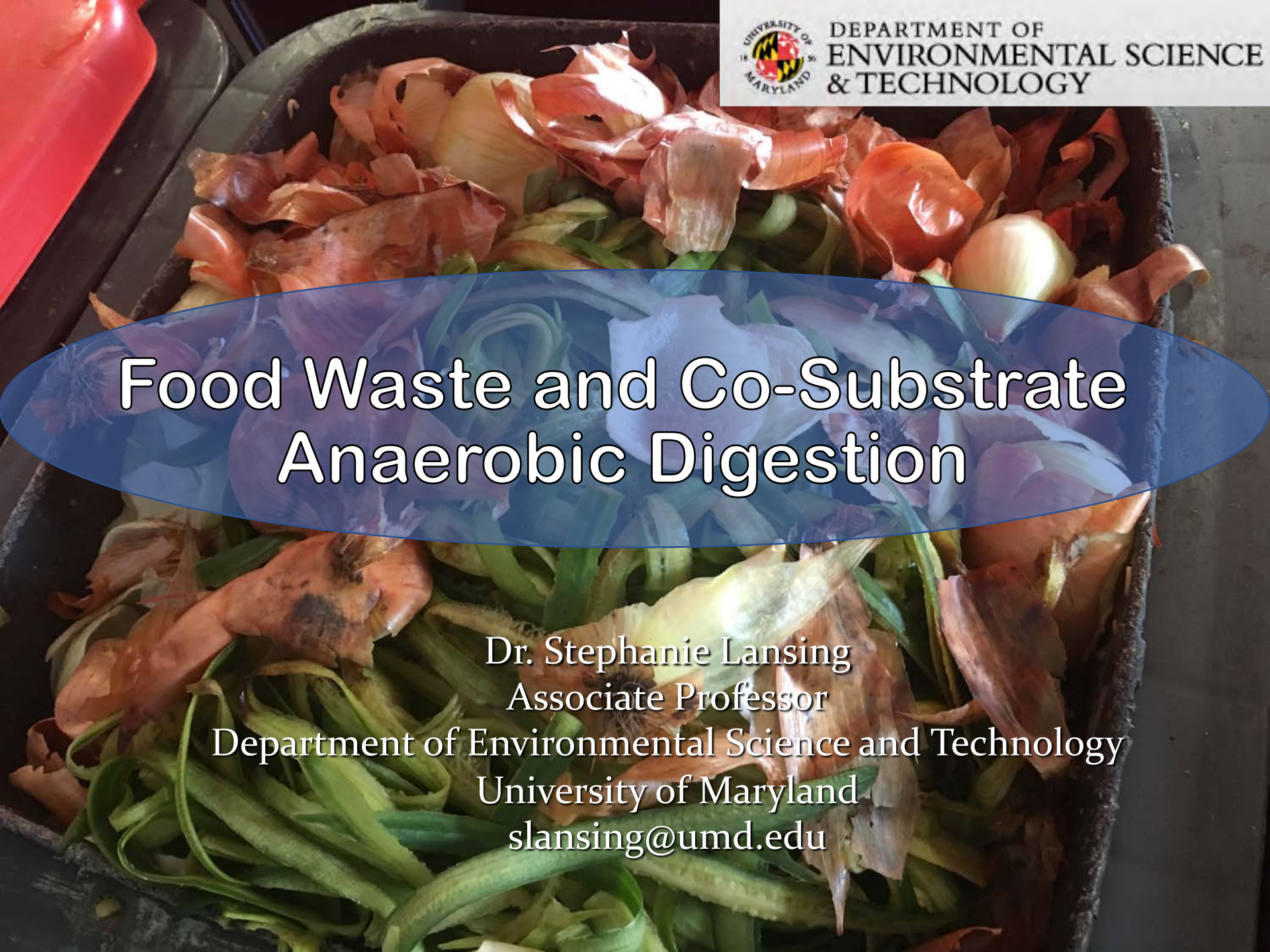


DEPARTMENT OF ENVIRONMENTAL SCIENCE & TECHNOLOGY

Food Waste and Co-Substrate Anaerobic Digestion

Dr. Stephanie Lansing
Associate Professor
Department of Environmental Science and Technology
University of Maryland
slansing@umd.edu

Presentation Overview

- State of co-digestion in US and Europe
- Effect of food waste in digestion
- Sourcing the material
- Pre-treatment and digestion of additional co-substrates

What comes in, must come out

Manure, Crops,
Wastewater Sludge
Food Waste
ANY ORGANICS

Biogas

CH_4 (Methane)

