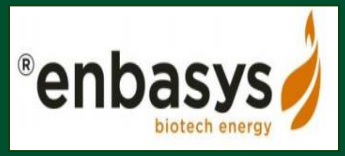
Anaerobic Digestion

System Selection for Organic Management

Speaker:
Prentiss A. Shaw, P.E.
Cornerstone Environmental Group, LLC
Co-Author: Laura Hammerer

CORNERSTONE
Environmental Group, LLC

How to Choose?



What's to Come

- AD Basics
- Proven Technology
- Why AD for Organics
- AD System Parameters
- System Categories & Providers
- System Selection Criteria

CORNERSTONE
Environmental Group, LLC

Anaerobic Digestion Basics

What is Anaerobic Digestion?

Anaerobic digestion is a biological process in which microorganisms break down organic material in the absence of oxygen.

CORNERSTONE
Environmental Group, LLC

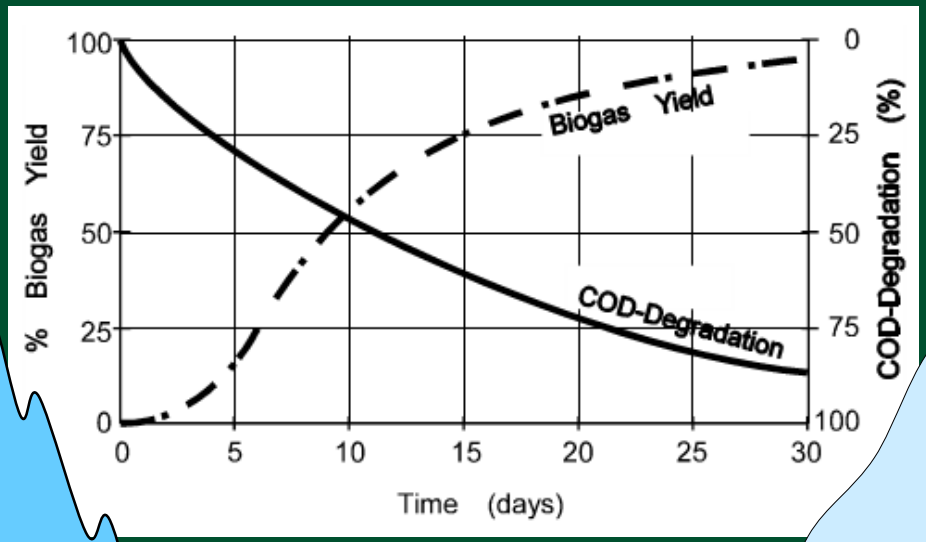
Anaerobic Digestion Basics

Anaerobic Digestion is Not…

- Composting – aerobic
- Gasification – thermal
- Pyrolysis – thermal
- Plasma Arc – thermal
- Depolymerization – chemical

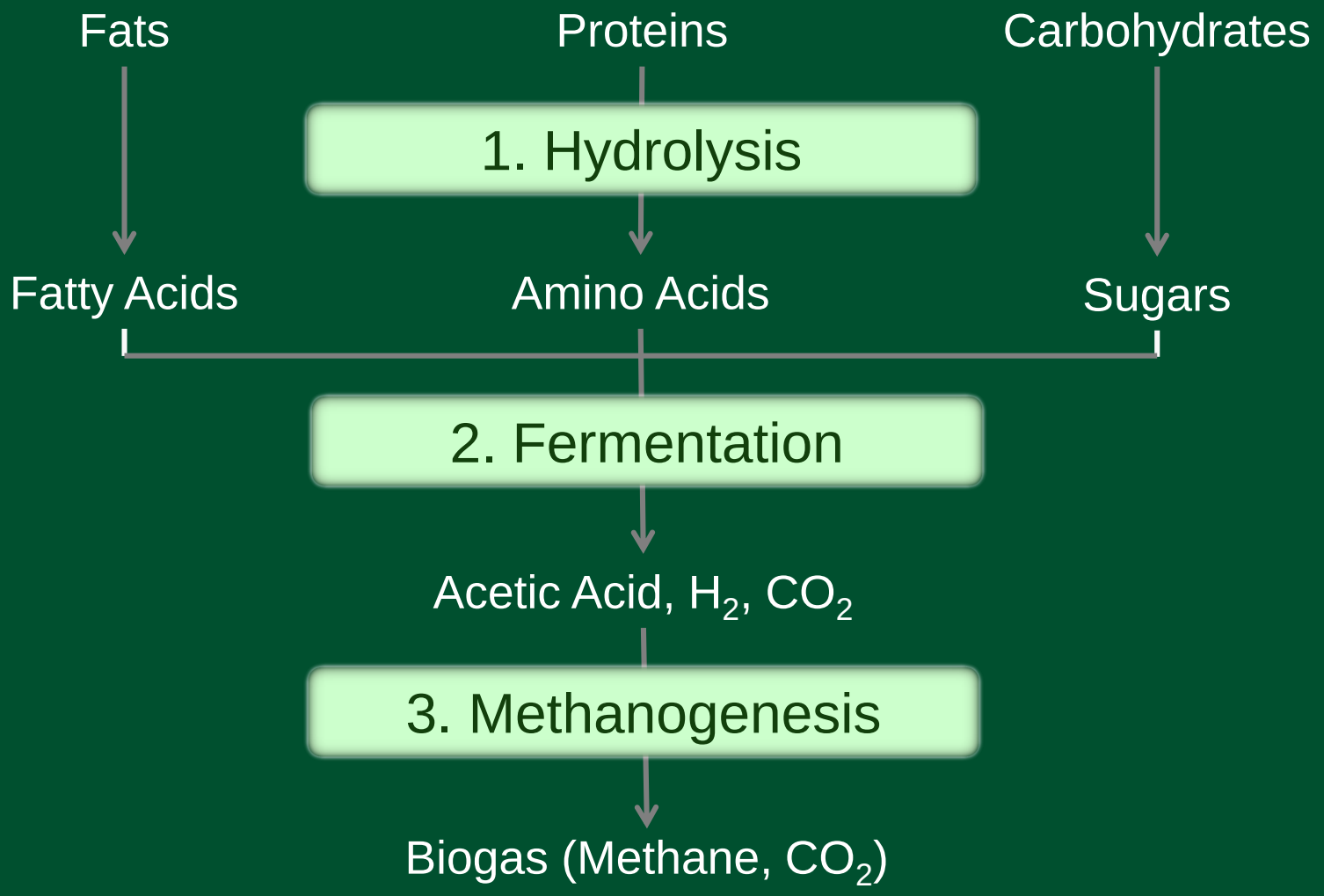
CORNERSTONE
Environmental Group, LLC

Anaerobic Digestion Basics



CORNERSTONE
Environmental Group, LLC

Anaerobic Digestion Basics



CORNERSTONE
Environmental Group, LLC

Anaerobic Digestion Basics

- Don’t get confused…

  Digester = Reactor = Fermenter

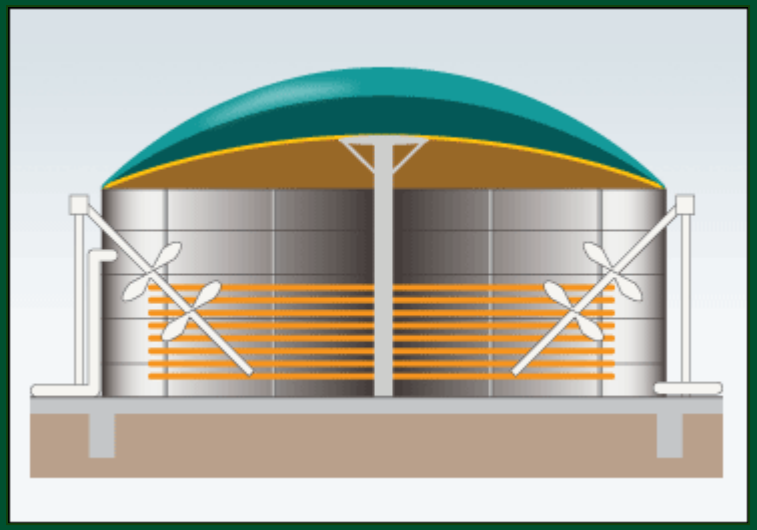
  They’re all the same!

- Terms may sometimes include entire system including substrate preprocessing and/or gas and digestate treatment (not just the AD process).

