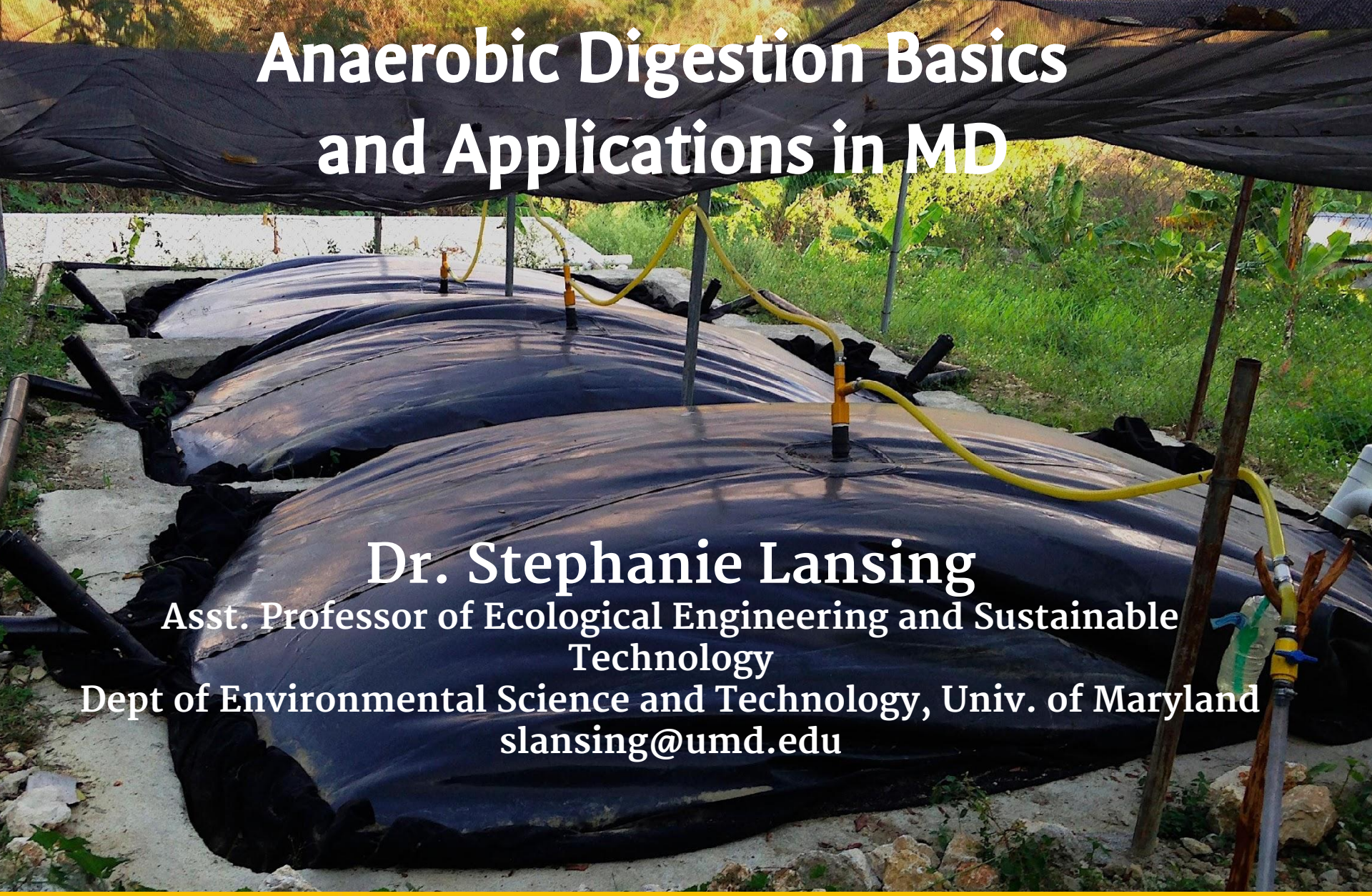
Anaerobic Digestion Basics and Applications in MD