H_2O

CO

H_2S

CO_2

H_2

→ **Electricity**
Renewable Natural Gas

Anaerobic Environment

(1) Hydrolysis → fatty acids, sugars

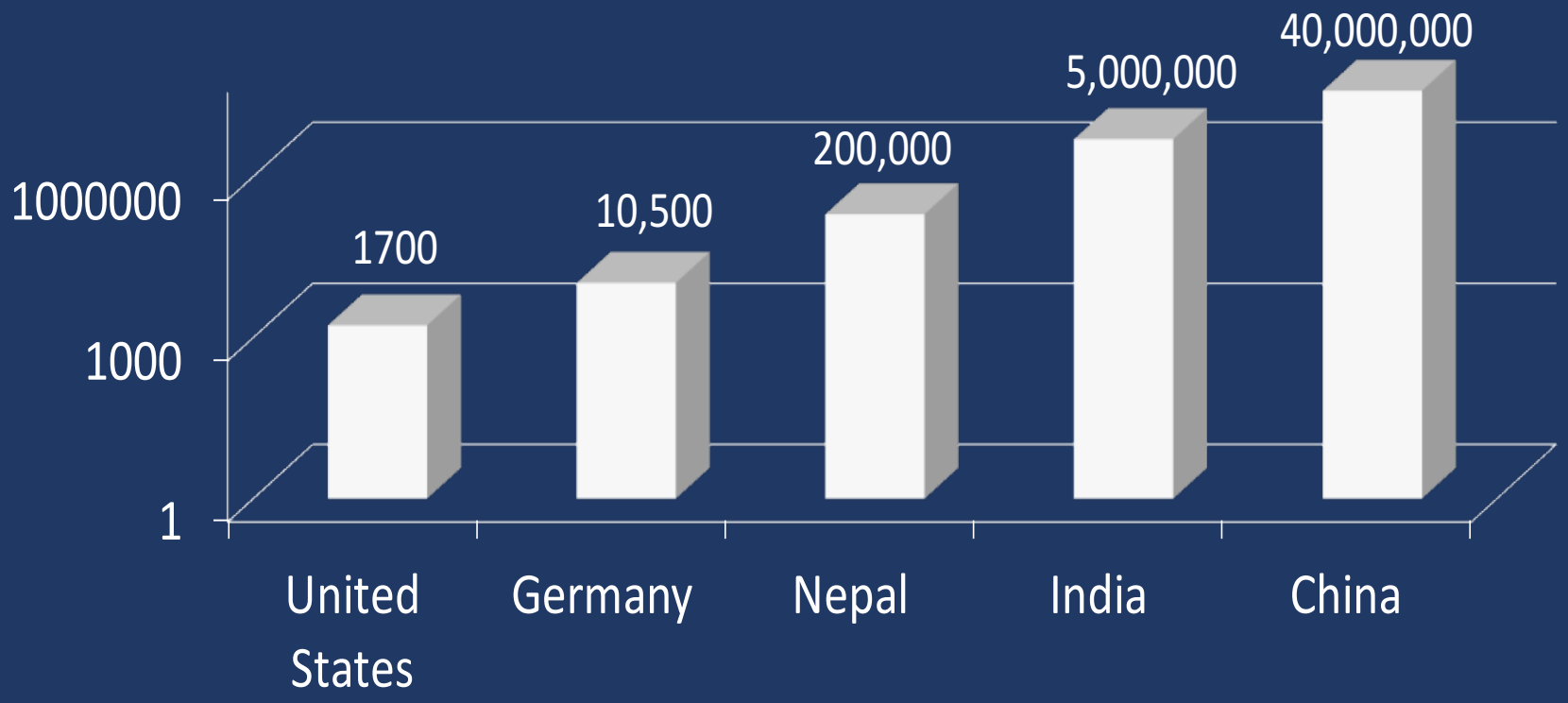
(2) Acidogenesis → alcohols CO_2, H_2

(3) Acetogensis → acetic acid, CO_2, H_2

(4) Methanogenesis → CH_4 and CO_2

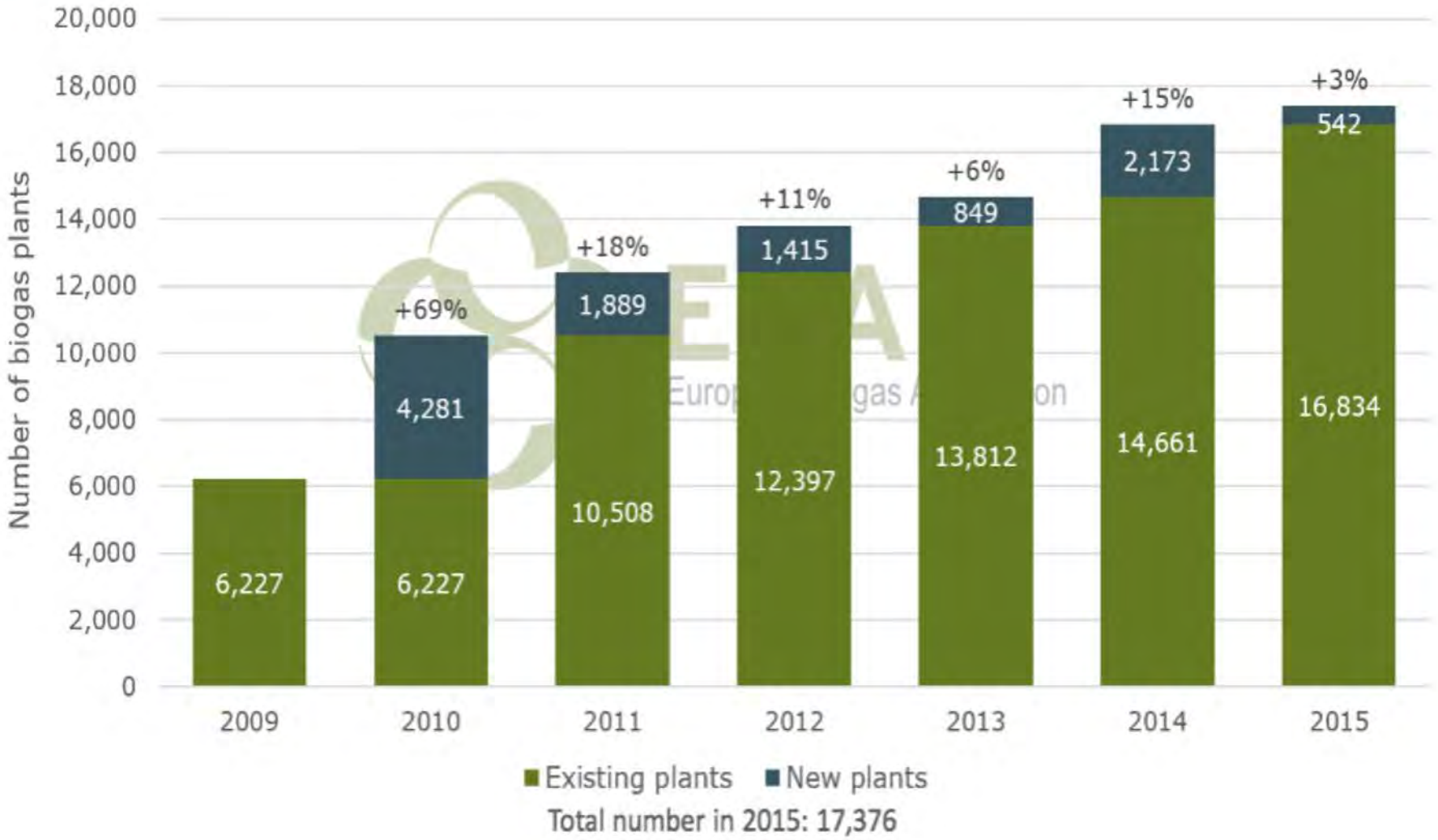
Liquid Fertilizer with
25 - 80% Less Solids
and ≈ 50% More
Dissolved Nutrients

Anaerobic Digesters in the World



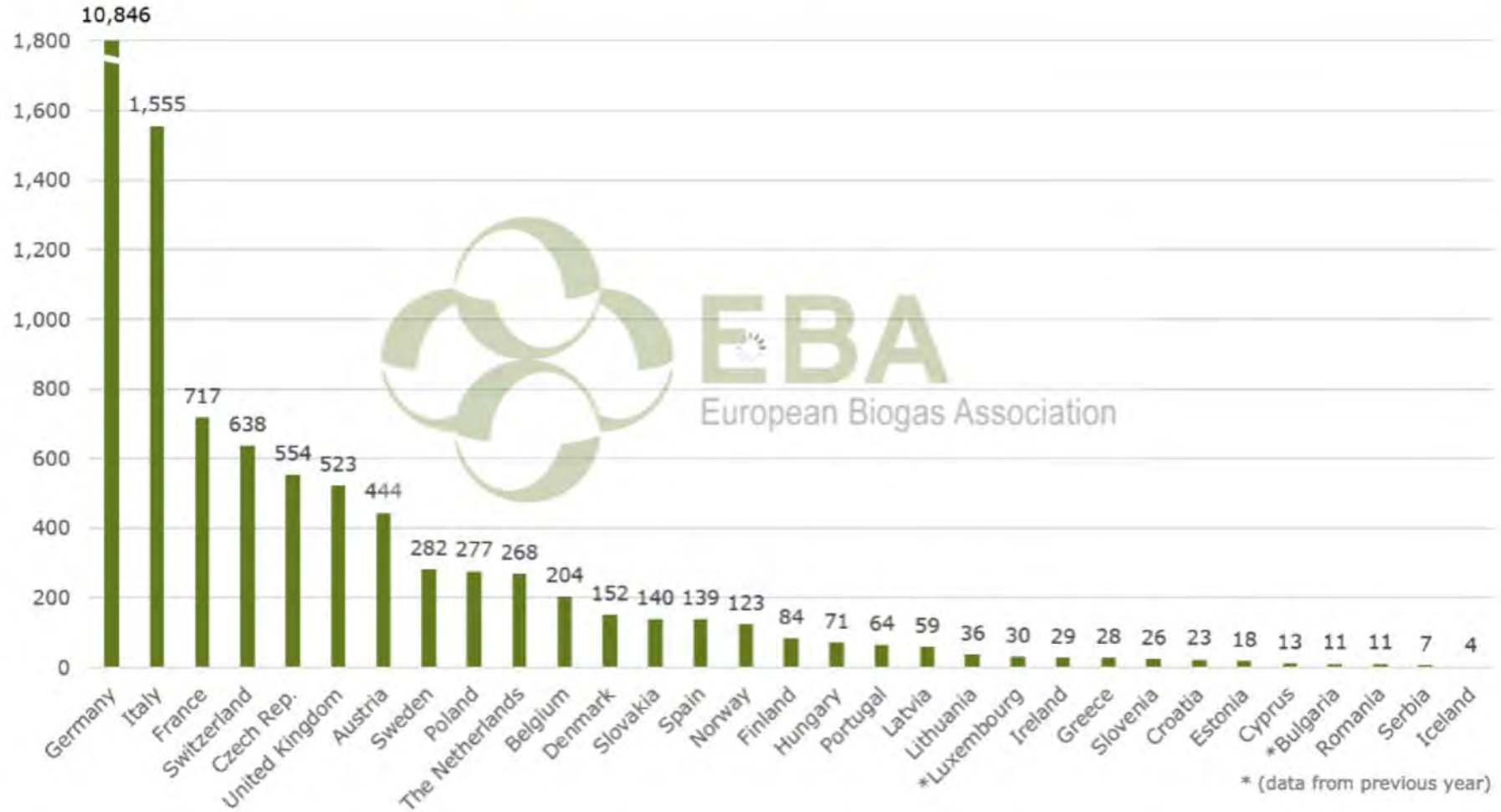
The majority of US digesters are at wastewater treatment plants, with only 265 on-farm digesters

Evolution of the Number of Biogas Plants in Europe



Slide Courtesy of Harm Grobrugge, Vice-President European Biogas Association

Number of Biogas Plants in 2015



Slide Courtesy of Harm Grobrugge, Vice-President European Biogas Association

Digesters in Europe

Digesters in Germany – Maize Silage

Where to put the corn?
Food vs Fuel

- Ethanol (US)
- Digester (Germany)

