Assessment of Coordinated Anaerobic Digestion of Dairy Manure

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Educational Webcast Series
August 11, 2017

Overview

• What is coordinated (centralized) management?
• Why consider cooperative digestion?
• Research questions
• Methodology
• Results and discussion
• Conclusions

What is centralized manure management?

Multiple independent producers collaborating on one or more aspects of manure processing/conversion/end-use

Pros:
• Economies of scale (cost per cow ↓)
• Higher participation in advanced processing

Cons:
• Logistical challenges
• Process sensitive to all parties involved

The archived presentation is available at:
http://articles.extension.org/pages/21819/chronological-webcast-archive
Research questions

1) What parameters control profitability of centralized digesters?
2) Does centralization offer an economic advantage to AD systems?
3) Are there any general rules that could be deduced regarding centralization digestion?

Study areas

Two regions
A. Upper Yahara, Dane County, WI
B. Kewaunee County, WI

Farm data
- Location (coordinates)
- Number of lactating cows
- Milk production

Farms spatial distribution

State of Wisconsin, USA

N_{farm} = 156 farms, N_{cows(A)} = 38,851 cows
N_{farm} = 151 farms, N_{cows(B)} = 46,557 cows
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**Key process parameters**

- **Source**
  - Capacity
  - Location
  - Quality

- **Process**
  - Conversion efficiency
  - Parasitic load (elect./therm.)
  - Generator eff. (elect./therm.)

- **Economic**
  - Capital
  - Cost share
  - Electricity price
  - Heat price
  - GHG credit
  - Renewables credit

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**Optimization in livestock waste management**

**Approach**

1. Use existing knowledge to generate values of the different parameters
2. Use mathematical optimization tools to determine optimal system in each case
3. Use statistical/graphical tools to analyze the optimal solutions

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**Optimization in livestock waste management**

**Approach**

- **Sampling**
  - Herd locations
  - Herd sizes
  - Milk production

- **Monte Carlo Simulations**

- **System parameters**
  - Source, Process, Economic

- **Optimization**

- **Analysis**

  1. Net Present Values
  2. Participating herds
Sampled model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure biomethane potential</td>
<td>2.9 – 4.9 cu.ft. CH4/lb VS</td>
</tr>
<tr>
<td>Digester efficiency</td>
<td>77 – 94 %</td>
</tr>
<tr>
<td>Generator efficiency (elect.)</td>
<td>27 – 33 %</td>
</tr>
<tr>
<td>Thermal recovery</td>
<td>27 – 33 %</td>
</tr>
<tr>
<td>Parasitic heating/electric load</td>
<td>23 – 28 %</td>
</tr>
<tr>
<td>Digester CAPEX</td>
<td>550 – 677 $/Cow (intercept = $355K)</td>
</tr>
<tr>
<td>Cost share</td>
<td>27 – 33 % of CAPEX</td>
</tr>
<tr>
<td>Electric energy sale price</td>
<td>0.05 – 0.10 $/kWh</td>
</tr>
<tr>
<td>GHG reduction credit</td>
<td>1 – 10 $/tCO2e</td>
</tr>
<tr>
<td>Renewable energy credits</td>
<td>1 – 10 $/REC (1 REC = 1 MWh)</td>
</tr>
<tr>
<td>Thermal energy price</td>
<td>2 – 3 $/MMBtu</td>
</tr>
</tbody>
</table>

Fixed model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>8 %</td>
</tr>
<tr>
<td>Project life</td>
<td>20 Years</td>
</tr>
<tr>
<td>Transportation cost (A)</td>
<td>2.0 $/ton</td>
</tr>
<tr>
<td>Transportation cost (B)</td>
<td>0.30 $/ton-mi</td>
</tr>
<tr>
<td>Feeding efficiency</td>
<td>1.50 lb. FCM/lb. DM</td>
</tr>
<tr>
<td>Dietary crude protein (%DM)</td>
<td>18 %</td>
</tr>
<tr>
<td>Dietary neutral detergent fiber (%DM)</td>
<td>36 %</td>
</tr>
<tr>
<td>Labor compensation</td>
<td>25 $/hr.</td>
</tr>
<tr>
<td>Full-time equivalent (FTE)</td>
<td>1.0 (-)</td>
</tr>
</tbody>
</table>

Problem size

Number of optimization runs

= study areas * objectives * parameters sampling events

= 2 * 2 * 1,000 = 4,000 optimization runs

In each run, the optimization solver:
1. iterates over thousands of possible solutions
2. selects the ideal solution that maximizes the objective function (i.e., profitability, or technology adoption)
Results

1. Regional differences
   - NPV > 0 (profitability) probability
   - Parameter effect
   - NPV per cow
   - Breakdown of revenue and operating costs

2. Sub-regional analysis (decision tool)
   - Ranking criteria
   - Ranking diagrams

Results

1. Regional differences

Optimization decisions for dairy manure digestion projects in N = 1,000
Results

Sub-regional analysis (decision tool)

1. Ranking of farm $j$ digester

   \[ \frac{\text{probability of a digester in farm } j}{\text{highest probability of digester construction on any farm}} \]

   \[(0 \sim 1)\]

<table>
<thead>
<tr>
<th>Farm ID</th>
<th>Probability</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>14.0%</td>
</tr>
<tr>
<td>2</td>
<td>143</td>
<td>100.0%</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1.4%</td>
</tr>
<tr>
<td>4</td>
<td>71</td>
<td>49.7%</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>8.4%</td>
</tr>
</tbody>
</table>

Results

Sub-regional analysis (decision tool)

2. Ranking of farm $j$ hauling to digester $i$

   \[ \frac{\text{probability of farm } j \text{ hauling manure to digester } i}{\text{highest probability of any farm participating in digester } i} \]

   \[(0 \sim 1)\]

   (Image of a bar chart or graph showing operating cost and revenue for different farms and digesters.)
Conclusions

• Profitability of dairy digesters for electricity is not there yet under current electricity markets.
• Profitability of cooperative dairy digesters are driven by herds size and spatial distribution.
• Both individual and cooperative digesters were sited at the largest herds.
• In both study areas, cooperative dairy digesters had the highest net present value (NPV) for digester projects.
Acknowledgments

- USDA National Institute of Food and Agriculture (USDA-NIFA BRDI Grant No. 2012-10006-19423)
- Brian Langolf, Dir. Of Biogas Systems and Research Development, UW-Oshkosh
- Part of this work is based on a study funded by Dane County, Wisconsin under Award Number 12486

Questions?

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