Curt Gooch
Dairy Environmental Systems Engineer
Team Leader – Dairy Environmental System Program
Cornell University
www.manuremanagement.cornell.edu

Challenges and Opportunities in Anaerobic Digestion: Maryland and the NE Experience

“Digester Systems in the NE: Successful Case Studies”
Environment

Economics

Society

Manure Management

Climate Change

Energy Efficiency & Renewable Energy

Farm Succession

Consumer Outreach

Soil and Water Conservation

Food Safety

Cow Comfort/Well-Being

Neighbor Relations

Source: Pronto, 2016
Presentation Outline

- Brief overview of farm-based AD
- What constitutes a successful anaerobic digestion system?
- AD case studies and lessons learned

www.manuremanagement.cornell.edu
Dairy Cow Manure:
- Total Mass = 150 lbs./cow-day
- Water = 130 lbs.
- Solids = 20 lbs.
- Volatile Solids = 17 lbs.
  - Digestibility = 32% VS
  - With co-digestion, digestibility substantially increases
- Nitrogen = 1 lb.
- Phosphorus = 0.2 lbs.
- Potassium = 0.2 lbs.
Anaerobic Digestion

A *controlled* process, that takes place in the absence of oxygen, where multiple microbe species, work together, to convert organic matter (manure solids) into biogas.

Manure and food waste \rightarrow \text{Nutrient-rich effluent} \rightarrow \text{Biogas (Carbon dioxide, methane, trace gases)}
Biogas Composition

- $\text{H}_2\text{O}$ vapor: 4%
- $\text{CO}_2$: 38%
- $\text{H}_2\text{S}$: 0.20%
- $\text{CH}_4$: 58%

Natural Gas
Anaerobic Digester

The liquid tight, gas tight vessel in which anaerobic digestion occurs.
Anaerobic Digestion Based Manure Treatment

Dairy Facility Effluent
(manure, bedding, waste water, etc.)

Imported Feedstock

Anaerobic Digester
(Mixed or Plug-Flow Reactor)

Biogas

H₂S Removal

Usage options:
- Boiler
- Engine-generator set
- Microturbine

Solid-liquid separation

Cropland Bedding Sale

Long-term Storage

Cropland

Flare

Excess biogas

heating loop
What is a Successful Digester System?
Anaerobic Digester System
What is a Successful Digester System?

A: Benchmarks:

- Consistent solid to biogas conversion
  - Manure only - >32% VS to biogas
  - Co-digestion - higher than manure only
<table>
<thead>
<tr>
<th>Material</th>
<th>SMY (mL methane g⁻¹ VS added)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn leachate</td>
<td>106.5 (n = 3)</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>122.2 (n = 3)</td>
</tr>
<tr>
<td>Manure separated liquid:whey 75:25</td>
<td>167.7 (n = 3)</td>
</tr>
<tr>
<td>Manure:switchgrass 75:25</td>
<td>207.8 (n = 3)</td>
</tr>
<tr>
<td>Meat pasta</td>
<td>216.2 (n = 3)</td>
</tr>
<tr>
<td>Manure:mouthwash 75:25</td>
<td>220.1 (n = 3)</td>
</tr>
<tr>
<td>Manure:plain pasta 90:10</td>
<td>224.0 (n = 3)</td>
</tr>
<tr>
<td>Manure:potatoes 75:25</td>
<td>227.7 (n = 3)</td>
</tr>
<tr>
<td>Manure:meat pasta 90:10</td>
<td>232.1 (n = 3)</td>
</tr>
<tr>
<td>Manure:cola 75:25</td>
<td>235.0 (n = 3)</td>
</tr>
<tr>
<td>Manure:whey 90:10</td>
<td>237.6 (n = 6)</td>
</tr>
<tr>
<td>Dairy manure</td>
<td>242.7 (n = 47)</td>
</tr>
<tr>
<td>Manure:whey 75:25</td>
<td>252.6 (n = 14)</td>
</tr>
<tr>
<td>Cabbage (whole)</td>
<td>256.5 (n = 3)</td>
</tr>
<tr>
<td>Manure:cola:mouthwash 75:12.5:12.5</td>
<td>258.0 (n = 2)</td>
</tr>
<tr>
<td>Manure separated liquid</td>
<td>261.3 (n = 3)</td>
</tr>
<tr>
<td>Mouthwash</td>
<td>274.3 (n = 3)</td>
</tr>
<tr>
<td>Eurasian Milfoil (Oneida lake plant)</td>
<td>279.0 (n = 2)</td>
</tr>
<tr>
<td>Manure:meat pasta 75:25</td>
<td>285.6 (n = 3)</td>
</tr>
<tr>
<td>Corn silage</td>
<td>296.1 (n = 3)</td>
</tr>
<tr>
<td>Plain pasta</td>
<td>326.1 (n = 6)</td>
</tr>
<tr>
<td>Potatoes (whole)</td>
<td>334.5 (n = 3)</td>
</tr>
<tr>
<td>Manure:plain pasta 75:25</td>
<td>353.5 (n = 6)</td>
</tr>
<tr>
<td>Water Chestnut (Oneida river plant)</td>
<td>359.4 (n = 2)</td>
</tr>
<tr>
<td>Manure:oil 75:25</td>
<td>360.6 (n = 3)</td>
</tr>
<tr>
<td>Cola beverage</td>
<td>373.1 (n = 2)</td>
</tr>
<tr>
<td>Water Celery (Oneida lake plant)</td>
<td>384.6 (n = 3)</td>
</tr>
<tr>
<td>Chara (Tully lake plant)</td>
<td>386.1 (n = 3)</td>
</tr>
<tr>
<td>Suspended FOG</td>
<td>402.3 (n = 6)</td>
</tr>
<tr>
<td>Settled FOG</td>
<td>413.4 (n = 5)</td>
</tr>
<tr>
<td>Cheese whey</td>
<td>423.6 (n = 10)</td>
</tr>
<tr>
<td>Dog food (fresh)</td>
<td>426.6 (n = 3)</td>
</tr>
<tr>
<td>Frogbit (Oneida lake plant)</td>
<td>451.5 (n = 3)</td>
</tr>
<tr>
<td>Manure:dog food:ice cream 50:25:25</td>
<td>467.3 (n = 3)</td>
</tr>
<tr>
<td>Ice cream</td>
<td>502.3 (n = 3)</td>
</tr>
<tr>
<td>Used vegetable oil</td>
<td>648.5 (n = 3)</td>
</tr>
</tbody>
</table>

Source: Labatut et al., 2010
What is a Successful *Digester System*?

A: Benchmarks:

• Consistent solid to biogas conversion
  • Manure only - >32% VS to biogas
  • Co-digestion - higher than manure only

• Biogas utilization
  • Eng-gen sets - Capacity factor (0.93 or above)
What is a Successful Digester System?

A: Benchmarks:

- Consistent solid to biogas conversion
  - Manure only - >32% VS to biogas
  - Co-digestion - higher than manure only

- Biogas utilization
  - Eng-gen sets - Capacity factor (0.93 or above)

- Economics
  - Annual revenue + displaced cost > annual cost of owning and operating AD system
At the present time...if the cost of renewable energy is cheaper than fossil fuel energy, we would not be meeting today (at lease about this topic!).
Long-term manure storage

Anaerobic Digester

Lactating Cow Barns
What is a Successful Manure Treatment System?

A: Benchmarks:

• Greenhouse gas reduction
  • Based on biogas production → destruction
  • Monetized value depends on base condition
Current 28 NYS Operating AD Systems...

- GHG reduction potential of 120,000 MTCO$_2$e
- GHG reduction sufficient to remove 25,500 cars from the highway annually
- Some off-farm organic matter imported for co-digestion increasing GHG reductions and renewable energy generation
What is a Successful Manure Treatment System?

A: Benchmarks:

• Greenhouse gas reduction
  • Based on biogas production → destruction
  • Monetized value depends on base condition

• Recovery of manure solids for bedding
  • Success in using recycled manure solids for bedding
What is a Successful Manure Treatment System?

A: Measure:

• Increase pumpability
  • Digested manure easier to pump long distances over raw manure
  • Decreased cost
  • Reduced farm truck traffic
What is a Successful Manure Treatment System?