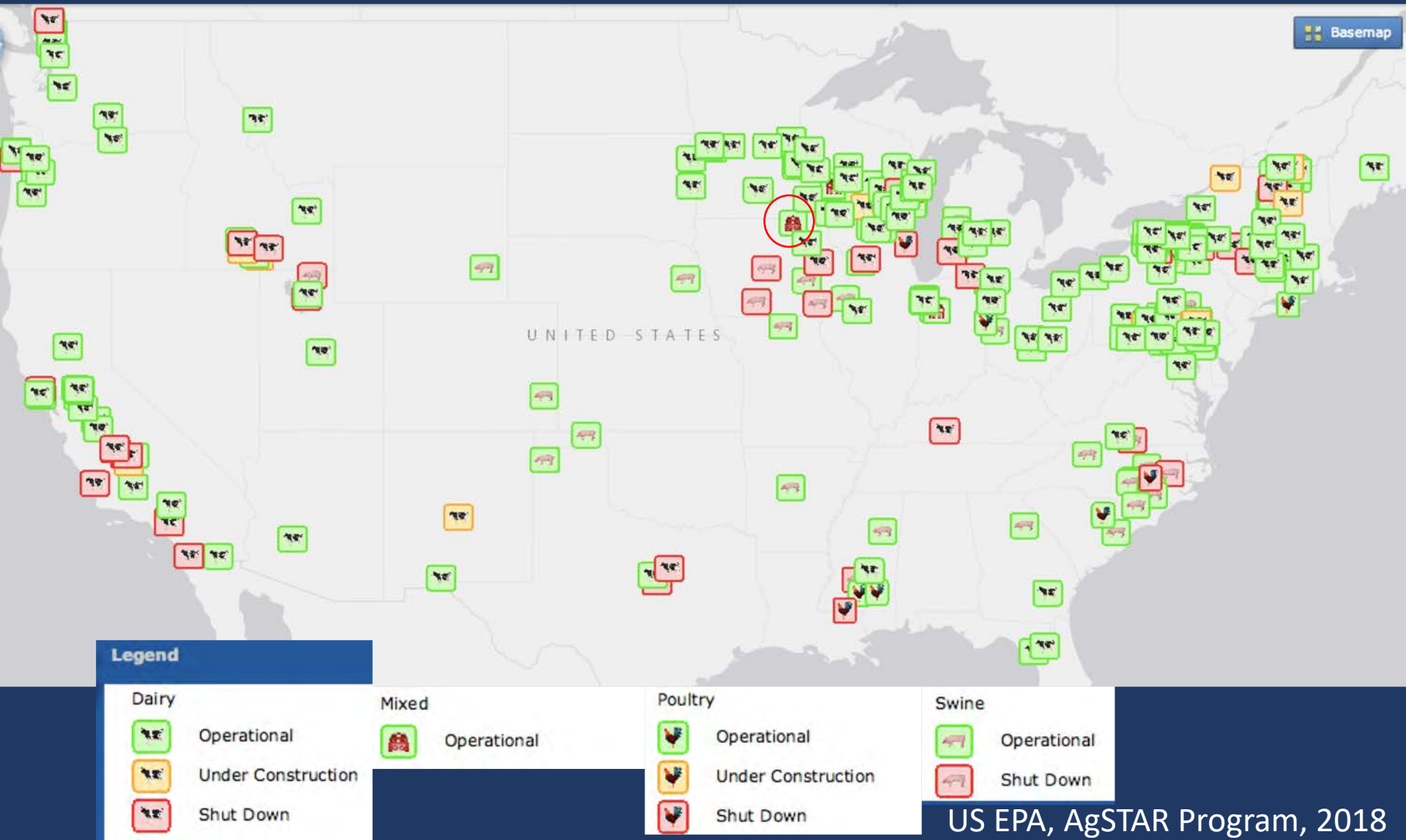
German digesters must reduce maize or cereals to 50% by 2018 and 44% by 2022 to get preferred electricity rates:

- 15.6¢ up to 150 kW
- 13.4¢ up to 500 kW
- 12.0¢ up to 5 MW
- 6.7¢ up to 20 MW

Screw-press for silage

Digester with maize silage

Agriculutral Digesters in the US



US EPA, AgSTAR Program, 2018

Food Waste Composting

US EPA, AgSTAR Program, 2018

Introduction: Food Waste Digestion

- Food waste is used as a single substrate or co-digestion material in anaerobic digesters to increase biogas production and/or receive tipping fees.
- Food waste co-digestion is slowly increasing in US due to forthcoming food waste landfill bans.
  - In Germany, food waste co-digestion is also increasing due to changes in regulations for maize silage in AD.
- As food waste use in AD increases, it is important to understand process stability during digestion and differences in biogas potential of substrates.

Food Waste Diversion

- Massachusetts, Connecticut, Rhode Island and Vermont all have food waste bans to landfills (most by 2020)
  - There are not adequate facilities in place to divert this waste.
  - Compost facilities are limited and do not produce energy.
- Food waste can increase renewable energy production
  - Up to 30 times more biogas than manure or wastewater sludge.
- After digestion, the nutrients from food waste added must be field applied (farm) or treated (wastewater treatment)
  - Nutrient can pose a problem for farmers with land limitations, increase treatment/electricity demand for wastewater treatment, and may need to be transported from urban food waste digesters to rural agricultural fields.

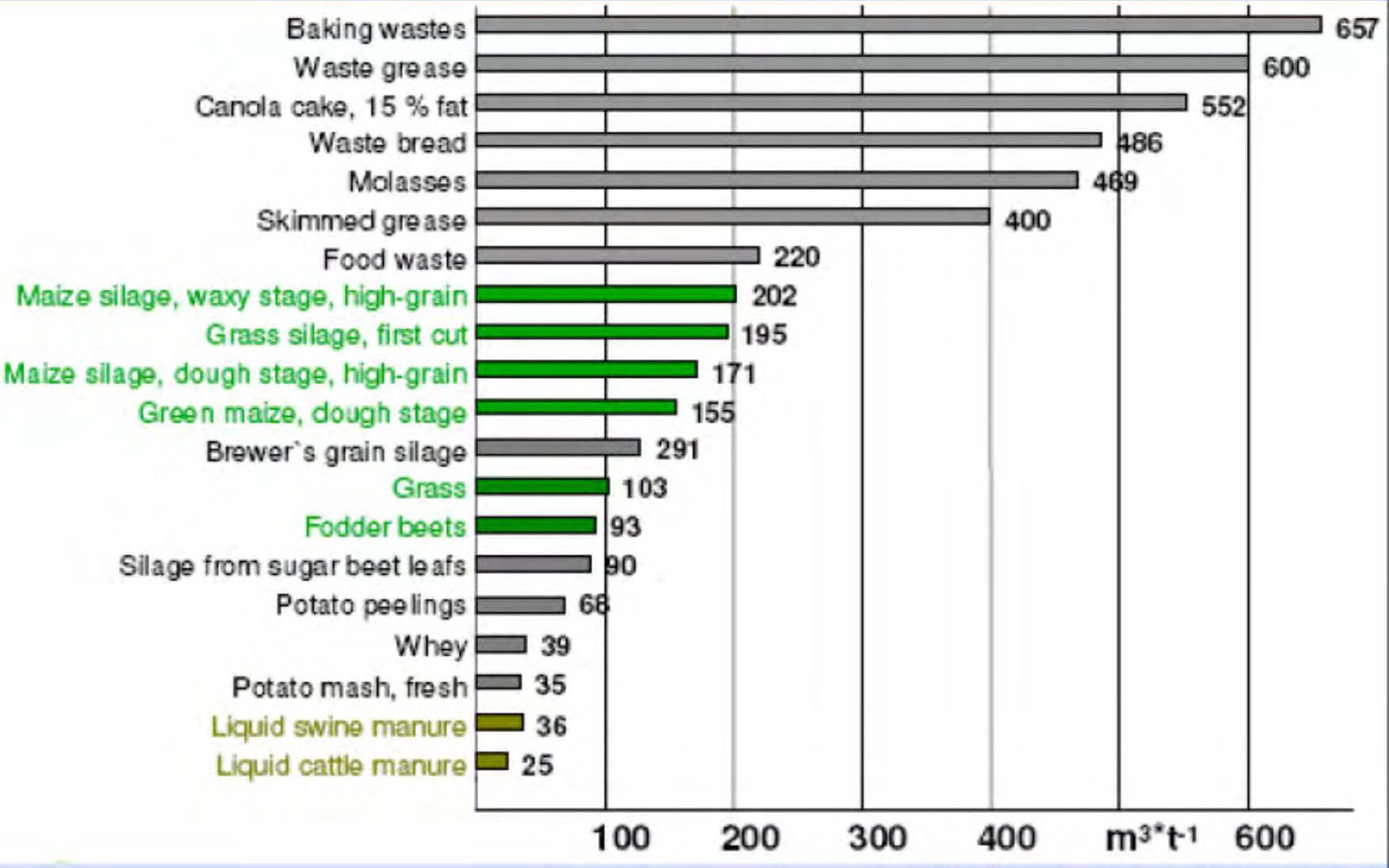
Food Waste in Landfills

- Food is the 2nd most abundant input (after paper) in US municipal landfills; 60 million MT of food waste is landfilled each year, representing 31% of the US food supply.
- US municipal landfills emit 10^8 MT of CO_{2e} each year.
- There are 600 US landfills that use landfill gas for energy; most landfills flare the biogas without producing energy.
- Landfill conditions are not optimal and produce a fraction of the biogas that could be produced in AD systems.
- Food waste diversion from landfills for industry has been mandated by Long Island, NY since 1990 and Massachusetts since 2014. New York City is working on food waste diversion programs for municipalities. It is standard practice in many European and Asian cities.