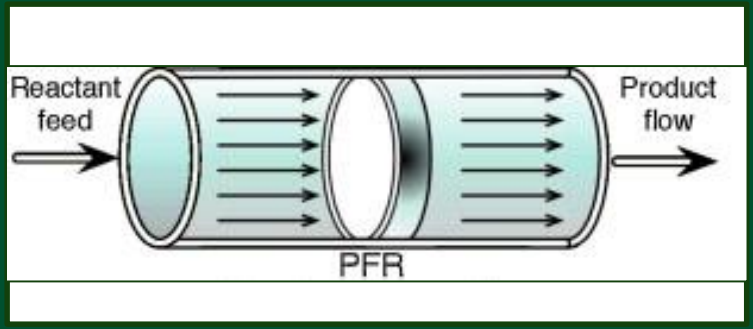
CORNERSTONE
Environmental Group, LLC

Proven Technology: Manure

- CSTR (1950s)
  - Developed due to odor from lagoon
  - Most common tech for AD treated sewage sludge



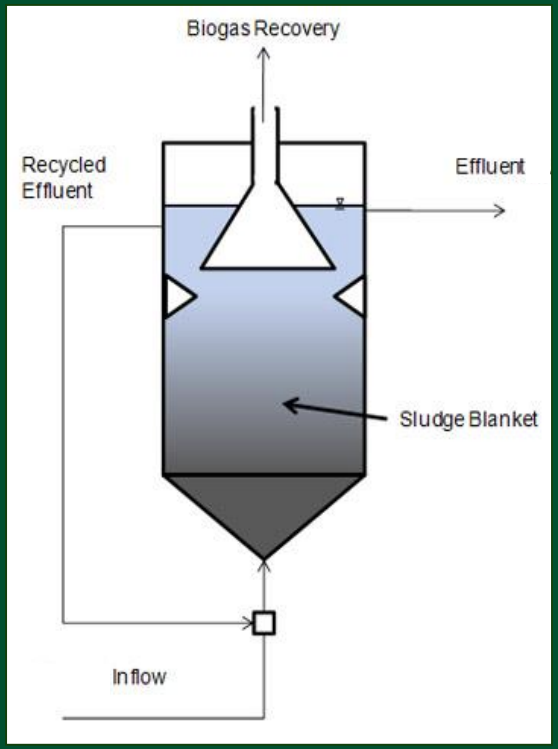
- PFR (1980s)
  - Developed as a cheaper alternative to CSTR



CORNERSTONE
Environmental Group, LLC

Proven Technology: Industrial Wastewater

- **Fixed Film**
  - Anaerobic Filters / Attached Growth Digesters
- **Suspended Media**
  - Expanded / Fluidized Bed Reactors
  - Upflow Anaerobic Sludge Blanket (UASB)
  - Induced Blanket Reactor (IBR)
- **Sequencing Batch**



CORNERSTONE
Environmental Group, LLC

Proven Technology – United States

According to AgSTAR, there are over 191 ADs on farms in the U.S. Of these, 178 generate electrical or thermal energy from the captured biogas.

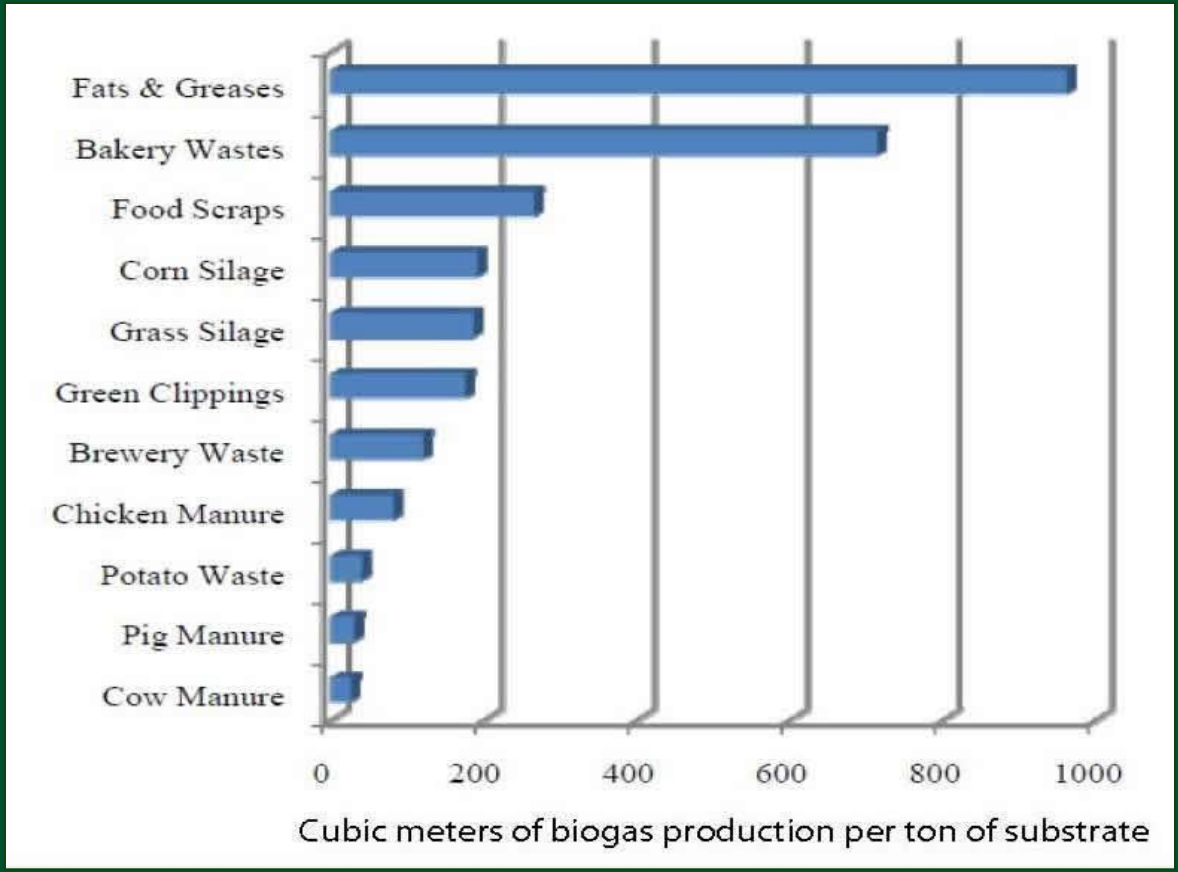
There are approx. 1,500 anaerobic digesters at wastewater treatment plants in the U.S. Of these treatment plants (WWTPs) that produce biogas, about 250 use the biogas.

CORNERSTONE
Environmental Group, LLC

But, What about Organics?

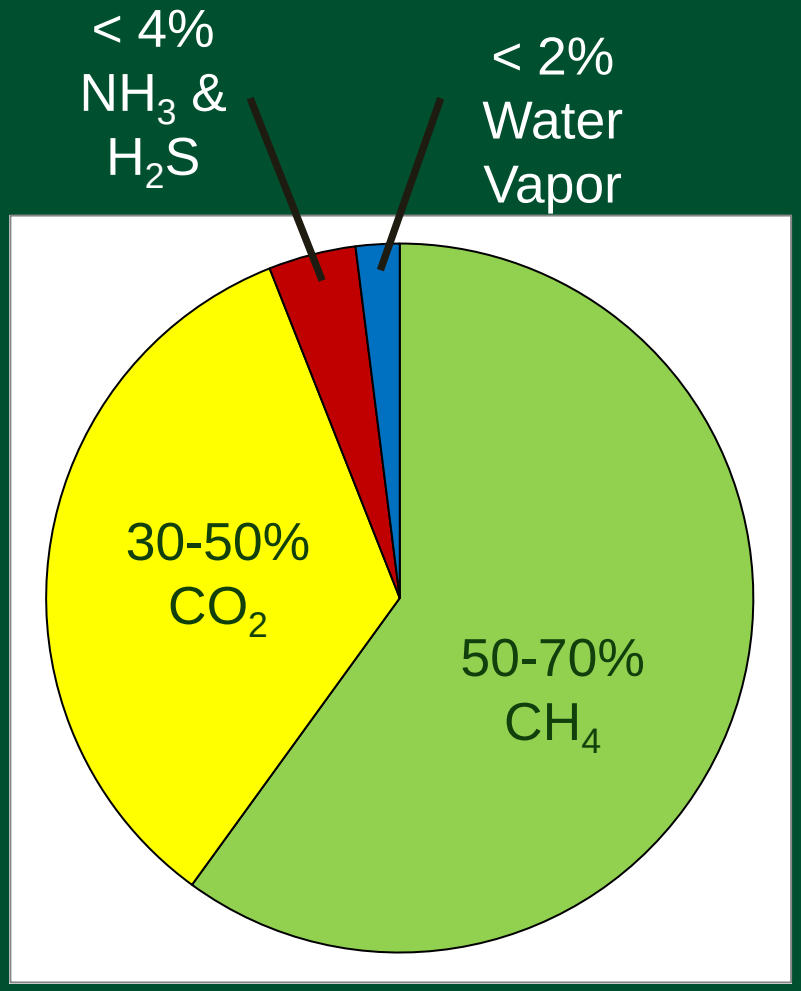
CORNERSTONE
Environmental Group, LLC

AD for Organics



CORNERSTONE
Environmental Group, LLC

AD for Organics

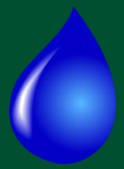


Biogas Composition

	% CH_4	%CO_2	%NH_3 & H_2S
Fats	**70**	**30**	**-**
Proteins	**68**	**18**	**14**
Carbs	**50**	**50**	**-**