A: Measure:

• Increase pumpability
  • Digested manure easier to pump long distances over raw manure
  • Decreased cost
  • Reduced farm truck traffic

• Increase crop nutrient utilization
  • Digested manure nutrients more plant available than raw manure
Benefits of Aerobic Digestion: Nutrient Recycling/Utilization

Diagram showing nutrient cycling processes such as ammonia (NH₃), nitrate (NO₃⁻), and biological fixation of nitrogen (N₂). Key processes include:

- Industrial Fixation
- Biological Fixation
- Volatilization
- Manure
- Microbes
- Immobilization
- Nitrification
- Denitrification
- Crop Uptake

Arrows indicate the flow of nutrients and processes in the ecosystem.
What is a Successful Manure Treatment System?

A: Measure:

• Reduce odor emissions
  • Happy neighbors!!!

• Reduce farm truck traffic
  • Happy neighbors!!!

• Water quality protection
  • Clean water
  • Happy neighbors!!!
# Farm-based Anaerobic Digestion

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Directly Monetizable</th>
<th>Society Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odor Control</td>
<td>n</td>
<td>Y</td>
</tr>
<tr>
<td>Pathogen Reduction</td>
<td>n</td>
<td>Y</td>
</tr>
<tr>
<td>Renewable Energy Gen</td>
<td>y</td>
<td>Y</td>
</tr>
<tr>
<td>Greenhouse Gas Reduction</td>
<td>y</td>
<td>Y</td>
</tr>
<tr>
<td>Water Quality Protection</td>
<td>n</td>
<td>Y</td>
</tr>
<tr>
<td>Fertilizer for Field Crops</td>
<td>n/y</td>
<td>dc</td>
</tr>
<tr>
<td>Low Cost Manure Application</td>
<td>v</td>
<td>dc</td>
</tr>
<tr>
<td>Nutrient Conc./Exportation</td>
<td>p</td>
<td>dc</td>
</tr>
</tbody>
</table>
Dairy-derived biogas is the only renewable energy that touches deep into other key basic human needs and has multiple benefits to the environment.
Take Home Point

- Despite all of the benefits anaerobic digestion provides to farms and society, adoption has not been widespread due to economic challenges.
Meeting New York State’s Energy, Environmental and Economic Goals While Strengthening Dairy Farms Through the Widespread Adoption of Manure-Based Anaerobic Digestion Technology

Working Paper

Prepared by:
Jennifer Pronto
Curt Gooch, P.E.
Peter Wright, P.E.

PRO-DAIRY Program
Cornell University, NY

Initial Version Released: October 31, 2017
Current Version Date: October 31, 2017

https://prodairy.cals.cornell.edu/
AN ACT to amend the public service law, in relation to setting the rate of credit per kilowatt hour for farm waste generating equipment customer-generators, which includes the anaerobic digestion of agricultural waste

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. Legislative Intent. It is the intent of this Legislature to support the ongoing financial viability of farm waste generating equipment customer-generators—more commonly known as anaerobic digesters—in New York state. Anaerobic digesters located on New York dairy farms create critical environmental attributes including, but not limited to, reducing methane gas releases and abating nutrient contamination of nearby water sources. The Legislature also recognizes that legacy anaerobic digesters are not financially viable under the current compensation methodology; as such, legacy anaerobic digesters are at risk of closure. Any closures would undo the significant financial investment made by the state of New York to install anaerobic digesters under the Clean Energy Fund program. Closures would also put New York behind on meeting greenhouse gas emission reduction goals as set forth under the State Energy Plan, and behind on developing a clean, distributed grid. While the New York state Public Service Commission has initiated a proceeding to transition to a compensation methodology based on the value of distributed energy resources, the implementation of the new methodology will not address the immediate financial need of existing, legacy, anaerobic digesters, or new digesters installed prior to the finalization of a meaningful value stack methodology that includes environmental values attributed to the avoided use of electricity generated by fossil fuels and the reduction of on-site greenhouse gas emissions.

The Legislature hereby determines that the public interest requires an increase in the rate of compensation for customer-generators operating

EXPLANATION--Matter in italics (underscored) is new; matter in brackets [ ] is old law to be omitted.
Consumers Want Milk That Is:

- Affordable
- High quality
- Safe
- Produced by healthy cows
- From farms that have low environmental impact
Presentation Outline

✓ What constitutes a successful anaerobic digestion system?