Food Waste Policies

- Using food waste in composting can be difficult to manage (odors, leachate, managing co-substrates)
- In Maryland, if farmers sell compost that incorporates food waste with their manure, they are required to install a concrete pad below the compost windrows (up to $40,000 to build), but if the farmer composts food waste and manure for their own use, they do not need concrete flooring (Code of Maryland Regulations 26.04.11).
- Food waste composting is limited to large commercial operations in MD that are not associated directly with on-farm husbandry (i.e. PG County expanding but at capacity).
- Currently, there is only one food waste/manure co-digester operating in Maryland, and one food waste-only digester under construction

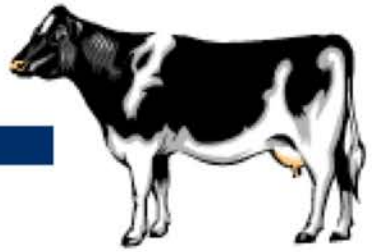
Potential Biogas Yields



Source: Mathias Effenberger, 2006

Energy production

LANDESANSTALT
für Agrartechnik
& Bioenergie



100 livestock units-farm
≙ 80 dairy cows

5 m³ liquid manure/d

with energy crops

5,5 t maize silage/d

with kitchen waste

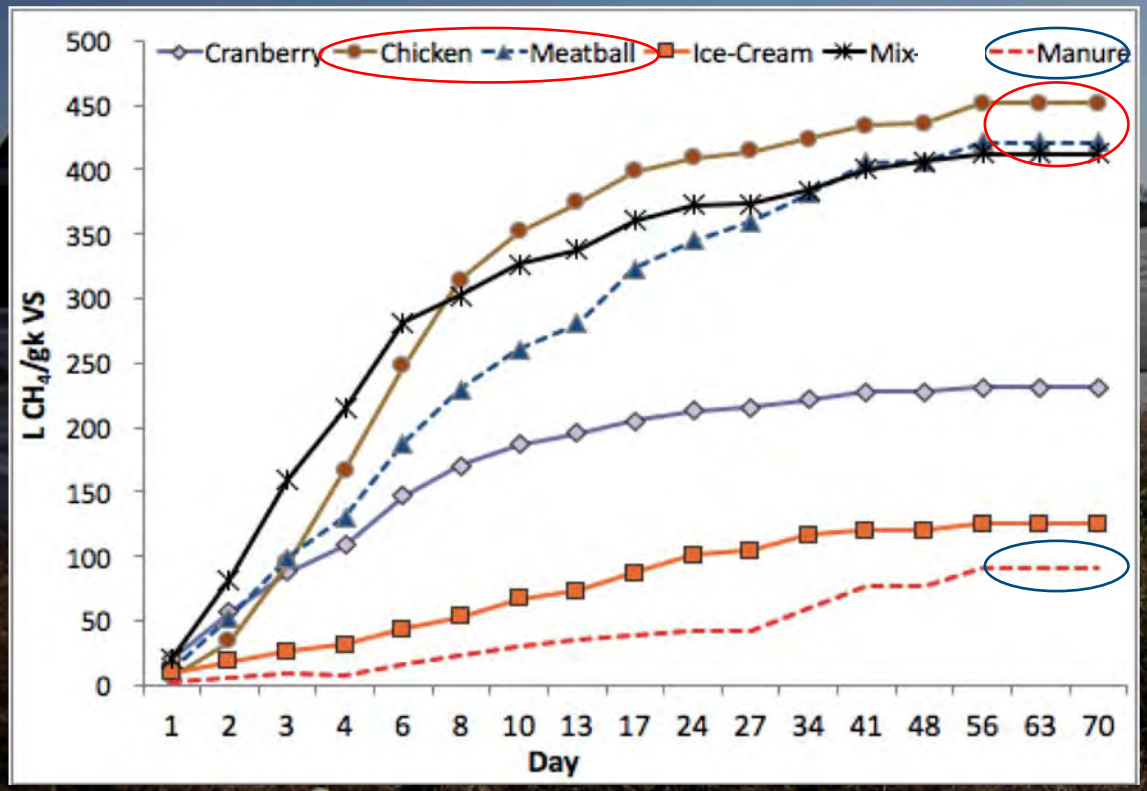
10 t kitchen waste/d

70 m³ methane / day	600 m³ methane / day	1200 m³ methane / day
about 13 kW_{el}	about 100 kW_{el}	about 200 kW_{el}
heat for 1 - 5 households	heat for 35 **households**	**heat for 70 households**
electricity for	**electricity for**	**electricity for**
12 households	140 households	280 households

Slide Courtesy of Hans Oechsner, University of Hohenheim

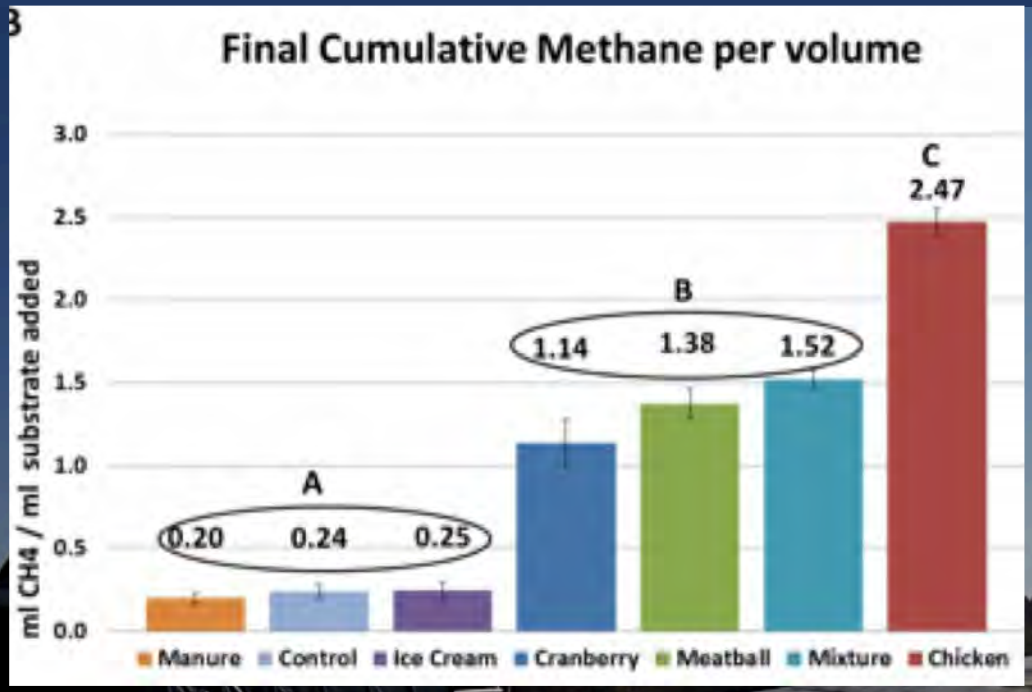
Prior Study: Food Waste Co-digestion at MD Farm

- Covered lagoon digester – unheated – in MD
- Food processing waste (≈ 2500 gal/day) from cranberry, ice cream, chicken and meatball processing digested with flushed dairy manure from 450 cows (64,000 gal/day)



- Food waste increased gas production from 38% (ice cream) to 398% (chicken)
- For food waste, 58 to 85% of the gas was produced in the first 12 days, while manure only had 39% of its gas total in this time.
  - Rapid production of VFAs with food waste.