CORNERSTONE
Environmental Group, LLC

AD System Parameters



- Moisture Content (wet or dry)

- Retention Time

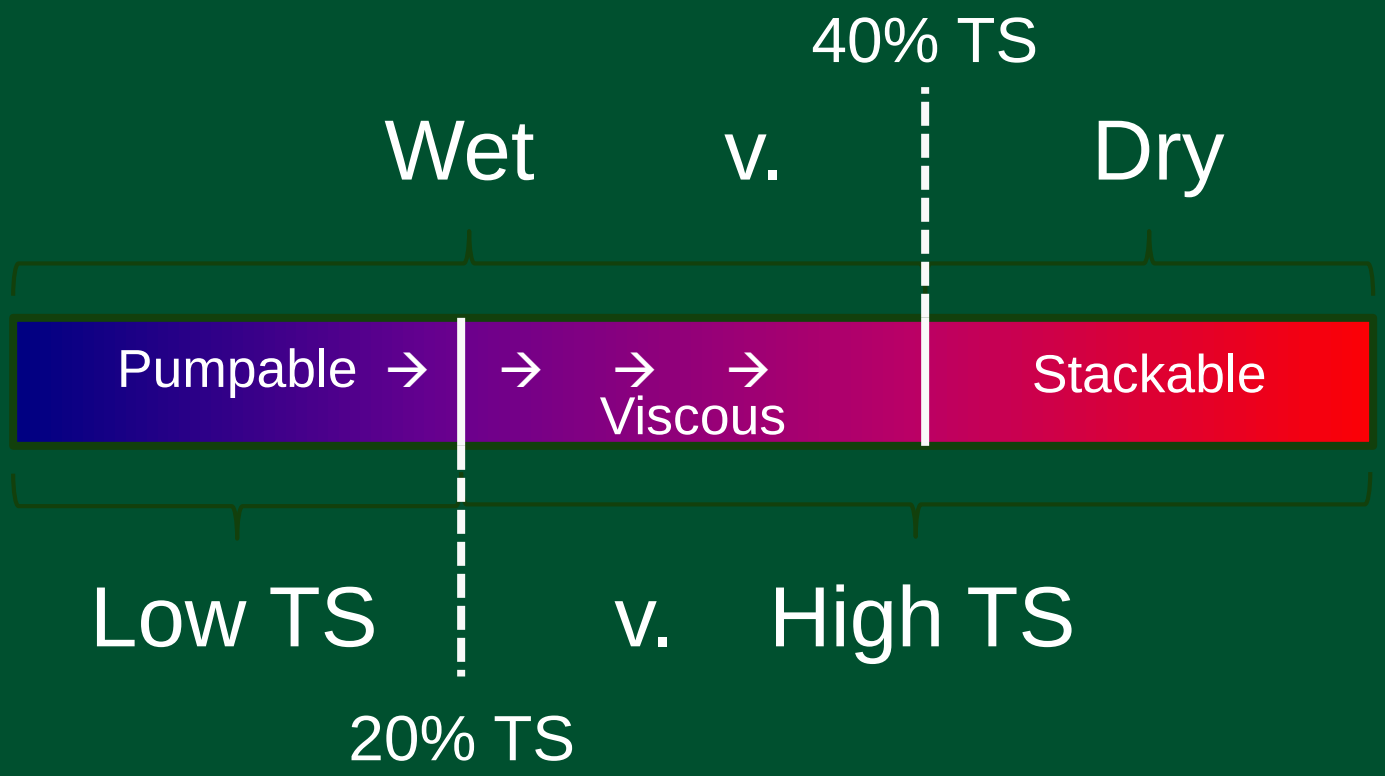
- Temperature (mesophilic or thermophilic)

- Loading Rate (batch or continuous)

- Stages (single or multistage)

CORNERSTONE
Environmental Group, LLC

Moisture Content



TS = Total Solids

CORNERSTONE
Environmental Group, LLC

Retention Time 

- Time it takes for AD process to be completed
  (how long substrate is in system)
- Dependent on amount and type of substrate and system
- Typically 15 to 40 days for high solids,
  1 to 5 days for low solids
- Mixing – decreases retention time
  - Impeller
  - Pumps
  - Pressurized gas

CORNERSTONE
Environmental Group, LLC

Temperature

- **Psychrophilic (<25°C)**
  - Low biogas yield and long retention time
- **Mesophilic (30 - 40°C)**
  - More stable – microorganisms are more tolerant to environment condition changes
- **Thermophilic (50 - 55°C)**
  - Higher biogas yield and shorter retention time
  - Sterilization of substrate
  - Sensitive to temperature and pH changes

CORNERSTONE
Environmental Group, LLC

Loading Rate

Batch	Continuous
• Substrate is added at beginning of process and is sealed for duration. • Lower equipment and design cost • Able to use gas generation curve to determine when process is complete	• Substrate is constantly added • Constant biogas production • Greater risk of overloading substrate (different phases in direct competition of one another, pH issues)

CORNERSTONE
Environmental Group, LLC

Stages

Single Stage

- All AD reaction stages occur in one vessel.
- Less space required for system
- Less control of the reaction (different phases in direct competition of one another, pH issues)
- Higher risk of odor

Multistage

- Different stages occur in different vessels.
- Maximum control over microbial communities
- Usually dual stage – methanogenesis separated from other processes
- First tank can act as buffer for loading rate.

CORNERSTONE
Environmental Group, LLC

Most Common AD Systems for Organics

- **Single-Stage Continuous Systems**
  - Low-solids ‘Wet’ {TS<20%}
  - High-solids ‘Dry’ {TS >20% & <40%}
- **Multistage Continuous Systems**
  - Dry-Wet
  - Wet-Wet
- **Batch Systems TS>40%**
  - One Stage
  - Two Stage

CORNERSTONE
Environmental Group, LLC

Another Approach

- **Wet System**
  - Pumpable, relatively homogenous
  - Low solids (LS): <5% to 20% TS

    (co-digestion with sewage sludge)
  - High solids (HS): 20% to 40% TS
- **Dry System**
  - Stackable, less well mixed substrate
  - High solids (HS): > 40% TS
- **Many variations operating (or available) today**

Single stage or Multistage

Mesophilic or Thermophilic

CORNERSTONE Environmental Group, LLC

System Categories & Providers

- Category 1 - Dry – HS (Batch)
- Category 2 - Wet – HS (Continuous)
- Category 3 - Wet – HS/LS (Multistage)
- Category 4 - Wet – LS

CORNERSTONE
Environmental Group, LLC

Cat. 1 -- Dry – HS (Batch): Attributes

- > 40% Total Solids
  - handled with a front-end loader
  - normally no additional water is added
- Percolate (Inoculation)
- Feedstock typically mixed with yard waste
- Typically simpler to design, build, and operate
- Mesophilic or Thermophilic
- Digestate Usually Composted

CORNERSTONE
Environmental Group, LLC

Cat. 1-- Dry – HS (Batch):

Advantages

- May require preprocessing but no pretreatment
- Can handle contamination
- Residuals easy to screen
- Batch loading simplifies material handling
- No dewatering of digestate
- Low electrical and water demand

Disadvantages

- Relatively low moisture content of the feedstock makes it more difficult to heat
- Less control over biological process
- C/N Ratio critical