✓ Brief overview of farm-based AD

➢ AD case studies and lessons learned

www.manuremanagement.cornell.edu
1998 – AA Dairy
AA Dairy – Key Lessons and Outcome…
2000 – J.J. Farber Farm

AA Dairy

J.J. Farber Farm
J.J. Farber Farm Anaerobic Digester – Lessons and Outcomes
Farber Farm Anaerobic Digester
Matlink Dairy – Key Lessons and Outcome...
Total Annual Economic Cost or Economic Benefit

Total Annual Cost – Total Annual Benefit
<table>
<thead>
<tr>
<th>Farm</th>
<th>AA</th>
<th>DDI</th>
<th>NH</th>
<th>ML</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Cows</td>
<td>500</td>
<td>850</td>
<td>1,100</td>
<td>740</td>
<td>100</td>
</tr>
<tr>
<td>Capital Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digester Set</td>
<td>$192,000</td>
<td>$44,000</td>
<td>$339,400</td>
<td>$298,149</td>
<td>$80,183</td>
</tr>
<tr>
<td>Separator Set</td>
<td>$50,000</td>
<td>$89,000</td>
<td>$61,000</td>
<td>$61,689</td>
<td>$44,013</td>
</tr>
<tr>
<td>Gas Utilization Equipment</td>
<td>$61,000</td>
<td>$138,200</td>
<td>$287,300</td>
<td>$130,431</td>
<td>$13,135</td>
</tr>
<tr>
<td>Total Capital Cost</td>
<td>$303,000</td>
<td>$669,400</td>
<td>$687,700</td>
<td>$490,269</td>
<td>$137,331</td>
</tr>
<tr>
<td>Total Capital Cost Per Cow</td>
<td>$606</td>
<td>$788</td>
<td>$625</td>
<td>$663</td>
<td>$1,373</td>
</tr>
<tr>
<td>Annual Projected Capital Cost</td>
<td>$25,468</td>
<td>$52,978</td>
<td>$63,274</td>
<td>$49,016</td>
<td>$13,396</td>
</tr>
<tr>
<td>Annual Projected Capital Cost Per Cow</td>
<td>$51</td>
<td>$62</td>
<td>$58</td>
<td>$66</td>
<td>$134</td>
</tr>
<tr>
<td>Total Estimated Annual Cost*1</td>
<td>$37,540</td>
<td>$79,317</td>
<td>$103,960</td>
<td>$70,880</td>
<td>$21,497</td>
</tr>
<tr>
<td>Total Estimated Annual Cost Per Cow*1</td>
<td>$75</td>
<td>$93</td>
<td>$95</td>
<td>$96</td>
<td>$215</td>
</tr>
<tr>
<td>Total Estimated Annual Revenues</td>
<td>$56,445</td>
<td>$60,400*3</td>
<td>$77,680</td>
<td>$287,685</td>
<td>$10,900</td>
</tr>
<tr>
<td>Total Estimated Annual Revenues Per Cow</td>
<td>$113</td>
<td>$71*3</td>
<td>$71</td>
<td>$389</td>
<td>$109</td>
</tr>
<tr>
<td>Total Estimated Annual Cost or Benefit*1 *2</td>
<td>$18,906</td>
<td>-$18,917 *2 *3</td>
<td>-$26,280*2</td>
<td>$293</td>
<td>-$106*2</td>
</tr>
<tr>
<td>Total Estimated Annual Benefit Per Cow*1 *2</td>
<td>$38</td>
<td>-$22*2 *3</td>
<td>-$24*2</td>
<td>$293</td>
<td>-$106*2</td>
</tr>
</tbody>
</table>

*1 Does not include system electrical use.
*2 Negative numbers mean the farm incurs a net loss from the digester system.
*3 The electrical savings for DDI assumes the price of electricity is 10 cents/ Kw. This farm actually incurs a lower cost due to a specific business initiative. Since this is not typical of most dairy farms, the higher price is used.
*4 This cost assumes the microturbines were purchased new.