Prior Study: Food Waste Co-digestion at MD Farm

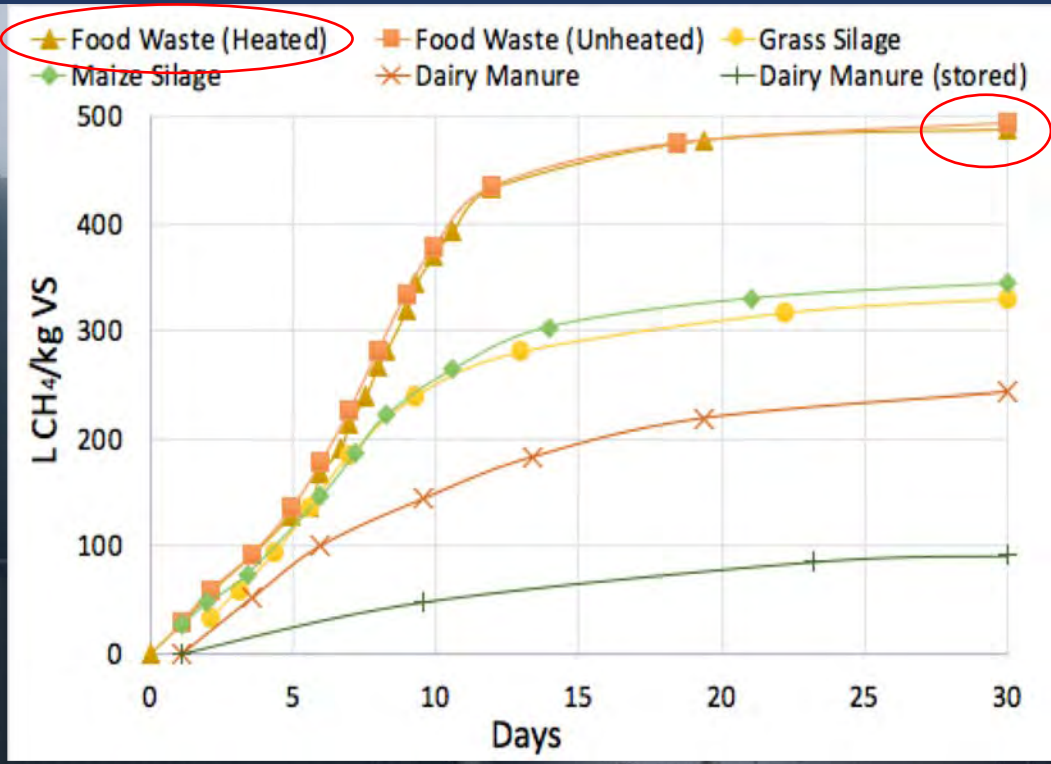


Substrates	VS (g/L)
Cranberry	225 ± 6
Chicken	275 ± 4
Meatball	135 ± 23
Ice-cream	9.3 ± 0.5
Manure	1.7 ± 0.1

- With flushed dairy manure, 15% (ice cream) to 81% (chicken) of the volatile solids (VS) in the digester was due to food waste.
- 83% of the gas production was attributed to food waste, even though it was only 4% of the volume.
- Daily gas production of the digester should average 670 m^3 CH_4/day, but fluctuated from 796 to 33.5 due to low temperature.
  - Temperature stability can greatly affect gas production from food waste.

Prior Study: Food Waste Co-digestion at a German Farm

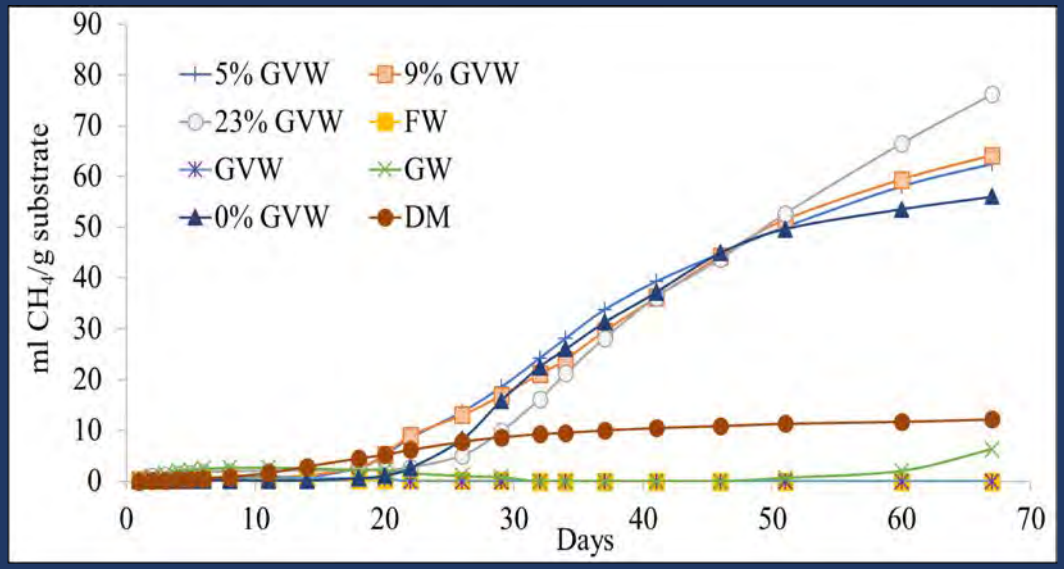
- Food waste increased gas production by 434% and maize silage by 276% compared to manure.
- Food waste and silage had 85-89% of the cumulative CH_4 in the first 14 days, while the fresh manure solids had 53%.
- 71% of the gas was due to food waste, which was 66% of the volume (5.5 m^3 per day).

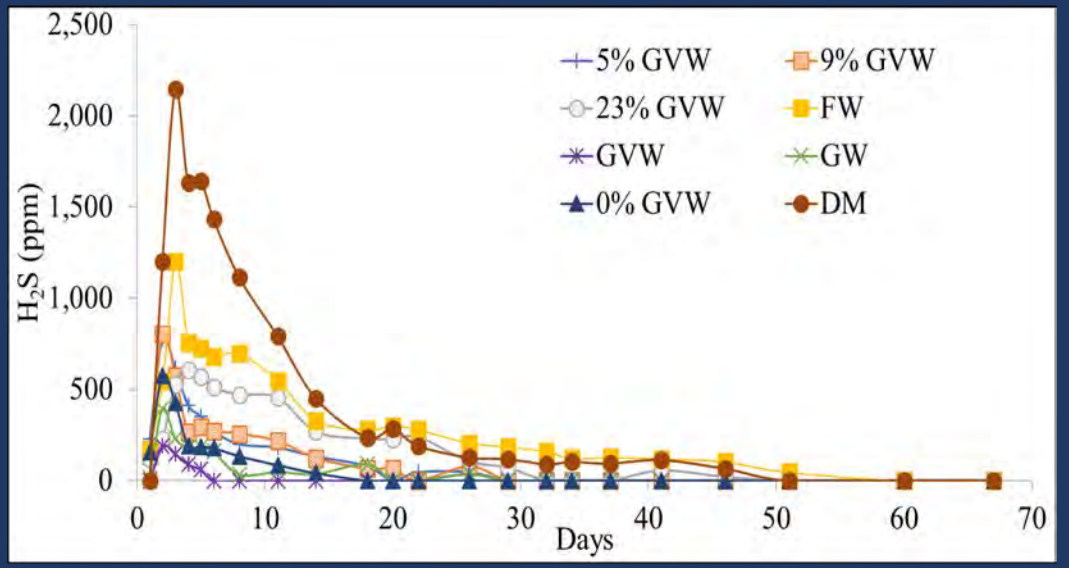


- Comparing lab to field results, showed there was 23% more gas than expected due to a longer retention time in the digester (110 days) due to German regulations

Prior Study: Food waste, Grease Waste and Gummy Vitamin Waste co-Digestion at a PA Farm

- Gummy vitamin waste (GVM) was added at varying ratios (0, 9, 5, 23, and 100%, by mass) to a dairy manure (DM), food waste (FW), and grease waste mixture (GW) for co-digestion.
- The 23% GVW addition increased CH_4 production by 518% compared to manure.
- Co-digestion with the gummy vitamin waste decreased the max H_2S concentration by 63 – 73%.