CORNERSTONE
Environmental Group, LLC

Cat. 1-- Dry – HS (Batch): System Technology

- **Viessman Group (Germany) – BIOFerm (WI)**
  - **The BIOFerm™ Dry Fermentation System**
    - Oshkosh WI – Operational Fall 2011
      - 25 TPD: Ag waste, SSO
    - Glouster, NJ – planning/permitting
      - Food waste and yard trimmings

CORNERSTONE Environmental Group, LLC

BioFERM™

BIOFERM™
ENERGY SYSTEMS
VIESMANN Group

CORNERSTONE
Environmental Group, LLC

Cat. 1-- Dry – HS (Batch): System Technology

- **Viessman Group (Germany) – BIOFerm (WI)**
  - **The BIOFerm™ Dry Fermentation System**
    - Oshkosh, WI – Operational Fall 2011
      - 25 TPD: Ag waste, SSO
    - Glouster, NJ – planning/permitting
      - Food waste and yard trimmings
- **Zero Waste Energy (CA) - Eggersmann Tech (Germany)**
  - **Kompoferm**
    - San Jose, CA – Operational 2013
      - 3 phases, 250 TPD each: pre & post SSO, MRF residuals, green waste
  - **SmartFerm**
    - Monterey, CA – Operational 2012 (15tpd)
    - S. San Fran, CA – Operational 2013/2014 (30tpd)

CORNERSTONE Environmental Group, LLC

SMARTFERM

ZeroWaste™
ENERGY, LLC.
Recovery and Energy with Zero Waste

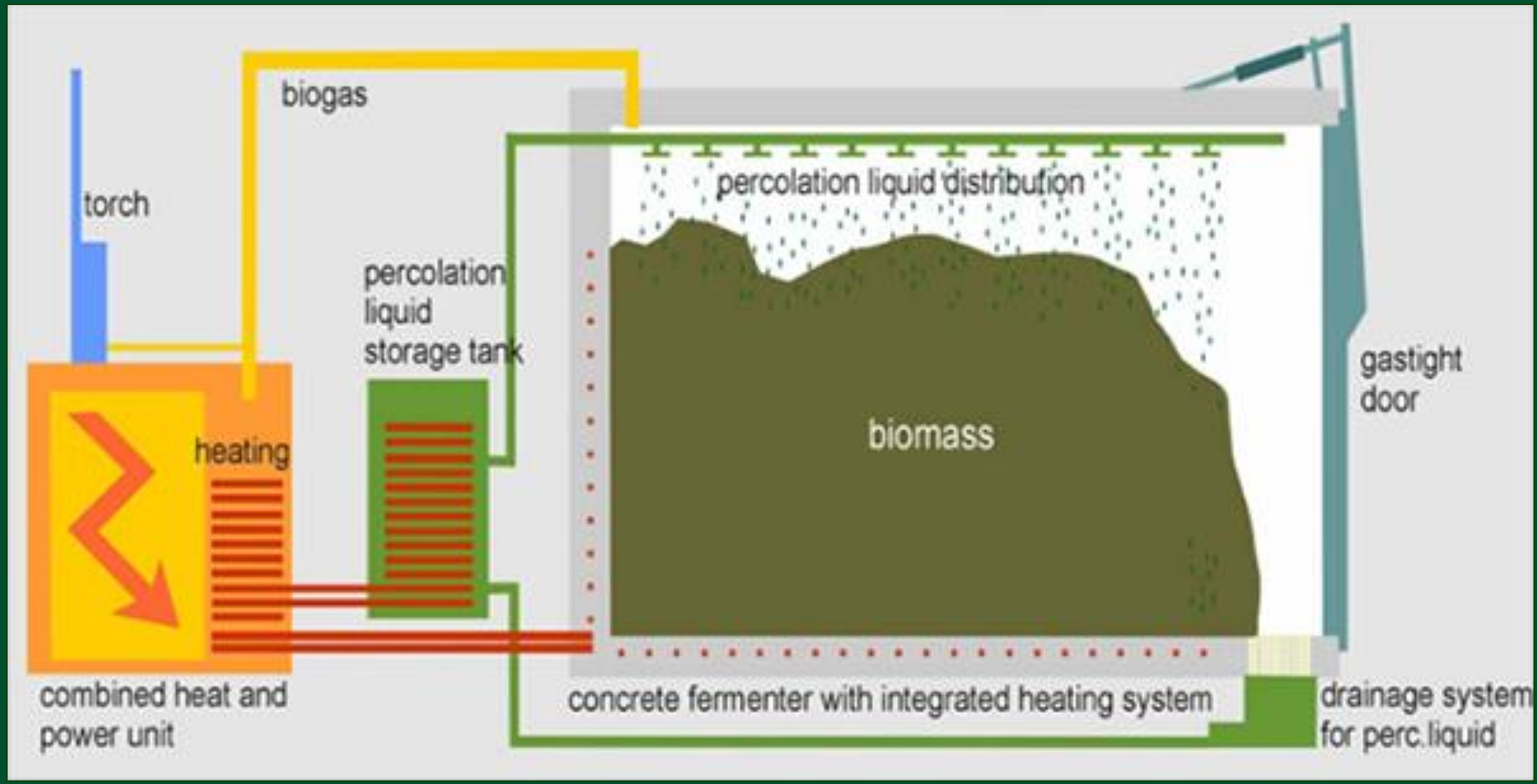
CORNERSTONE
Environmental Group, LLC

Cat.1 -- Dry – HS (Batch): System Technology

- **BEKON (Germany)**
  - **The BEKON Process**
    - Santa Barbara – planning/permitting, estimated construction 2014
      - 200 TPD: MRF residue, SSO

CORNERSTONE Environmental Group, LLC

BEKON



BEKON

CORNERSTONE
Environmental Group, LLC

Cat. 1 -- Dry – HS (Batch): System Technology

- **BEKON (Germany)**
  - **The BEKON Process**
    - Santa Barbara – planning/permitting, estimated construction 2014
      - 200 TPD: MRF residue, SSO
- **Turning Earth (PA)**
  - **Aikan™ HSAD Technology (Denmark) {multi-stage}**
    - CT – planning/permitting 2014
      - (food waste, yard waste, other)

CORNERSTONE Environmental Group, LLC

AIKAN

TURNING™ EARTH

Image used with permission from Turning Earth, LLC and Solum A/S

CORNERSTONE Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous): Attributes

- 20 to 40% Total Solids
- Handling material at high solids concentration requires different pretreatment and transfer equipment (i.e., conveyor belts, screw press, and special pumps for the highly viscous streams).
- Mesophilic or Thermophilic
- Digestate can be dried and used as fertilizer or composted.

CORNERSTONE
Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous)

Advantages

- Dried digestate can be used as fertilizer or composted.
- Can handle liquid waste and slurries
- Can handle some contamination (plastics, metals, etc.)
- Less wastewater & more energy efficient than wet low solids digestion

Disadvantages

- Slurry may not be completely mixed – uneven digestion.
- Generally require costly preprocessing

CORNERSTONE
Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous): System Technology

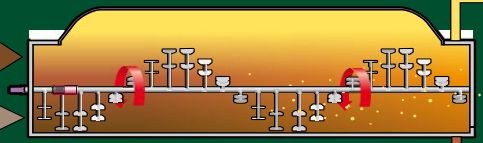
- **Eisennmann Corp (IL)**
  - **BIOGAS-GW**
    - Chicago stockyards “The Plant" Q3 2013
      - 15 TPD spent brewery grains, food waste
    - Columbia, SC – planning/permitting
      - 150 TPD; commercial food waste
    - S. CA – construction
      - 220 TPD; green waste

CORNERSTONE Environmental Group, LLC

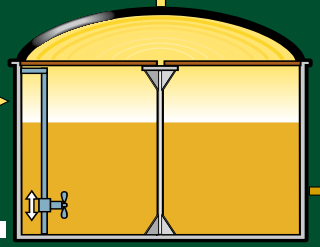
BIOGAS-GW

Organic Solid Waste

Organic Liquid Waste



Main Digester

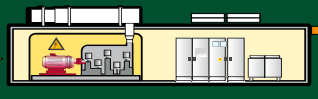


Final Storage/ Post Digester

Pump

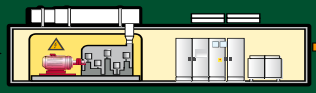
Separator

Digestate Solids

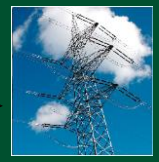


Gas Upgrading

CNG Gas Station/ Pipeline



CHP



Electric Energy

Thermal Energy

Liquid Soil Amendment

Solid Soil Amendment

EISENMANN

CORNERSTONE Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous): System Technology

