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Take Home Points
- Manure-based anaerobic digesters provide more value to society than the current revenue streams provide
- Numbers provided are not absolutes – lots of variance at the farm level → focus on trends
- More work is needed including to communicate the values and lobby for change

Talk Outline
- Brief summary of anaerobic digestion in NYS
- Proposed → enacted changes in NYS energy policy and opportunity for value for NYS farms
- Quantification of greenhouse gas emissions for NYS anaerobic digester systems
- Value of greenhouse gas reductions using EPA Social Cost of Carbon

The archived presentation is available at:
http://articles.extension.org/pages/21819/chronological-webcast-archive
About 50,000 Dairy Farms in the US and under 100 intensively managed anaerobic digestion systems.
Total Annual Economic Cost or Economic Benefit Analysis

\[ \sum \text{Total Annual Costs} - \sum \text{Total Annual Benefits} \]
Greenhouses and Dairy Manure Based Anaerobic Digestion: Quantifying Energy Synergies

Anaerobic Digestion Impact NYS Goals (Appendix A)

- Clean Water (CAFO Storage of Manure)
- Renewable Energy
- GHG Reduction
- Organic Waste Reduction in Landfills
- Nutrient Recycling
- Improve Upstate Rural Economy
- Support Dairy (Yogurt) Industry
Changes in NYS → Opportunities for Dairy Manure-Based Anaerobic Digestion??

- Dec. 2, 2015 – Governor Cuomo directed the Department of Public Service CEO to immediately establish a Clean Energy Standard for the State
- State Energy Plan: Renewable Energy 50% by 2030
- GHG Reduction: 40% by 2030 (from 1990 levels)
- GHG Reduction: 80% by 2050
- Clean Energy Standard to be presented to the PSC by June 2016

Future of Energy

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Approach Used

∑Baseline GHG Emissions – ∑ADS Implications on GHG Emissions

Baseline Condition

Base condition – Fossil fuels used for electricity

\[ 1,100 \text{ kWh yr}^{-1} \text{ (typ. NY dairy (Shelton & Gosch, 2012))} \times 0.000526 \text{ MT CO}_2\text{e kWh}^{-1} \text{ (typ. NY energy prod. (PSC, 2016))} = 0.58 \text{ MT CO}_2\text{e yr}^{-1} \]
Base condition —
CH$_4$ from manure storage
IPPC Tier 2 method \textsuperscript{(USDA 2014)}

\[
\text{ECH}_4 = \text{VS} \times B_s \times 0.67 \times \left(\frac{\text{MCF}}{100}\right)
\]

\[
\text{ECH}_4 = \text{Mass of CH}_4 \text{ emissions (kg CH}_4 \text{ cow}^{-1} \text{ d}^{-1})
\]

\[
\text{VS} = \text{Mass of volatile solids in manure (kg cow}^{-1} \text{ d}^{-1})
\]

\[
B_s = \text{Max. vol. of CH}_4 \text{ producing capacity for manure (m}^3 \text{ CH}_4 \text{ kg}^{-1} \text{ VS})
\]

\[
0.67 = \text{Conversion factor for m}^3 \text{ CH}_4 \text{ to kg CH}_4
\]

\[
\text{MCF} = \text{CH}_4 \text{ conversion factor for the manure management system (IPCC, 2006)}
\]

\[
\text{ECH}_4 = 38 \text{ kg CH}_4 \text{ cow}^{-1} 6 \text{ mo}^{-1} \text{ (winter), 79 kg CH}_4 \text{ cow}^{-1} 6 \text{ mo}^{-1} \text{ (summer)}
\]

\[
\text{34 CO}_2/\text{CH}_4 = \text{GWP factor for CH}_4 \text{ (100yr.)}
\]

\[
\approx 4 \text{ MT CO}_2/\text{e yr}^{-1}
\]