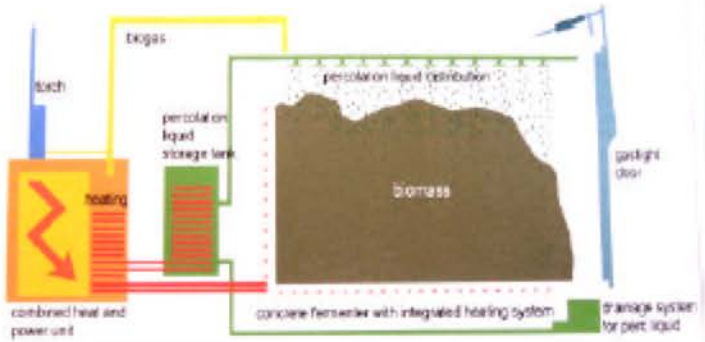
Food Waste Digestion – Individual Collection

Food Waste Collection and Pre-treatment in Germany

Heated to 70 °C for at least one hour, as required by German law.

Anaerobic Digestion of "Dry" Municipal Solid Wastes - BEKON Process, Munich Municipal Waste Facility (Munich, Germany)

Process description of the BEKON Biogas Technology



U of Wisconsin at Oshkosh Food Waste Digestion System
Food waste from dining halls with leaf litter




Food Waste Contracts

- Food processing waste
  - Tends to be liquid
  - More uniform
  - Easier to load – less impurities
  - Walmart Sustainability Index and Project Gigaton
- Supermarket Wastes
  - Can have rubber bands, plastic
  - More variable, likely need heavy grinder pumps
- De-packaging Systems
  - Increase options for waste inputs - added infrastructure
- EPA Food Waste Locator Tool

Scrw-press for silage

Available at:
https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map

Displays locations of 500,000 excess food generators, including:

- correctional facilities
- educational institutions
- food banks
- healthcare facilities
- hospitality industry
- food manufacturing, processing & distributors

Displays locations of source separated organics programs and 4,000 potential recipients of excess food, including:

- anaerobic digestion facilities
- composting facilities
- food banks

Functionality of Map

The map *does* provide:

- Geographic locations of potential generators and recipients.
- Estimates of excess food generation rates at the establishment level.
- Estimated edible fraction of excess food for grocery stores & supermarkets only.
- Plate excess estimates for colleges & universities only.
- Service area for communities with organics collection programs.
- Select contact information.

The map *does not* provide:

- Exact measurements of excess food.
- Indication of existing generator diversion activity.
- Capacity of potential recipients to accept excess food.
- Estimates of on-farm excess food or that from the food services sector.

Rethink

CHANGING HOW WE THINK ABOUT OUR RESOURCES FOR A BETTER TOMORROW

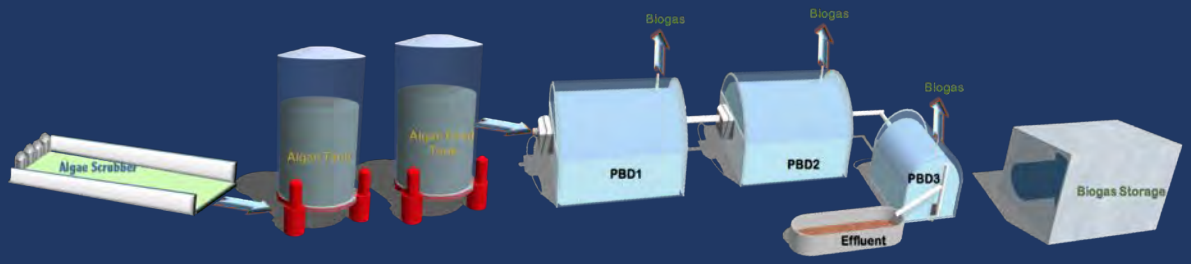
EPA United States Environmental Protection Agency

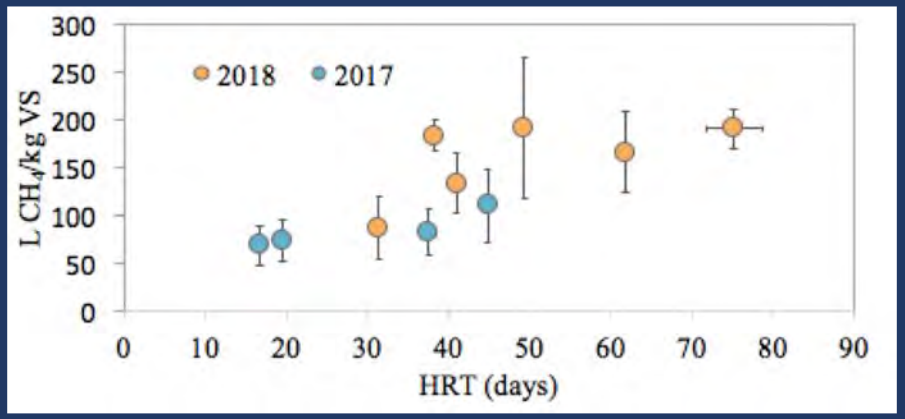
Claudia Fabiano, U.S Environmental Protection Agency

Digestion of other Co-Substrates

- Algae
- Municipal Solid Waste
- Industrial waste
  - Must be approved by regulations and be field applied
- Additives – Higher biogas production or decreased H_2S, but not organics
  - Biochar
  - Nanoparticles
  - Iron Addition

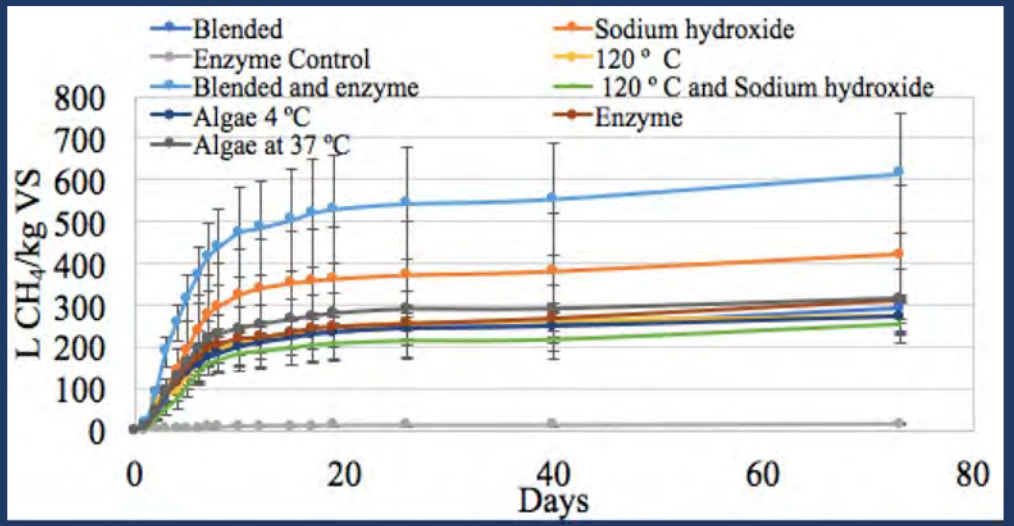
Algae Digestion





Field Scale Studies of algae digestion

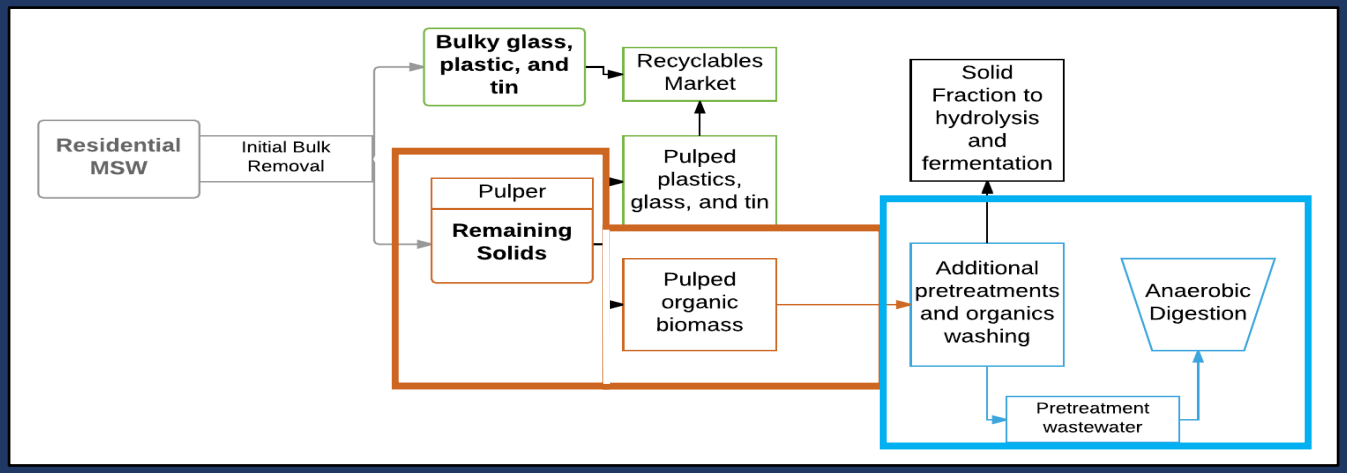
- Methane production was 137 L CH_4/L algae (no pre-treatment), with decreased production at lower temperatures and retention times.
- Pre-treatment with enzymes and blending increased CH_4 production by 56% and sodium hydroxide by 35% compared to the untreated algae.