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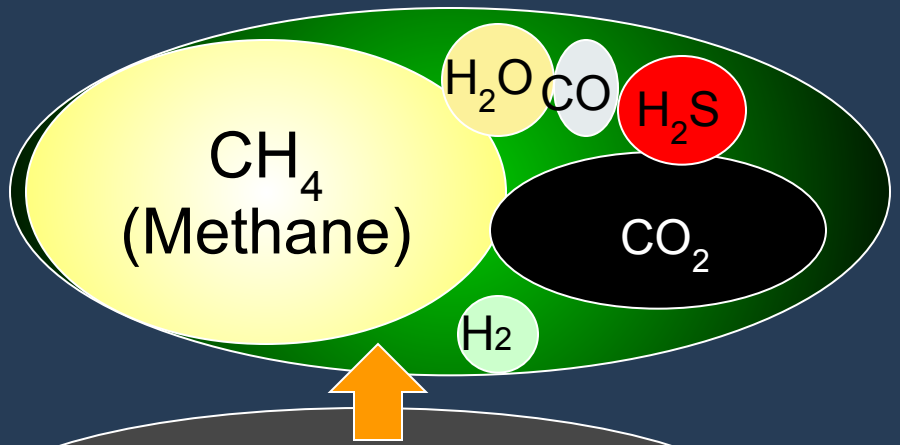
ANAEROBIC DIGESTION

Biogas



Manure, Crops,
Wastewater Sludge
Food Waste
ANY ORGANICS

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

Conversion of biomass to biogas and to usable energy

LANDESANSTALT
für Agrartechnik
& Bioenergie

Usable substrates:

Manure

Residues or byproducts of food-production f.e. kitchen-waste

Biogas Process

Biogas plant

H_2S scrubbing

CO_2 Scrubbing
Compression

Gasboiler

heat

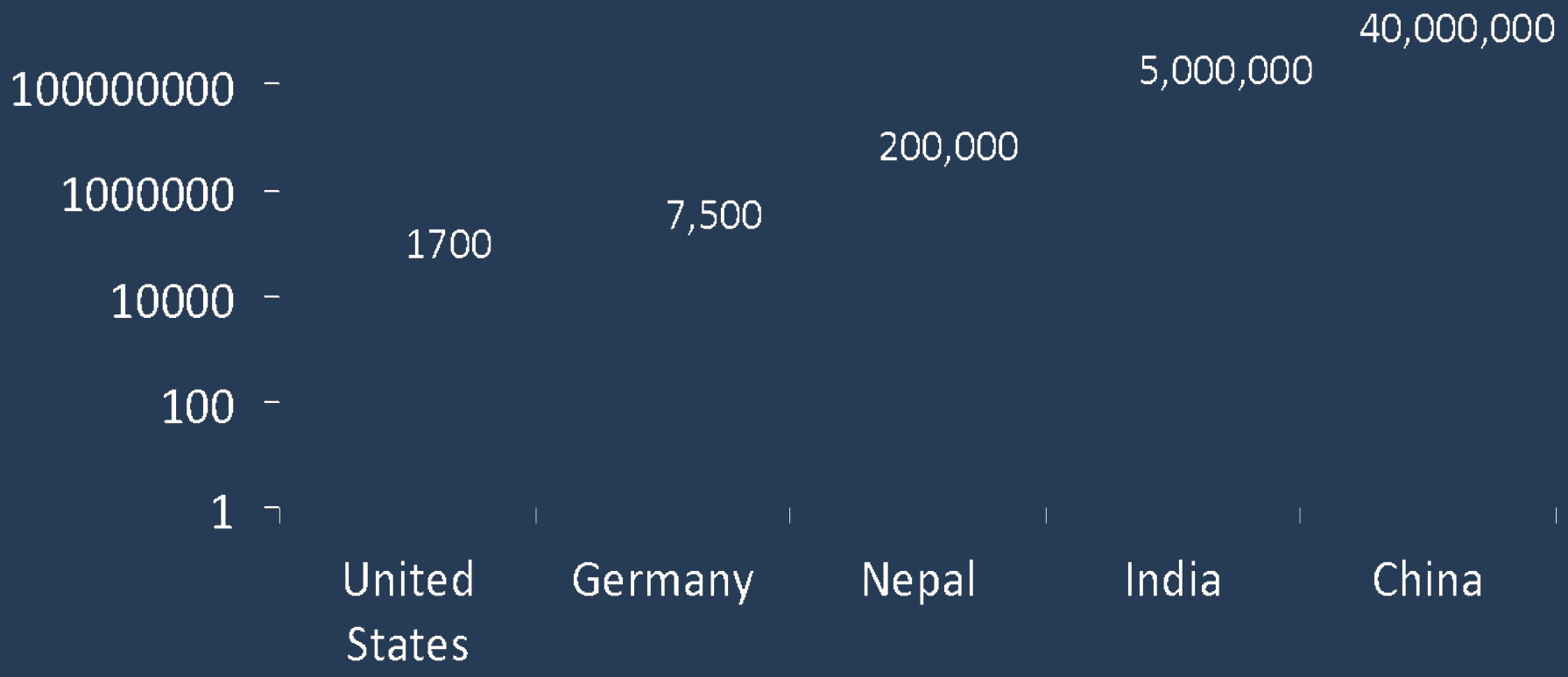
Electricity, heat

CHP-Unit

Pressure-storing

green gas, SNG

Anaerobic Digesters in the World



The majority of US digesters are at WWTP, only 264 on-farm

DC Water – Anaerobic Digester

- DC Water processes 370 million gallons of wastewater per day.
- DC Water is the first in North America to use thermal hydrolysis to “pressure-cook" the waste solids prior to Anaerobic Digestion. This is the largest thermal hydrolysis plant in the world