- **Eisennmann Corp (IL)**
  - **BIOGAS-GW**
    - Chicago stockyards “The Plant" Q3 2013
      - 15 TPD spent brewery grains, food waste
    - Columbia, SC – planning/permitting
      - 150 TPD; commercial food waste
- **Enbasys (Austria) – Columbia Biogas (OR)**
  - **EnbaFerm**
    - Portland, OR (permitting)
      - 300 TPD; commercial & industrial liquid & solid food waste

CORNERSTONE Environmental Group, LLC

EnbaFerm

enbasys
biotech energy

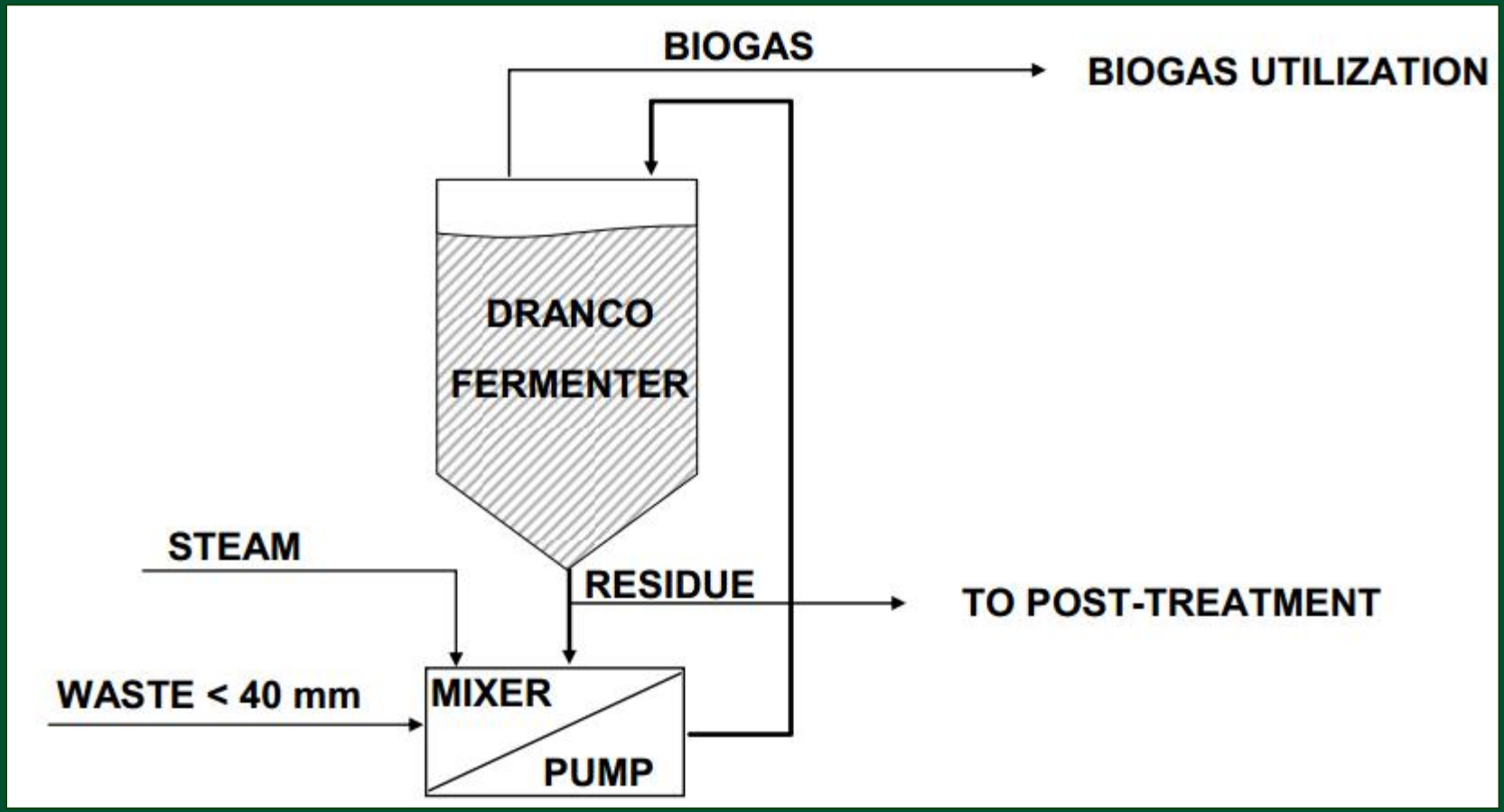
CORNERSTONE
Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous): System Technology

- **CC&R and OWS nv (Belgium) – OWS Inc. (OH)**
  - **DRANCO (Belgium)**

CORNERSTONE
Environmental Group, LLC

DRANCO



OWS
Organic Waste Systems

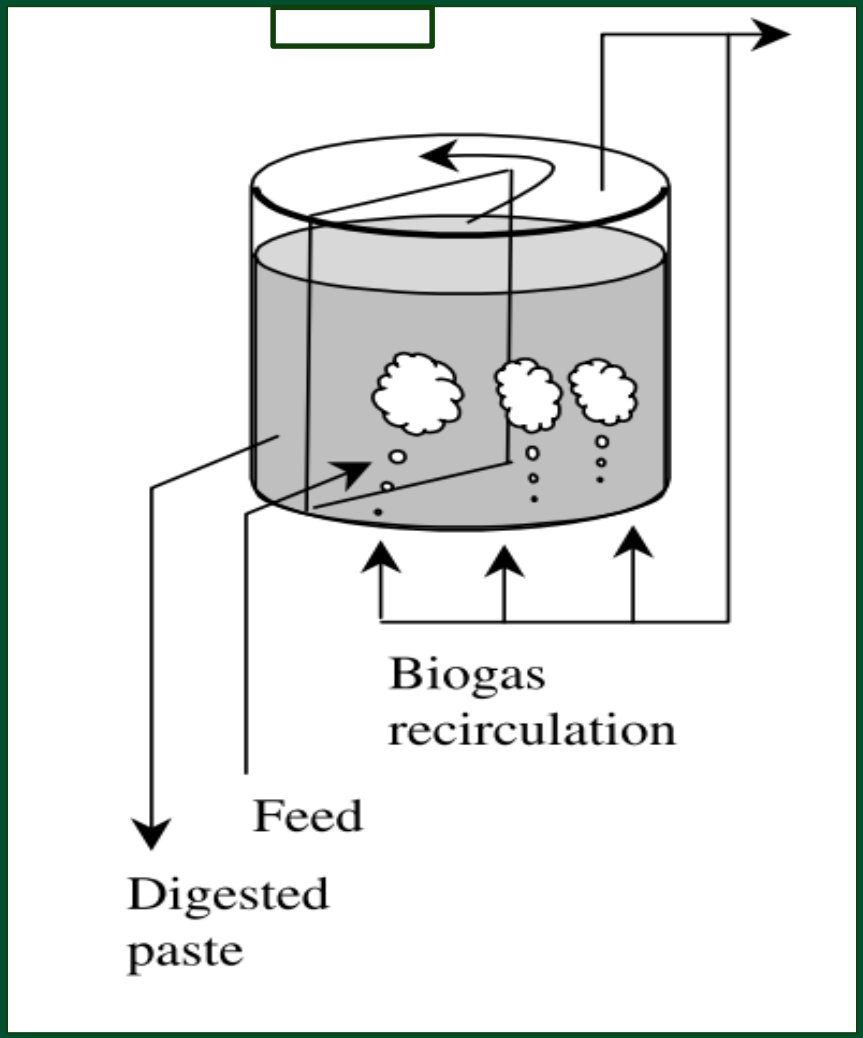
CORNERSTONE
Environmental Group, LLC

Cat. 2 -- Wet – HS (Continuous): System Technology

- **CC&R and OWS nv (Belgium) – OWS Inc. (OH)**
  - **DRANCO (Belgium)**
    - Perris CA – planning/permitting
      - 150 TPD: MRF residue, SSO, yard waste
- **Valorga Int'l (France) – Waste Recovery Systems**
  - **Valorga**
    - No North American projects

