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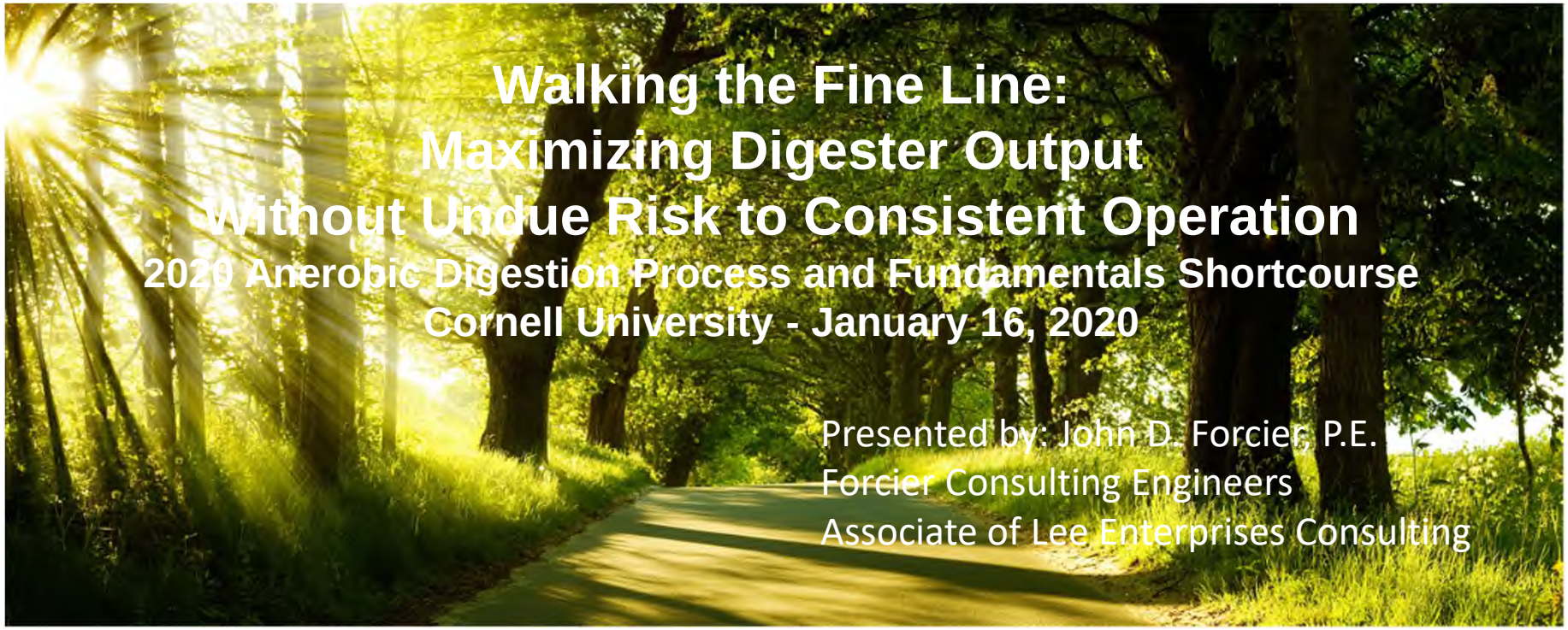

Walking the Fine Line: Maximizing Digester Output Without Undue Risk to Consistent Operation

2020 Anerobic Digestion Process and Fundamentals Shortcourse

Cornell University - January 16, 2020

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Associate of Lee Enterprises Consulting

Your Organics to Energy Experts

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CHALLENGES:

- Low Energy Base Feedstocks:
  - Manures and WWTF sludge have limited energy due to previous digestion.
- High Energy Feedstock Issues:
  - Limited local availability
  - Appropriate pre-processing
  - Recipe Management
- Permitting Requirements:
  - Solid waste and air permits
  - Maintaining nutrient management plan with additional feedstocks
  - Electrical/NG interconnection

OPPORTUNITIES:

- Mixed Feedstocks:
  - Significant energy gain (3 to 10 times manure/sludge only) from adding appropriate feedstocks.
- Optimizing Energy Output:
  - Select best-suited feedstocks
  - Design advanced AD features
  - Optimize Recipe Management
- Creative Permitting Approach:
  - Utilize innovative designs to minimize project costs while meeting permit requirements.

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Typical AD Feedstock Relative Energy Potentials:

- Cow Manure including feed waste (~12% TS)= **1X**
- Liquid Food Waste including yogurt and cheese whey and food processing waste (3% to 5% TS)= **0.7X to 3X**
- Brewery Waste including high strength liquid waste and spent grain (6% to 25% TS)= **3X to 15X**
- Cafeteria Food Waste (10% to 25% TS)= **6X to 10X**
- Ice Cream Waste (20% to 35% TS)= **7X to 20X**
- Semi-Solid Food Waste Fruits & vegetables & de-packaged SSO and FOG (15% to 30% TS)= **9X to 12X**
- Glycerin Bio-Diesel By-Product (35% to 75% TS)= **40X to 80X** [Be careful to not add too much and too quickly!]