- The digesters is expected to produce 13 MW of electricity (enough to power 8,000 homes and a $10 million savings annually). With additional generation possible with incorporation of off-site food waste, fats and grease. Also, they will save $10 million in trucking costs and reduce their carbon emissions associated with transportation by half."

Lack of US Small-scale on-farm Digestion in the US

Of the 247 farm-based US digestion systems only FOUR dairy digesters are on farms with 200 cows or less (87% of dairy farms).

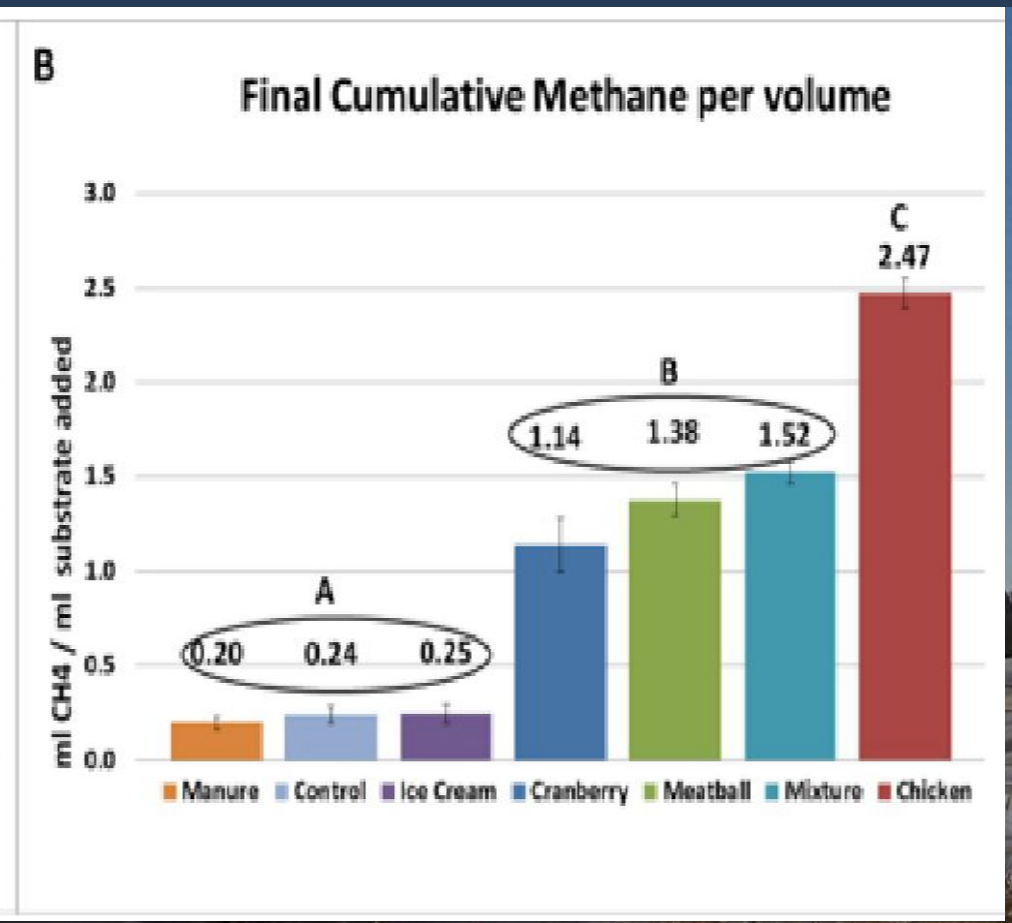
Number of Dairy Cows on-Farm	Number of US Operations (2012)	Percent of Total US Dairies
1-29	18,800	32%
30-49	9,700	17%
50-99	14,500	25%
100-199	7,900	14%
200-499	3,800	7%
500+	3,300	6%

