Anaerobic Digestion, Nutrient Recovery and Co-Product Development

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Background
• 8 AD installations, 6.0 MW installed capacity
• Two Dairy Sectors—Whatcom County in NW and Yakima Basin in Central WA
• Puget Sound Electric in NW and Pacific Power in Central—varied PPA arrangements, both decreasing
• All but one mesophilic, mixed-plug flow design by DVO/Andgar
Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington

Reports of excessive nitrate levels in well water in both dairy sectors in Washington State. Recently, unprecedented agreement between Washington dairy CAFOs and EPA on practices and technologies to be implemented for improved control of potential manure nutrient contaminants (US-EPA, 2013b).
Co-Products—Co-Digestion

- Multiple Co-Product CHP Model
- Co-Digestion Model

CHP model under pricing threats, co-digestion under regulatory, competition threats

CNG/RNG Model

As compared to CHP model with severely depressed prices ($0.025/Kwh), CNG/RNG model has potential for large increases in net cash flow, especially if disconnect between CNG and diesel fuel (and RINs) is leveraged via direct fuel station sales.
Nutrient Recovery

WSU AIRTRAP Approach
AIRTRAP

Use outputs of AD (excess thermal heat, increased alkalinity, increased ammonia-N, production of non-crystalline phosphate salts to yield low-input ammonia stripping, phosphorus removal and biogas scrubbing system.)

Zhao, Q., Dvorak, S., Van Loo, B., Chen, S., Frear, C. (Pending) Nutrient recovery systems and methods, USPTO, Publication number 20120118035, priority date 06/10/11.
CO₂ Stripping for pH Elevation and Ammonia Removal

Results confirm that simple aeration and subsequent CO₂ stripping leads to effective pH elevation (~9.5) and subsequent ammonia stripping (~60-70% removal)—especially at elevated temperature of around 55°C which is feasible with waste engine heat.
Chemical Equilibria Involved

\[
\text{CO}_2(\text{aq}) \quad \rightarrow \quad \text{CO}_2(\text{g})
\]

\[
\text{H}_2\text{CO}_3 \quad \rightarrow \quad \text{H}_2\text{O} + \text{CO}_2(\text{aq})
\]

\[
\text{HCO}_3^- + \text{H}_2\text{O} \quad \rightarrow \quad \text{H}_2\text{CO}_3 + \text{OH}^-
\]

\[
2\text{HCO}_3^- \quad \rightarrow \quad \text{H}_2\text{CO}_3 + \text{CO}_3^{2-}
\]

\[
\text{CO}_3^{2-} + \text{H}_2\text{O} \quad \rightarrow \quad \text{HCO}_3^- + \text{OH}^-
\]

\[
\text{NH}_3(\text{aq}) \quad \rightarrow \quad \text{NH}_3(\text{g})
\]

\[
\text{NH}_4^+ + \text{OH}^- \quad \rightarrow \quad \text{NH}_3(\text{aq}) + \text{H}_2\text{O}
\]
Aeration followed by 1-3 days of gravity settling in weir basins or much shorter use of dissolved air flotation (DAF) can reduce TP by 80%. The result is an organic solid with fertilizer dry weight values of ~2:3:1 NPK, although the does require additional drying/pelletizing for long distance marketing and sales.
Biogas Scrubbing

Effluent after aeration is high in pH, we can use this liquid as a scrubbing agent to preferentially remove H2S impurities in the biogas while simultaneously returning effluent to more appropriate pH levels suitable for fields.
Commercial Demonstration

1.5 million layer egg operation in Fort Recovery OH, USA. Produces 2.0 MW of electricity using AD, then 2,300 gallons ammonium sulfate solution (8:0:0:9) per day using WSU nutrient recovery system—treated effluent is used for dilution water to system, saving on overall water use.
Above is on-going techno-economic analysis of demonstration site at Enumclaw WA. Numbers for nutrient recovery system only although it resides within AD project enterprise. Recovery is assumed to be 50% of ammonia-N, although actual performance varies due to higher than design flow rate. Dewatering and actual product pricing/revenue are on-going and reflective of continued market analysis/opportunities across the US.

Models, markets site specific, not mature—much work needed here.

<table>
<thead>
<tr>
<th>Capital (50,000 gallons/day)</th>
<th>$689,000</th>
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</thead>
<tbody>
<tr>
<td>Expenses</td>
<td>Revenue</td>
</tr>
<tr>
<td>Electricity (58 Kwh/h@ $0.06/Kwh)</td>
<td>110</td>
</tr>
<tr>
<td>Sulfuric Acid ($200/ton)</td>
<td>162</td>
</tr>
<tr>
<td>DAF Dewatering ($0.001/gallon)</td>
<td>50</td>
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<tr>
<td>O&amp;M (labor, contingency parts)</td>
<td>154</td>
</tr>
<tr>
<td>Heat (assume thermal available CHP)</td>
<td>---</td>
</tr>
<tr>
<td>Storage (assume on-site storage)</td>
<td>---</td>
</tr>
<tr>
<td>Transportation (assume near sales)</td>
<td>---</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>476</strong></td>
</tr>
</tbody>
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Value-Added Fiber

WSU research has shown that digested fiber has air and water holding capacity as well as porosity equivalent to peat moss, subsequent adjustment of pH, control of pathogens, and moisture levels while watching EC produces a product that can be as effective as peat and perhaps achieve price of peat.

Organix uses their unique modified ag-bag approach to accomplish the needed pH, moisture, pathogen and soil quality refinements to make a peat replacement that they have trademarked at RePeet.
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