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Other AD Feedstock Relative Energy Potentials:

- Domestic Human Waste Derived:
  - Wastewater Sludge (~6% TS)= **1X**
  - Wastewater Sludge Cake (20% to 30% TS)= **3X to 5X**
  - Septage (1% to 3% TS)= **0.3X to 1X**

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Extra Energy With Select Mixed Feedstocks:

- Note that cow manure and wastewater sludge (and even sludge cake) have limited energy potential, as shown above.
- As stated above, this is due the fact that the manure has been digested in the cow's four stomachs and the wastewater has been digested in our digestive tracks.
- Since they have limited energy potential, I consider these materials to be "kindling".
- There is much more potential energy by combining these with other select feedstocks.
- However, care needs to be taken to maximize digester output without undue risk to consistent operation.

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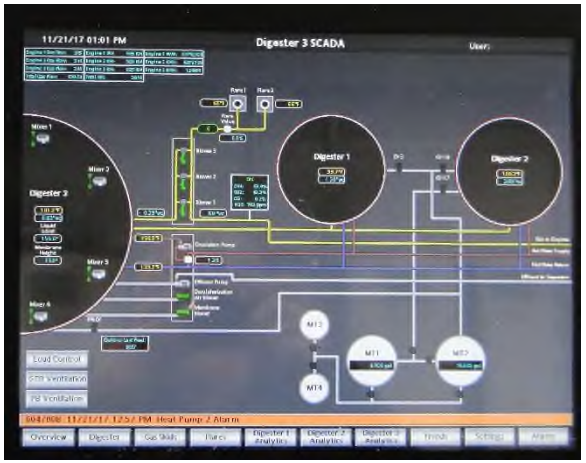

Extra Energy With Advanced AD Features:

- Receiving Systems-
  - Manure or Sludge and Other Feedstocks- Separate Receiving Tanks with mixing, chopping/slurrying systems and pre-heating.
  - Separate tank(s) for higher energy feedstocks.
- Feedstock Feeding Systems- Batch-controlled pumps suitable for the respective feedstocks.
- AD Tanks- With insulation, heating and timed, adjustable mixers.
- Desulphurization/Gas Cleaning- Maintain H_2S, Struvite and Siloxane levels below the CHP's allowed limits.
- Intergrated Controls- PLC & SCADA with remote access.

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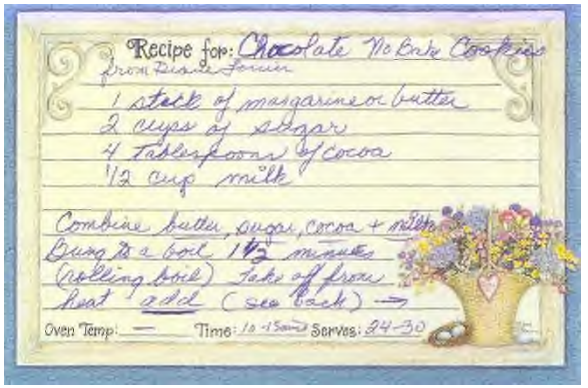
Extra Energy With Optimum Recipe Management:

- Baseline Materials- Manure or wastewater sludge form the basis for the recipe.
- Select Best-Suited Feedstocks & Recipe Management- Relative energy, %TS, %VS, organic fraction, COD, pH
- Operating Factors To Consider- Temperature, pH, VFA/TA ratio, ammonia toxicity, foaming, etc.
- Bacteria Like Consistency (Temperature, pH)- But also prefer consistent energy level +5% to 10% per day.
- Major Changes in Energy Potential- Over 2 to 4 weeks.
- Overfeeding Problems- Bacteria can get a “sugar high and crash”, resulting in significantly decreased output.
- Monitor & Adjust- Monitor the key factors and adjust the feed rates/recipe to maximize the energy output.



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1+1=3: Sample Farm AD System:

- Baseline Materials-
  - Manure from 1,000 cows @ 25,000 gpd (80%)
  - FOG/Food Waste @ 35 tons/day (20%)
- Theoretical Yield (Individually)-
  - 80% Cow Manure (0.80 x 1X= 0.8Y) [110 kW]
  - 20% FOG/Food Waste (0.20 x 12X= 2.4Y) [330kW]
  - Total 0.8Y + 2.4Y= *3.2Y* [**Total=** 110 kW + 330 kW= **440 kW**]
- Actual Yield (Combined)-
  - Cow Manure= 240 kW
  - FOG/Food Waste= 825 kW
  - **Total=** 3.2Y x 1,065 kW/440 kW= *7.75Y* **[1,065 kW]**
- Similar Results With WWTF Sludge-
  - Note: WWTF sludge + mixed feedstocks can have similar results.

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Summary

- Typical AD Feedstock Relative Energy: Use best-suited available feedstocks.
- Extra Energy With Select Mixed Feedstocks: Optimize the mixing and pre-processing of feedstocks.
- Extra Energy With Advanced AD Features: Design an AD system with advanced AD features to take full advantage of the mixed feedstocks.
- Extra Energy With Optimum Recipe Management: Monitor key factors and optimize the feedstock feed rates/recipe to maximize the energy output.

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