Adapted from: USDA, NASS Farms, Land in Farms and Livestock Operations

Small-Scale Digesters for US

- Six flexible biogas bags digesters situated in insulated, heated culverts
- Influent can be pre-heated and radiant piping used for in-vessel heating
- Automatic loading and temperature control at 30°C

Food Waste Co-digestion at Kilby Farm



Covered lagoon dairy manure digester – currently unheated – in Colora, MD

- Food processing waste from manufacturing of Cranberry, Ice cream, Chicken and Meatballs and manure from 600 cows.
- Digester input consists of 96.8% (by volume) dairy manure and the remaining is the food waste.

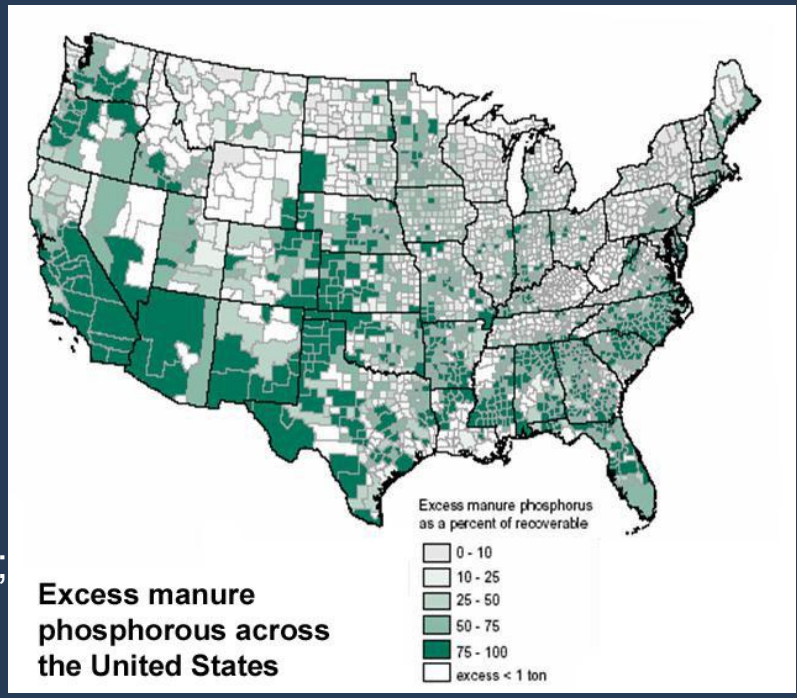
Lisboa and Lansing, 2013 in Waste Management

Anaerobic Digestion of Poultry Manure

- Can be inhibited by high levels of ammonia
- Use of high-solids digestion is increasing but most poultry litter digesters add water to influent
- Product is liquid, solids can be separated and liquid re-used (after ammonia removed)
- Largely conserves N and P, but allows for furth nutrient management
  - Struvite formation, ammonia scrubbing