Source: Gooch and Inglis, 2006
Noblehurst Farms and Affiliates
Noblehurst Green Energy

• One of the newest anaerobic digesters in NYS
  – Completed Fall 2014, interconnected April 7, 2015

• Drivers
  – Business diversification
  – Reducing dairy costs (lower electricity costs over time)
  – Eliminating smell in the manure
  – Providing service to on-site milk processing facility

• Goals
  – Self sufficiency – “standing on its own” financially
  – Income diversification (electricity and food waste)
  – Job creation
Noblehurst Green Energy

- 1.33 million gallon EnviTec complete mix digester
- 450 kW Guascor CHP net metered with National Grid
- Wholly owned subsidiary of Noblehurst Farms
  - 1800 cow multi-generation, multi-family dairy farm
  - Farming 3000 acres of corn, alfalfa and triticale
- Co-located with Craigs Station dairy complex
  - Craigs Station Creamery separation facility operational in 2014
  - Craigs Station Cheese facility commissioned February 2018
  - Innovative wastewater pre-treatment by Clear Cove Systems
Current Process:

- Manure
- Food waste
- Anaerobic Digester (1.3M Gallon)
  - Biogas
  - Digestate
  - Flared Biogas
- Heat for AD
- CHP (450 KWH)
  - Electricity
  - Electric Grid
  - On Campus Facilities (Creamery, Cheese Factory, Solids Treatment, Farm and Parasitic loads)

Figure 1: Current Process at NGE
Noblehurst Green Energy

• Current energy production and utilization
  – Approximately 315 SCFM biogas produced
  – Utilizing +/- 150 SCFM through the CHP
  – Flaring another 50-60% of the biogas and not yet optimized

• Electricity production approximately 3,500,000 kWh/year

• Net metered – 70% used on campus
  – 45% Noblehurst Farms (average w/seasonality)
  – 25% Craigs Station Creamery
  – Remaining 30% National Grid and/or Clear Cove (just started)
  – Projected to be neutral production vs consumption by 2019
• Current feedstocks
  – **Manure** from 1800 dairy cows at Noblehurst Farms
  – Committed high-strength **dairy processing waste** direct piped from Craigs Station Cheese facility
  – Additional **acid whey** and high-strength volumes direct piped from Craigs Station Creamery
  – **Source separated organics** – up to 15 tons per day of clean, pre-consumer material delivered by Natural Upcycling
  – **Packaged liquid and semi-solid organics** – processing 20-30 tons per day of juices, soda, syrups, etc. delivered by Natural Upcycling
  – Bulk tanker loads including **condensed whey** from Craigs Station Cheese and customers in the region
Noblehurst Green Energy

- Opportunities – “Challenging” Feedstock
Noblehurst Green Energy

• Challenges
  – Logistics: from customer to disposal site
  – Contamination: wanted control over the feedstock quality
  – Variety: all food waste isn’t created equal
  – Episodic: especially on packaged food waste

• Solution
Where we are – SSO collection

[* = Home area]
What Can Be Upcycled?

Let's UPcycle IT!

- Fish & Seafood Products
- Beef & Pork Products
- Poultry Products
- Fruits & Vegetables
- Dairy Products
- Bread & Wheat Products
- Rice Products
- Coffee Products
- Pasta Products
- Egg Products
- Leaf & Bush Waste
- Floral & Tree Trimmings
- Grass & Weed Waste

Please Note:
Plastic, plastic bags/wrap/straws, styrofoam, bottles and cans, milk or cream cartons, aluminum foil, cardboard, wood, metal or hazardous waste
Organics Pickup Service

• Participating businesses place food waste in color-coded bins located in kitchens or food prep areas.
• Once bins are loaded, they are wheeled to a back dock or other convenient location to be picked up.
• These bins are serviced up to 5 days per week by a specialty vehicle and cleaned by a high pressure system all contained within the truck.
• Sanitized containers limit odor and provide a sterile work environment.
Packaged Food Waste

• Developed strategic relationships with disposal sites that can cost-effectively accommodate these substrates
• Sites in New York, Pennsylvania and Connecticut

Noblehurst Green Energy, NY
Reinford Farms, PA
What We Do Well

• Align with companies that are leaders in sustainability
• Reduce methane gas emissions & create renewable energy
• Communicate with our partners and customers
• Share the message of keeping food waste out of landfills
• Core value of doing the right thing

Sample Customers

- Gimme! Coffee
- Wegmans
- RIT
- WhiteWave Foods
- Hobart and William Smith Colleges
- Rich’s
Got Manure?

Enhancing Environmental & Economic Sustainability Conference

Anaerobic Digestion: The Cornerstone of an Integrated Manure Treatment System

Curt Gooch, P.E.
Dairy Housing and Waste Management Engineer
Biological and Environmental Engineering
Cornell University

www.manuremanagement.cornell.edu
Ammonia-N Stripping