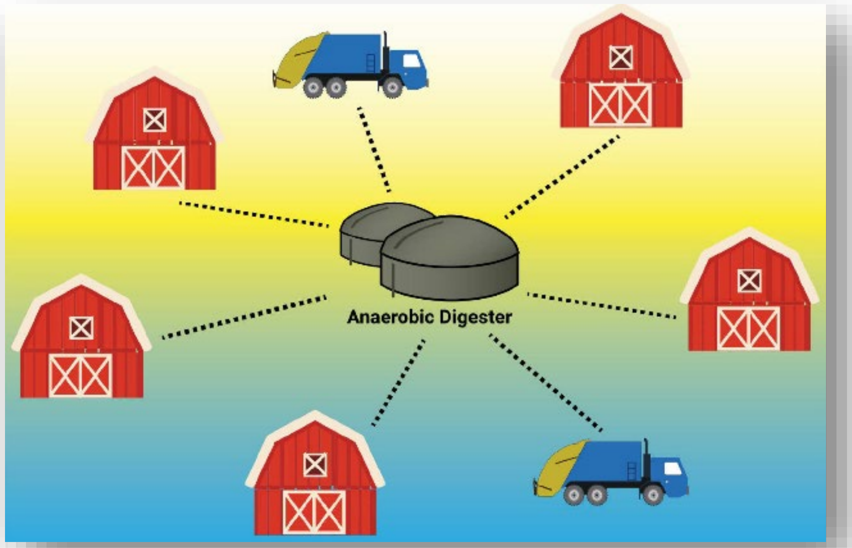
Tipping Fees received from co-digestion feedstocks are a potential revenue source. Organizations that produce large volumes of waste will often partner with an AD facility to off-take their waste.

Owner and Operator Models

- Involve partners along the value chain, such as co-ops, customers, suppliers, and processors;
- Draw on strengths, such as marketing, contracting, permitting, energy, design, or operations;
- Search for common goals, such as financial, public relations, or market expansion;
- Evaluate third party investment, ownership, and operation; and
- Look to traditional cooperative models for use with manure solids, nutrients, energy, or fuel.







Financial Assistance for Agricultural Projects

<u>Grants and Cost-Sharing</u>

<u>Loan Guarantees and Industrial Bonds</u>

<u>Other Cost-Sharing Agreements</u>: the farm operator and another entity (e.g., an electric utility, other company) share the capital and/or operating costs of the anaerobic digester. In exchange for providing funding, the entity receives a tangible return (e.g., owning the electricity generated) or receives environmental credits, such as the renewable energy credits/certificates (RECs) or the carbon offset credits.

AgSTAR Funding On-Farm Anaerobic Digestion

September 2012

Anaerobic digestion of on-farm manure resources offers livestock and poultry producers (farm operators) a unique opportunity to increase on-farm revenue. As energy costs become a larger part of the farm operation budget, farm operators are increasingly looking to energy efficiency and renewable energy projects as a viable option for increasing farm revenues. One such option is anaerobic digestion of animal manure, a waste resource that has considerable potential for generating clean, renewable, domestic energy.

One of the biggest obstacles to widespread adoption of on-farm anaerobic digestion has been its cost. Anaerobic digesters require significant amounts of up-front capital costs (expenditures), in addition to relatively high break-even prices for the electricity and fuel produced from the biogas. (The break-even price is the price at which an operator generates enough revenue to cover all costs.) To help overcome the burden of up-front capital costs, operators of anaerobic digesters may rely on several different funding mechanisms, including grants, cash reimbursements, loan guarantees, industrial bonds, private funding, and other cost-sharing agreements. Many anaerobic digester operators apply for and receive a combination of funding mechanisms (e.g., loan guarantees and grants) to fund their projects.

This fact sheet presents overviews of the various funding mechanisms available to farm operators, as well as case study examples for each.

Grants and Cost-Sharing

There are multiple **grant and cost-share programs** available for farm operators who are interested in anaerobic digestion. With a grant, a federal or state agency provides an award of cash to financially support a farm operator in the purchase and installation of an anaerobic digester. Grant funding may be received before the anaerobic digester is constructed and does not require repayment.

Some examples of programs where federal and state agencies provide grant funding for the construction and operation of anaerobic digesters include the U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) and Ohio's State Energy Program. In some cases, federal-level funding sources (i.e., American Recovery and Reinvestment Act of 2009, or ARRA) provide states with grant money that is administered at the state level. For additional information on funding programs available for anaerobic digesters, see the fact sheet *Funding Programs for Developing Anaerobic Digestion Systems* (http://www.epa.gov/agstar/documents/agstar_federal_incentives.pdf), and also the AgSTAR Funding database, Funding On-Farm Biogas Recovery Systems: A Guide to Federal and State Resources (http://www.epa.gov/agstar/tools/funding/index.html).

For cost-sharing, also sometimes referred to as cash reimbursement, farm operators typically purchase and construct the anaerobic digester and then apply for funding after project completion. Cost-sharing and cash reimbursements do not require repayment. An example of cost-share programs would include the USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP).