Watershed Implications of Digestion: Nutrient Management

- There is an emerging US digestion industry focused on agricultural livestock waste (USEPA, 2012)
- Regulatory oversight is increasing in terms of nutrient management requirements (TMDL standards) (Rasmussen and Adams, 2004; Branosky et al., 2011; USEPA, 2011)
- Most U.S. operations separate manure solids post-digestion and then compost or reuse as bedding, which decreases on-farm expenses (Kramer, 2009; Scott et al., 2010)



Excess manure phosphorous across the United States

Opportunities

- Livestock operations have considerable energy generating potential, with consistent, low-cost biomass collected in one spot
- Small-scale farms are >50% of market
- Reduce farmer-incurred capital costs
- Co-digestion of food waste, with tipping fee
- Operate at seasonally lower temperatures with alternative inoculum sources

Klavon, Lansing et al., 2013 in Biomass & Bionenergy

Challenges ($ $ $ $ $ $ $ $)

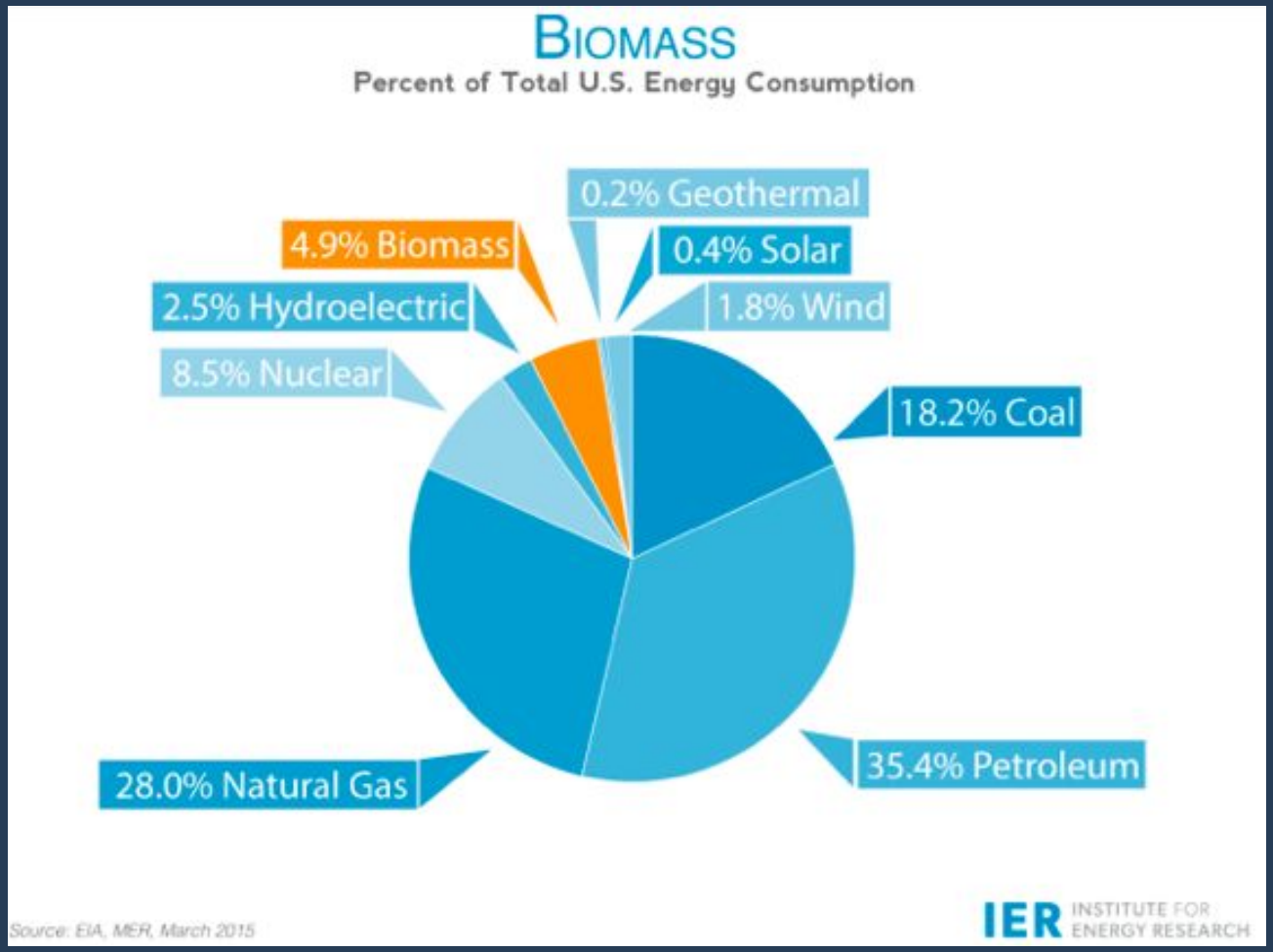
- Understanding dairy industry pressures and low economic return from manure-only waste digestion
- Importance of scrubbing H2S from biogas, especially for electric generation and frequency of generator malfunction
- Dependent on electricity price for large-scale systems and year-round demand for direct use of biogas for small-scale
- Difficulties (time devoted to)