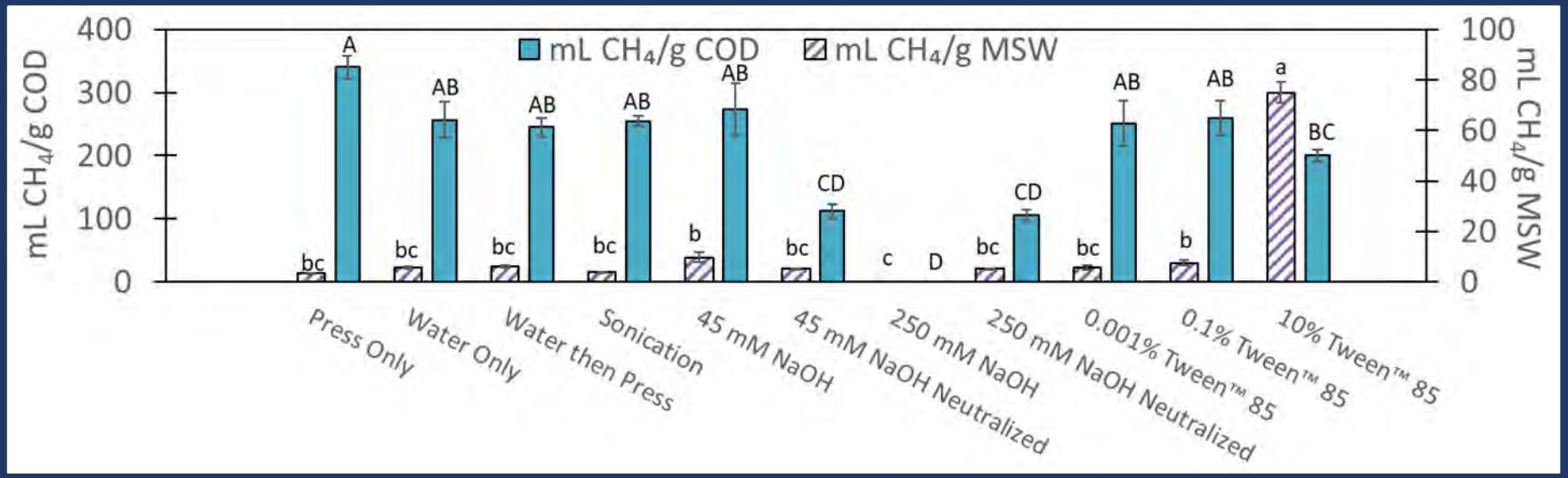
Lab-Scale Studies of pretreatment of algae

Cellulosic Ethanol Production with Methane Recovery

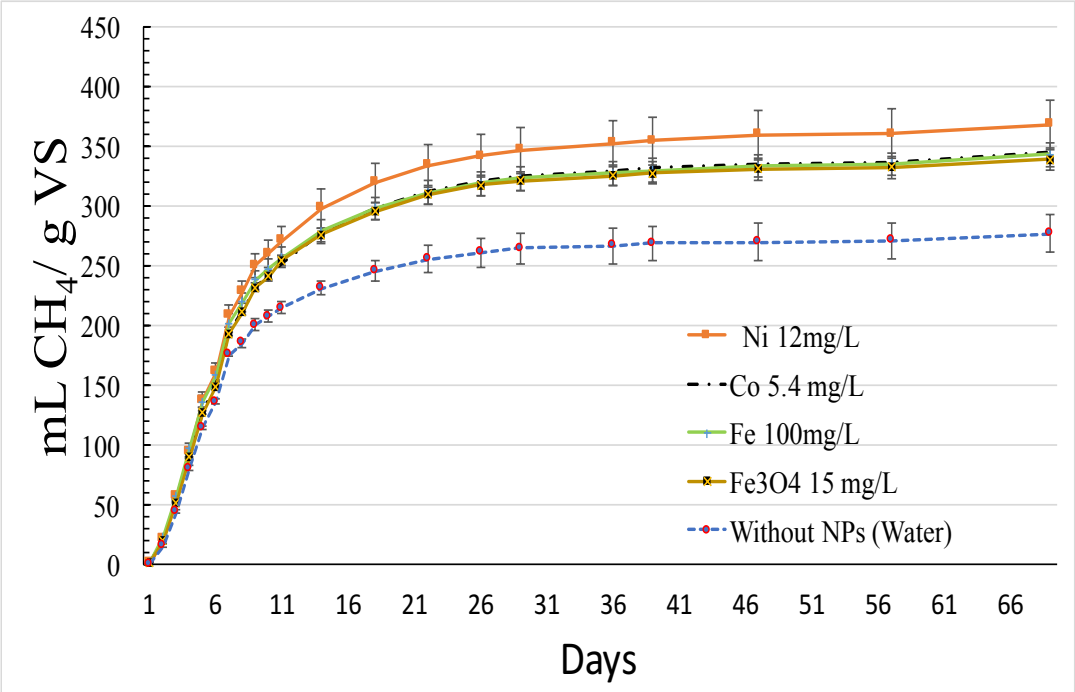
Ethanol and Digestion

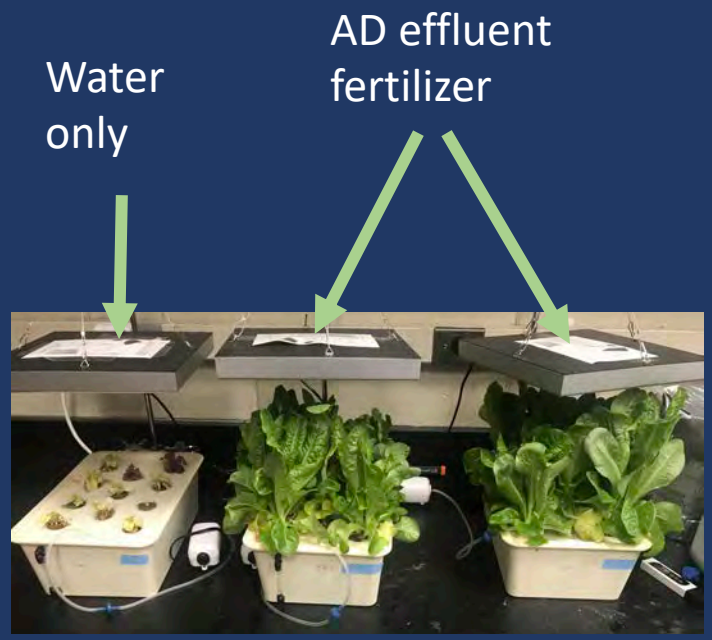


Digesting MSW waste, pulped at 66 °C, and washed at a 1:5 solids to water ratio was 2.03 x 10^7 MJ, which was 113% of total energy required (1.79 x 10^7 MJ) to produce a million gallons of ethanol