CORNERSTONE Environmental Group, LLC

Valorga



VALORGA International

CORNERSTONE Environmental Group, LLC

Cat. 3 -- Wet – HS/LS (Multistage): Attributes

- **Separation of AD decomposition stages**
  - Typically hydrolysis and methanogenesis phases separated
  - Environmental conditions (temp and pH among others) are controlled and optimized
- **Two-stage**
  - HS-LS
  - LS-LS
- **Mesophilic or Thermophilic**

CORNERSTONE
Environmental Group, LLC

Cat. 3 -- Wet – HS/LS (Multistage):

Advantages

- Higher loading rates
- Improved process stability
- Increased process flexibility
- Biogas yield enhancements

Disadvantages

- Added complexity
- Increased expense of building and operating multiple reactors
- Relatively few commercial, operational multi-stage AD units

CORNERSTONE
Environmental Group, LLC

Cat. 3 -- Wet – HS/LS (Multistage): Technology Systems

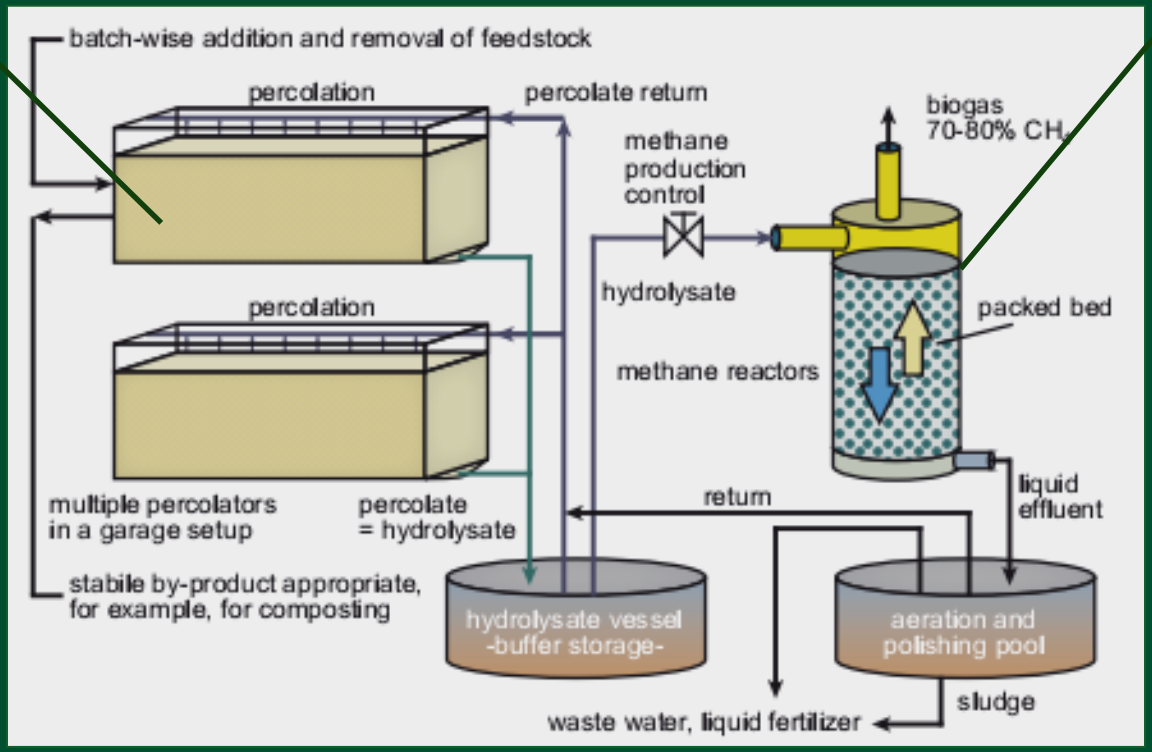
- **Harvest Power (MA)**
  - **GICON Biogas (Germany)**
    - Richmond BC Canada (2012)
      - 100 TPD: commercial & multi family organics

CORNERSTONE Environmental Group, LLC

GICON Process

Stage 1

Stage 2



"Two-stage HSAD with split hydrolysis"

HARVEST™ Power of We™

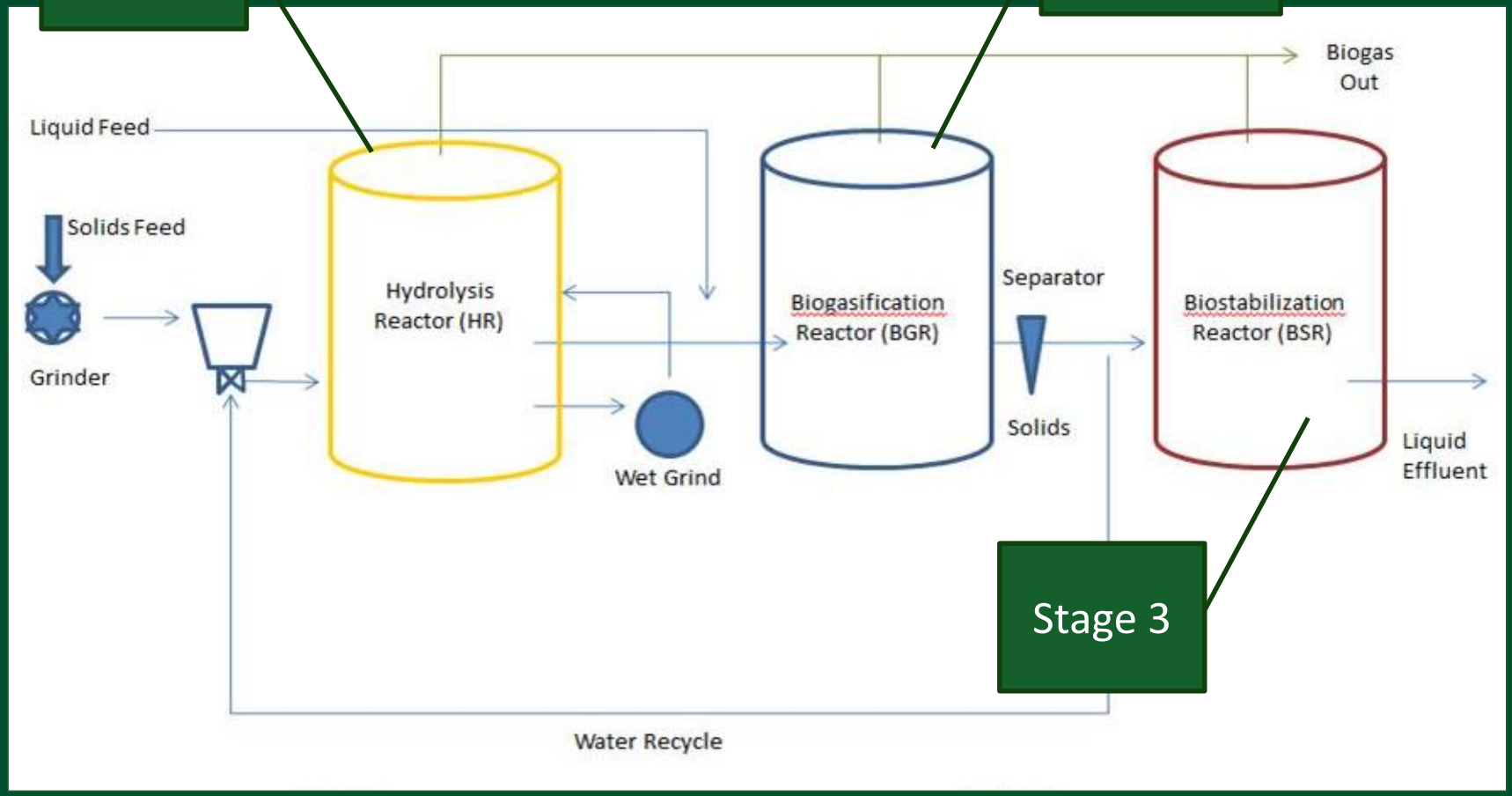
CORNERSTONE Environmental Group, LLC

Cat. 3 -- Wet – HS/LS (Multistage): Technology Systems

- **Harvest Power (MA)**
  - **GICON Biogas (Germany)**
    - Richmond BC Canada (2012)
      - 100 TPD: commercial & multi family organics
- **CleanWorld (CA)**
  - **High-Rate Digestion (HRD)**
    - South Area TS Sacramento, CA – 25/100 TPD '12/13
    - American River Packaging ('12)– 10 TPD corrugated/SSO
    - UC Davis READ Project ('12) – 50 TPD manure/SSO
  - **Anaerobic Phased Solids (APS)** UC Davis Pilot – 5 TPD