Photograph courtesy of Tatjana Vujic of Duke University, Duke Carbon Offsets Initiative.

IOWA ENERGY CENTER
ENERGY INFRASTRUCTURE REVOLVING LOAN PROGRAM

Loan Amounts:
- **Minimum:** $50,000
- **Maximum:** $2,500,000
- Can cover up to 75% of project costs

Loan Terms: 5-10 years for most projects (IEC Board may approve up to 15 years)

Interest Rate: 2%

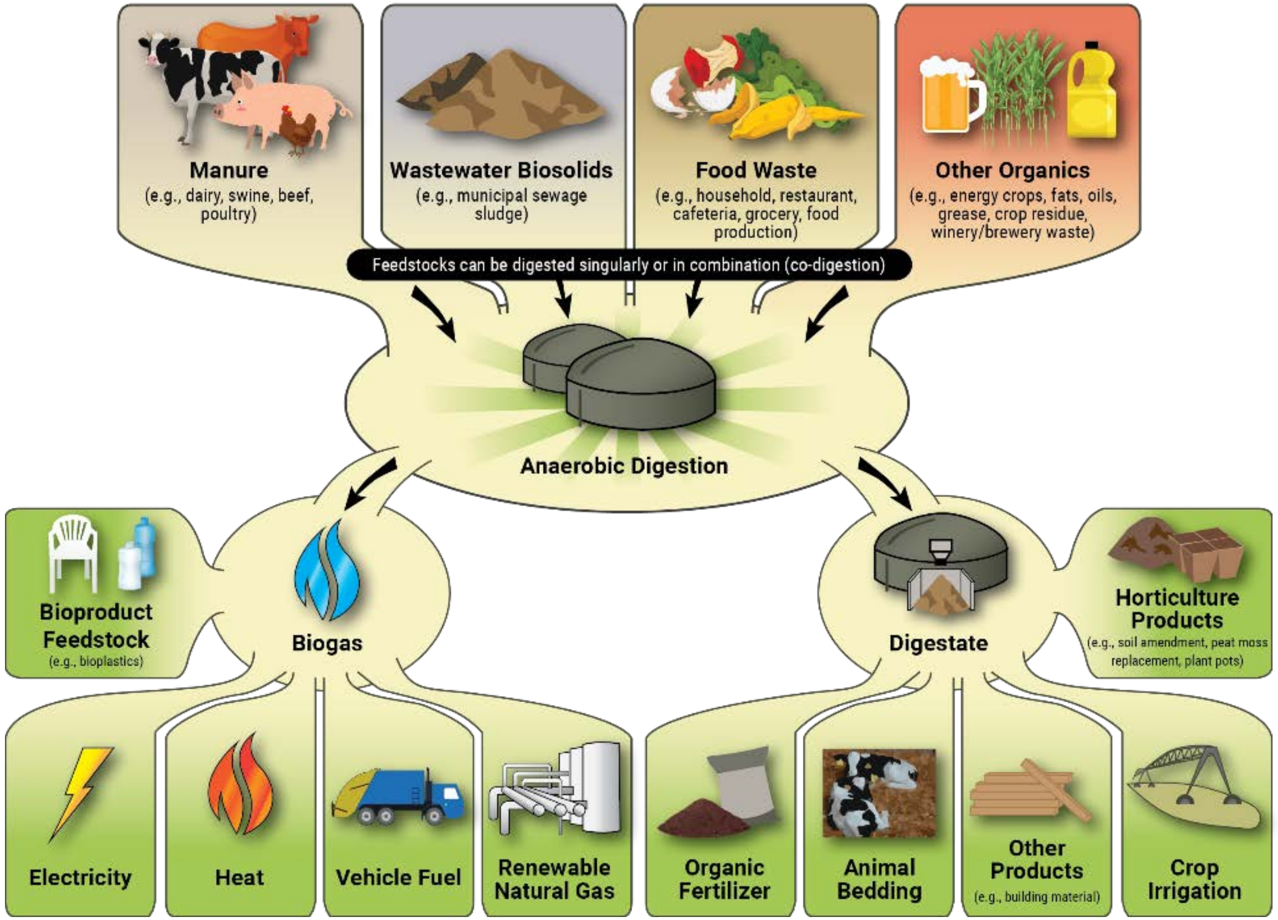
PROGRAM MANAGER

Stephanie Weisenbach
stephanie.weisenbach@iowaeda.com
515.348.6221

The purpose of the program is to support:

- Energy infrastructure development
- Electric grid modernization
- Energy-sector workforce development
- Emergency preparedness for rural and underserved areas
- Expansion of biomass, biogas and renewable natural gas
- Innovative technologies
- Development of infrastructure for alternative fuel vehicles

Closing Remarks



Next up:

5:00 - 5:45 pm: Conference Kickoff, Sun Room
5:45 - 6:45 pm: Poster Session and Opening Reception, Sun & South Ballroom
7:00 - 8:00 pm: Keynote, Marcelo Mena-Carrasco, Sun Room
8:00 - 9:00 pm: Keynote Reception and Poster Viewing, Sun & South Ballroom