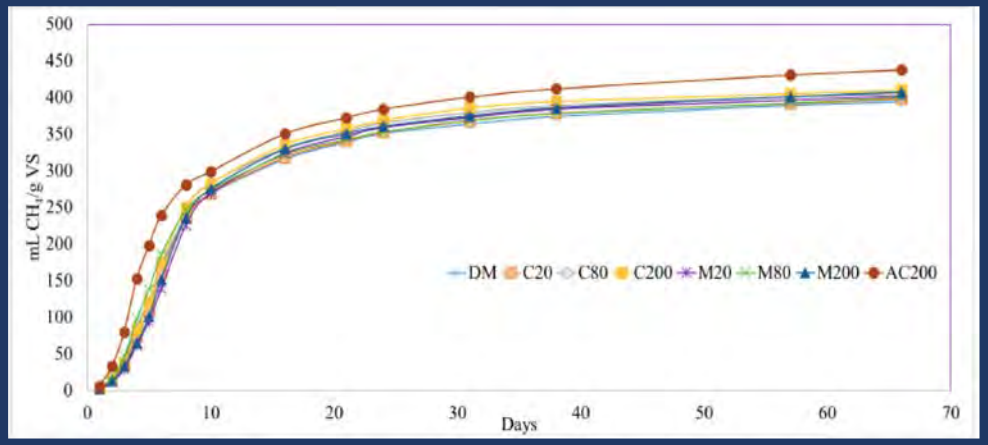
Nanoparticles

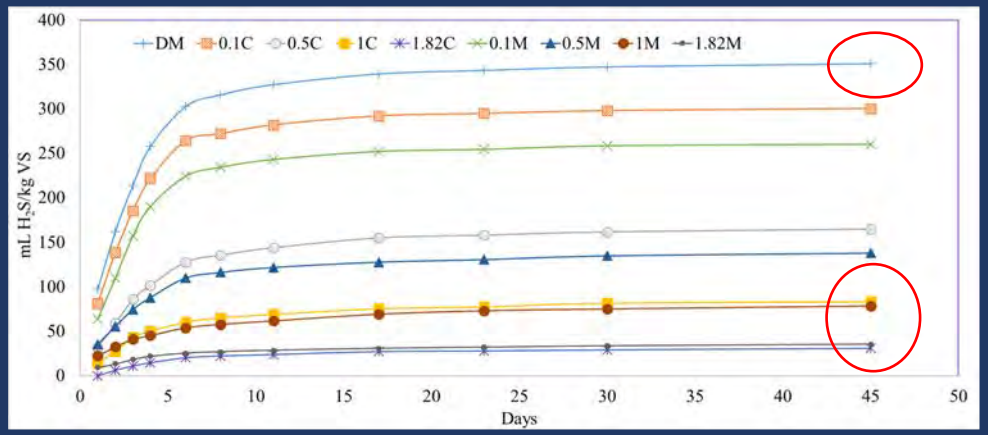


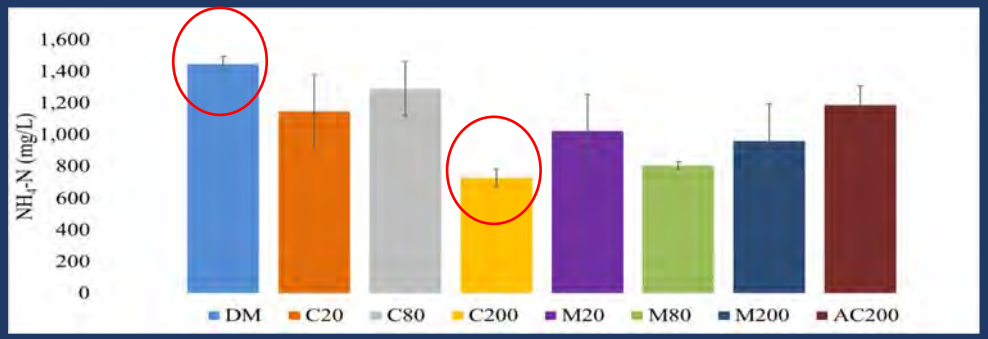


- Nickle (Ni), Cobalt (Co), Iron (FE) and Iron Oxide (Fe_3O_4), added at the nano-scale, increased CH_4 production by 22.3 to 15.2% compared to poultry litter digestion without nanoparticles.
- After digestion, Fe and Fe_3O_4 were detected by SEM, but Ni and Co were not detected and had been absorbed into the bacterial cells.
- The effect of the nanoparticles on subsequent fertilizer application was tested.

Biochar in Anaerobic Digestion

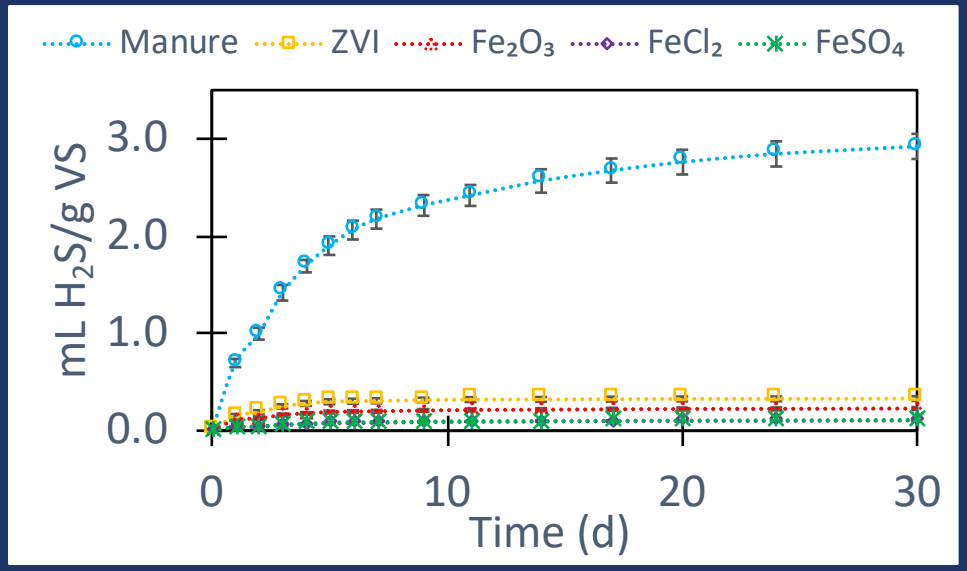


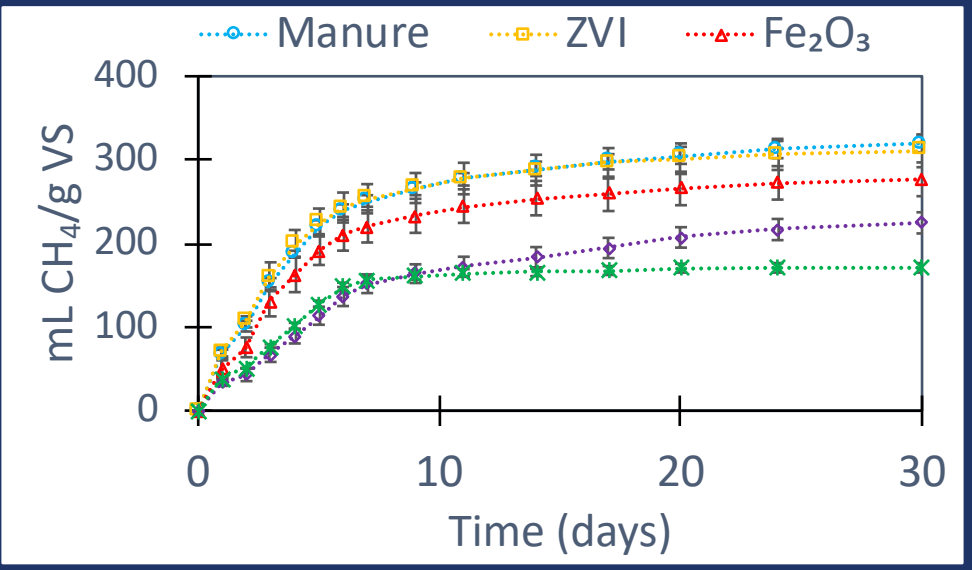




- Two types of biochar (corn stover, wood chips) were added to dairy manure digestion.
- Biochar did not increase CH_4 production. Only activated carbon (AC200) increased CH_4 production above dairy manure digestion.
- The highest biochar additions did have up to 90% reduction in H_2S compared to dairy manure-only.
- The biochar sorbed the NH_4-N in the effluent, with a 50% NH_4-N reduction for corn stover (C200) compared to dairy manure-only.

Iron Additions and Digestion





Iron Addition	H_2S Reduction (%)	Average H_2S (ppm)
$FeCl_2$	96	114
$FeSO_4$	96	134
Fe_2O_3	92	204
ZVI	89	272

- Added 50 mM of zero valent iron, iron oxide, ferrous sulfate, or ferrous chloride to diary manure.
- H_2S reduction was 96 – 89%, with the reductions of Fe(II) > Fe(III) > ZVI.
- $FeSO_4$ and $FeCl_2$ additions did significantly reduce CH_4 production compared to manure-only digestion.


Questions?