CORNERSTONE Environmental Group, LLC

HDR



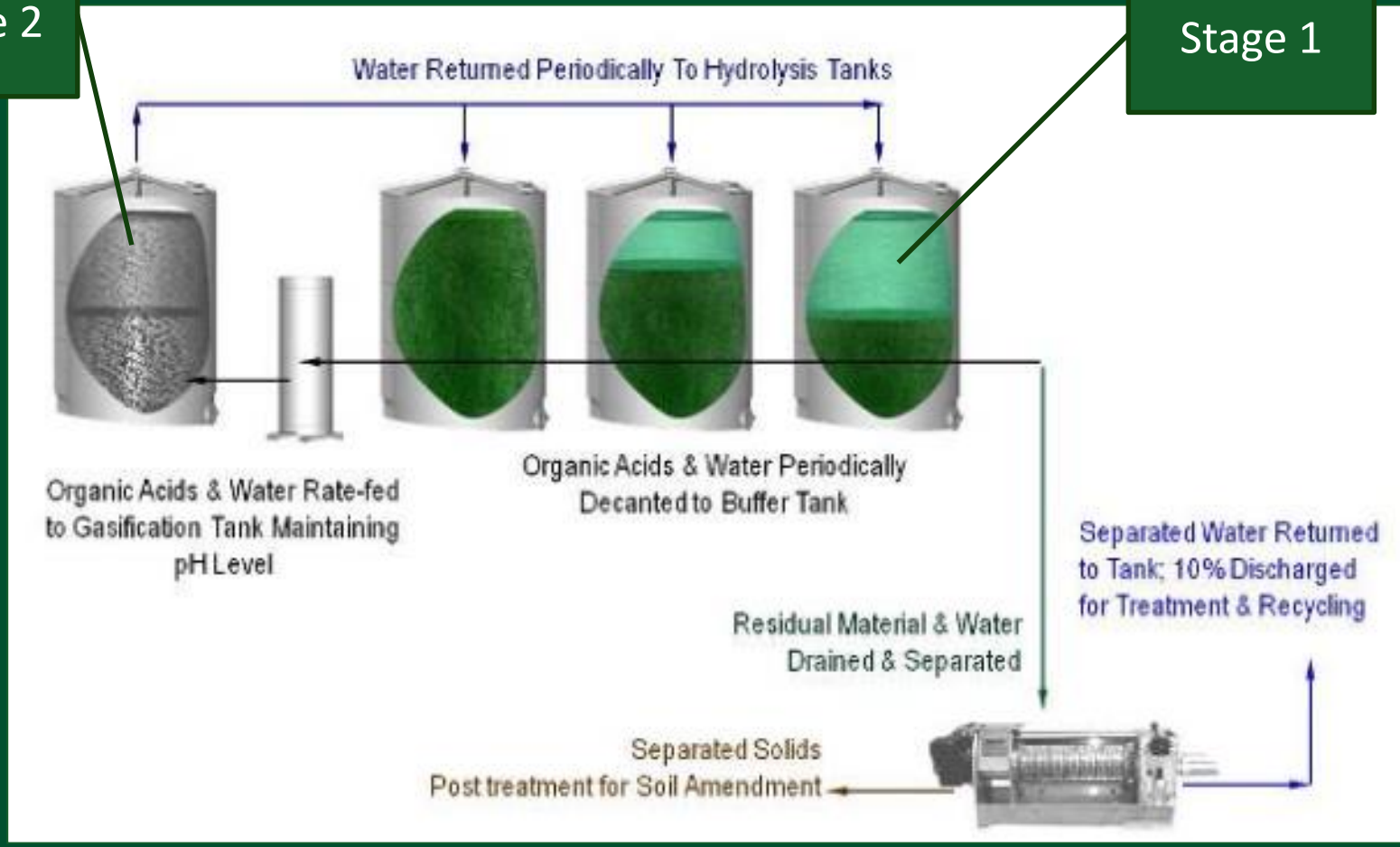
CleanWorld

CORNERSTONE Environmental Group, LLC

APS

Stage 2

Stage 1



CleanWorld

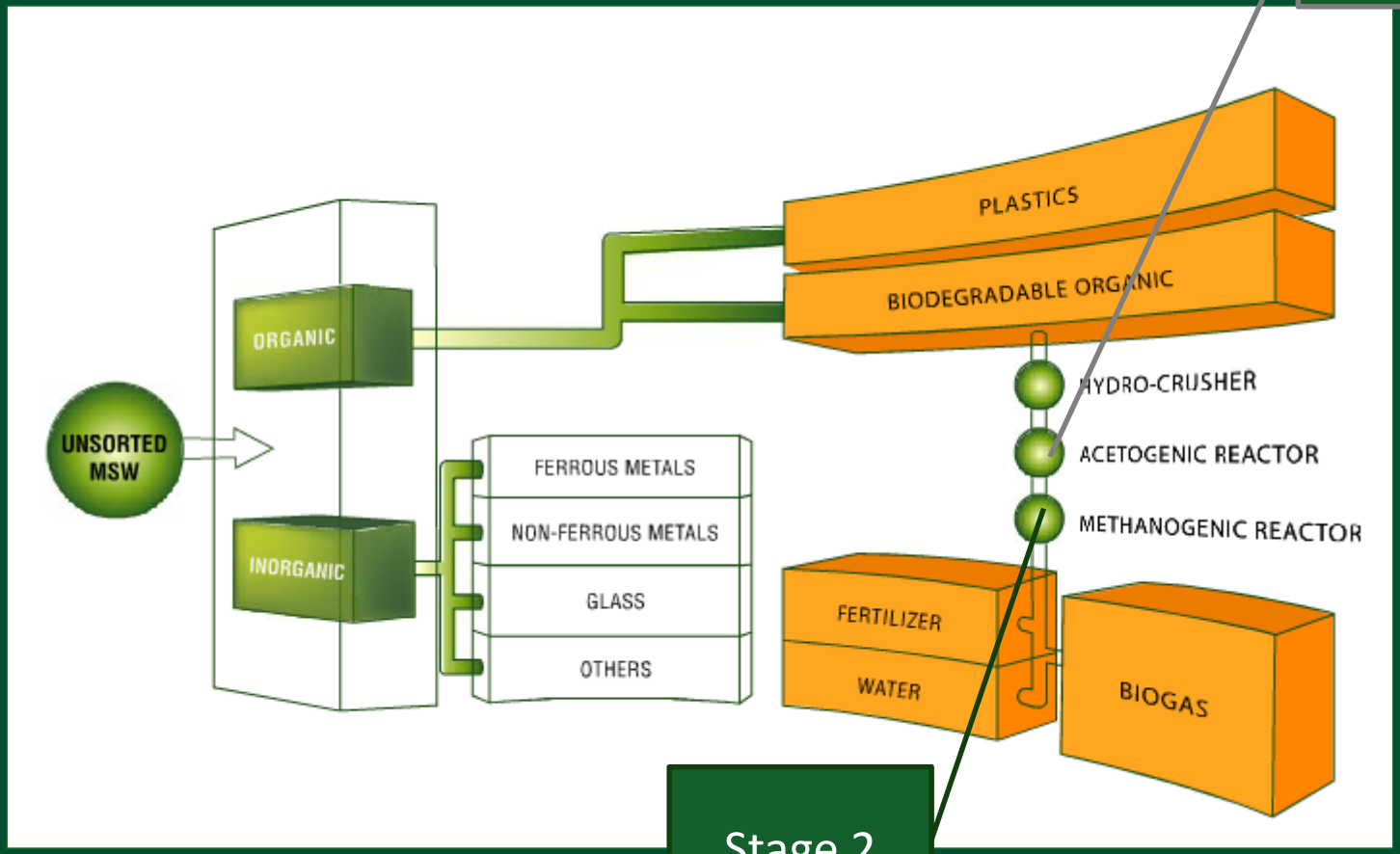
CORNERSTONE Environmental Group, LLC

Cat. 3 -- Wet – HS/LS (Multistage): Technology Systems

- **Harvest Power (MA)**
  - **GICON Biogas (Germany)**
    - Richmond BC Canada (2012)
      - 100 TPD: commercial & multi family organics
- **CleanWorld (CA)**
  - **High-Rate Digestion (HRD)**
    - South Area TS Sacramento, CA – 25/100 TPD '12/13
    - American River Packaging ('12)– 10 TPD corrugated/SSO
    - UC Davis READ Project ('12) – 50 TPD manure/SSO
  - **Anaerobic Phased Solids (APS)** UC Davis Pilot – 5 TPD
- **Arrow Ecology & Engineering**
  - **ArrowBio (Israel)**
    - No US projects (phase 2 study -NYC)