---

Base condition —
N$_2$O from manure storage
IPPC Tier 2 method \textsuperscript{(USDA 2014)}

\[
\text{CO}_2\text{eq} = 298 \text{ CO}_2/\text{N}_2\text{O GWP} \times \text{EF}_3 \times N \times 44 \text{ N}_2\text{O}/28 \text{ N}_2\text{O-N}
\]

\[
298 \text{ CO}_2/\text{N}_2\text{O} = \text{GWP factor for N}_2\text{O}
\]

\[
\text{EF}_3 = \text{Emission Factor for N}_2\text{O-N from manure mgmt.}
\]

\[
= 0.005 \text{ [long-term slurry storage w/ crust (EPA, 2009)]}
\]

\[
N = \text{kg N excreted cow}^{-1} \text{ d}^{-1}
\]

\[
= 0.45 \text{ kg cow}^{-1} \text{ d}^{-1} \text{ (ASABE, 2005)}
\]

\[
= 0.38 \text{ MT CO}_2\text{e cow}^{-1} \text{ yr}^{-1}
\]

---

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\]

\[
\sum \text{E}_{FF} + \text{E}_{CH}_4 + \text{E}_{N2O} = 4.96 \text{ MT CO}_2\text{e/cow-yr}
\]
AD system scenarios

<table>
<thead>
<tr>
<th>Variables</th>
<th>Conservative</th>
<th>Achievable</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaks (% CH₄)</td>
<td>10</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Flare Efficiency (%)</td>
<td>90</td>
<td>99</td>
<td>96</td>
</tr>
<tr>
<td>Capacity Factor (Novel)</td>
<td>0.85</td>
<td>0.97</td>
<td>0.95</td>
</tr>
<tr>
<td>Engine efficiency (%)</td>
<td>38</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td>Parasitic load (ann cow⁻¹yr⁻¹)</td>
<td>0.30</td>
<td>0.07</td>
<td>0.18</td>
</tr>
<tr>
<td>Eff. Biodegradability (%)</td>
<td>70</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>VS after SLS (%)</td>
<td>60</td>
<td>20</td>
<td>50</td>
</tr>
</tbody>
</table>

Conservative: AD under normal management with no emphasis on GHG control
Achievable: AD under excellent management with an emphasis on GHG control
Typical: AD under normal management with an emphasis on GHG Control and an E value

ADG System with Solid-Liquid Separation

(MT CO₂e cow⁻¹ yr⁻¹ unless otherwise noted)

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Typical AD System Summary

<table>
<thead>
<tr>
<th>Variables</th>
<th>Typical</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuel avoided (net)</td>
<td>0.99</td>
<td>MT CO₂e cow⁻¹ yr⁻¹</td>
</tr>
<tr>
<td>Engine unburnt CH₄</td>
<td>3.1E⁻³</td>
<td>MT CO₂e cow⁻¹ yr⁻¹</td>
</tr>
<tr>
<td>Flare Unburnt CH₄</td>
<td>0.03</td>
<td>MT CO₂e cow⁻¹ yr⁻¹</td>
</tr>
<tr>
<td>AD system leaks</td>
<td>0.14</td>
<td>MT CO₂e cow⁻¹ yr⁻¹</td>
</tr>
<tr>
<td>Long-term Storage CH₄ emissions</td>
<td>1.87</td>
<td>MT CO₂e cow⁻¹ yr⁻¹</td>
</tr>
</tbody>
</table>

AD System Net Total: 1.06 MT CO₂e cow⁻¹ yr⁻¹

Baseline: 4.96 MT CO₂e cow⁻¹ yr⁻¹

Reduction in CO₂e: 3.90 MT CO₂e cow⁻¹ yr⁻¹

Baseline – AD System = 4.96 – 1.06 = 3.9 MT CO₂e/cow-yr

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Basis of Calculating Social Cost of Carbon Saved for Manure-based ADG Systems

- Fossil fuel avoided:
  - ((Total kWh-Parasitic kWh) x 0.000703 MT CO₂eq. per kWh)
  - Parasitic electrical energy accounted for - electrical energy specifically used to operate an ADG system
  - 0.000526 MT CO₂eq. per kWh (NYS specific value)
- SCC Saved = $47.82 /MT CO₂eq. x (Base Condition - Σ(Losses) + Fossil fuel avoided)

3.9 MT CO₂e/cow-yr x $47.82/MT CO₂e = $186/cow-yr
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- Numbers provided are not absolutes—lots of variance at the farm level → focus on trends.
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www.manuremanagement.cornell.edu
https://prodairy.cals.cornell.edu/facilities-engineering