Klavon, Lansing et al., 2013 in Biomass & Bionenergy

Additional Waste to Energy Projects

- Post-digestion nutrient capture from liquid digestate of poultry litter digesters
- Gasification of poultry litter
  - Life cycle assessment (LCA) comparing the two poultry litter waste-to-energy technologies
- Inoculum sources for colder temperature digestion and freeze drying of inoculum for decreasing start-up time of digestion
- Effect of digestion and composting on antibiotic transformations with modeling of field to stream outputs
- Cover crop (radish) co-digestion with manure to increase yield
- Biogas use in lower-cost solid oxide fuel cells
- Digesters for University of Maryland campus food waste
- Digesters for low-cost sanitation options
- Digester effluent into Microbial Fuel Cells for direct electricity production

US Biomass Energy
There's Room for Growth



US Energy Production (Trillion BTUs)

Renewable Energy

- 9660

Biomass Energy

-4800

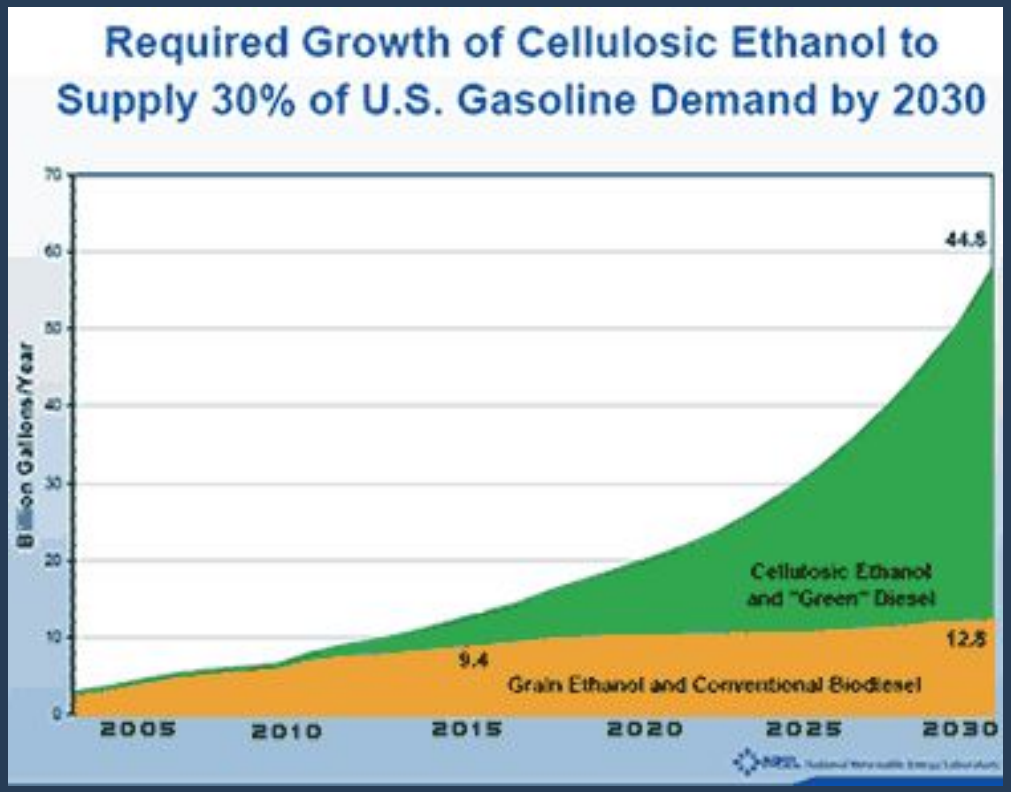
Biofuels Production

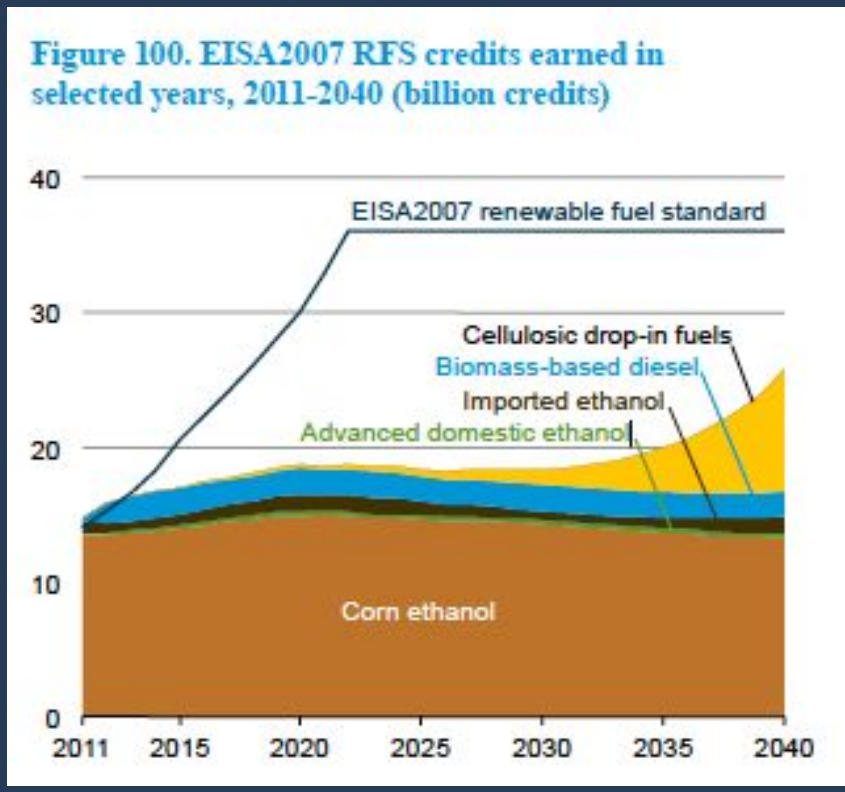
-2100

Waste Biomass

-488

US Policy Effects on Ethanol





US Energy Independence and Security Act of 2007 states that by 2022 we will have 36 billion gallons of biofuel

- 21 billion gallons of ethanol from non-grain products (e.g. sugar or cellulose, such as switchgrass)
- 15 billion gallons of ethanol from grain (corn/sorghum)

Environmental Markets for Biogas

Market	Credit	Biogas Use	Geographic Limitation
California Cap-and-Trade	Offset	Any	Anywhere in the US
California Low Carbon Fuel Standard	LCFS Credit	Transportation fuel	Fuel consumed in California
US Renewable Fuel Standard	RIN (Renewable Identification Number)	Transportation fuel	Anywhere in the US

Value Comparison

	Average Price	$/DGE equivalent
Carbon Offset	$8.60/mtCO2e	$0.21
Low Carbon Fuel Standard	$45.41/mtCO2e from target	$0.52
RIN	$0.98/D3 RIN proxy	$1.50

Cannot sell both offset and LCFS credit

Understanding Biofuels Market in the US

- Biogas as a Transportation Fuel should increase, as natural gas production continues to decrease the US electricity prices.
- Technology is not widely utilized in the US due to lack of in the market.

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Questions?