CORNERSTONE Environmental Group, LLC

ArrowBio



ARROWECOLOGY
THE WAY TO ZERO WASTE

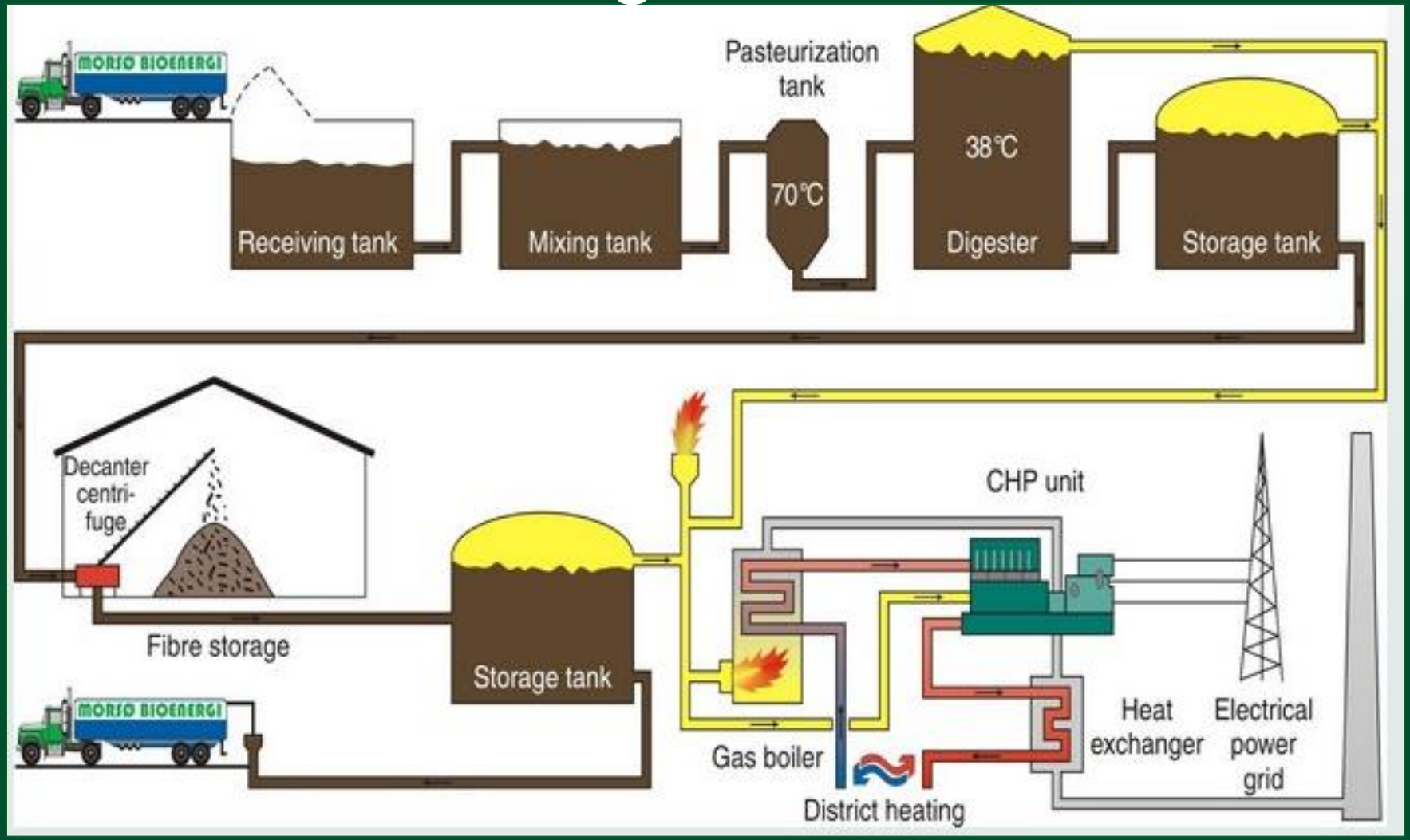
CORNERSTONE
Environmental Group, LLC

Cat. 4 -- Wet – LS: Incorporating Organics

- **CH4 Biogas (FL)**
  - **Bigadan (Danish technology)**
    - Synergy Dairy LLC in Wyoming County, NY

CORNERSTONE
Environmental Group, LLC

Bigadan



CH4 BIOGAS
Renewable Energy & a Better Environment

CORNERSTONE
Environmental Group, LLC

Cat. 4 -- Wet – LS: Incorporating Organics

- **CH4 Biogas (FL)**
  - **Bigadan (Danish technology)**
    - Synergy Dairy LLC in Wyoming County, NY
- **Harvest Power**
  - **Various CSTR Technologies**
    - London, Ontario – Operational 2012
    - Florida – Construction
- **CCI Bioenergy**
  - **BTA Technology**
    - Toronto, Ontario – Dufferin Organics Facility & Disco Road Facility

CORNERSTONE
Environmental Group, LLC

Cat. 4 -- Wet – LS: Incorporating Organics

- **CH4 Biogas (FL)**
  - **Bigadan (Danish technology)**
    - Synergy Dairy LLC in Wyoming County, NY
- **Harvest Power**
  - **Various CSTR Technologies**
    - London, Ontario – Operational 2012
    - Florida – Construction
- **CCI Bioenergy**
  - **BTA Technology**
    - Toronto, Ontario – Dufferin Organics Facility & Disco Road Facility
- **Quasar**
    - Multiple projects in Ohio
    - Rutland, MA – Jordan Dairy Farm

CORNERSTONE
Environmental Group, LLC

The Perfect System

- Low CAPEX
- Low OPEX
- Small project footprint
- Handle multiple feedstocks
- No preprocessing required
- Maximize biogas produced

CORNERSTONE
Environmental Group, LLC

No Perfect System

There are advantages and disadvantages to each.

Use the system selection criteria to help determine the best fit.

CORNERSTONE
Environmental Group, LLC

System Selection Criteria: Project Goals

- Regional facility taking diverse feedstock
- Need to handle a particular feedstock
- Want to fit project into existing infrastructure with tight footprint
- Want to produce particular end product from digestate
- Generate maximum levels of biogas for alternative energy project
- Desire to start project with limited capital

CORNERSTONE
Environmental Group, LLC

System Selection Criteria: Feedstock

- Moisture Content
- Sources & Contract Periods
- Contamination
- Receiving/Mixing Areas Needed

CORNERSTONE
Environmental Group, LLC

System Selection Criteria: Existing Infrastructure

- Water or liquid sludge supply
- Location of heat, electricity or CNG users
- Footprint for project
- Existing composting operation
- Sewer for waste water/digestate
- Equipment for handling feedstock
- Proximity to Neighbors

CORNERSTONE
Environmental Group, LLC

System Selection Criteria: End Markets

- **Digestate:**
  - Compost
  - Fertilizer
  - Livestock Bedding
- **Biogas:**
  - Electricity
  - CHP
  - CNG

CORNERSTONE
Environmental Group, LLC

System Selection Criteria: Miscellaneous

- Capital Cost
- Potential Energy Output
- Operating Cost
- Emissions

CORNERSTONE
Environmental Group, LLC

Choose by Category

DRY – HS (Batch)

BIOFERM ENERGY SYSTEMS — VIESMANN Group

ZeroWaste ENERGY, LLC. Recovery and Energy with Zero Waste

BEKON

TURNING EARTH

WET – HS (Continuous)

EISENMANN

enbasys biotech energy

OWS Organic Waste Systems

VALORGA International

WET – HS/LS (Multistage)

CleanWorld

HARVEST Power of We

ARROWECOLOGY THE WAY TO ZERO WASTE

WET - LS

CH4 BIOGAS Renewable Energy & a Better Environment

HARVEST Power of We

CCI Bio Energy

quasar energy group

CORNERSTONE Environmental Group, LLC

Contact Information

Prentiss A. Shaw, P.E.

Cornerstone Environmental Group, LLC

prentiss.shaw@cornerstoneeg.com

Phone: (845) 695-0202

Building lifetime relationships with our clients and employees

CORNERSTONE
Environmental Group, LLC