Biogas Use in Industrial Anaerobic Wastewater Treatment

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Anaerobic Treatment

Waste + Heat (35°C/55°C)

- 90% COD Removal
- Endothermic

Low COD Effluent +

Biogas (65% CH₄ + 35% CO₂)

- Slow Growing Bugs...
- No Sludge, COD to Biogas

Energy Costs

Larger Reactors
The Buswell Equation

\[ C_nH_aO_b + \left( n \frac{a}{4} \frac{b}{2} \right) xH_2O \rightarrow \left( \frac{n}{2} \frac{a}{8} + \frac{b}{4} \right) xCO_2 + \left( \frac{a}{8} \frac{n}{2} \frac{b}{4} \right) xCH_4 \]

Buswell & Mueller (1952)
How Much Biogas Can I Get?

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 \]

192g COD

\[ C_6H_{12}O_6 \rightarrow 3CH_4 + 3CO_2 \]

3x22.4=67.2 litres/mol

\[ \frac{1000}{192} \times (67.2) = 0.35m^3 / kg \text{ COD} \]
COD Density

Low Strength

High Strength
## What is Biogas Worth?

<table>
<thead>
<tr>
<th>Fuel</th>
<th>MJ/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Gas</td>
<td>16.7-18.5</td>
</tr>
<tr>
<td>Biogas</td>
<td>20-26</td>
</tr>
<tr>
<td>Methane</td>
<td>34-38.6</td>
</tr>
<tr>
<td>Propane</td>
<td>86-94</td>
</tr>
<tr>
<td>Butane</td>
<td>109-118</td>
</tr>
</tbody>
</table>
Cogeneration from Biogas
Electricity or Boiler Fuel?

Cogeneration

- 33% electricity
- 50% free heat!
- 17% waste heat

Boiler Use

- 25-40% hot water
- 60-75% waste heat
Comparison of Hot and Cold Climate Applications

- COD (mg/l)
- Biogas Revenue (£/y)
- UK (5°C)
- India (35°C)

CHP
Boiler
Micro-Turbines
Micro-Turbines
CHP sets
Flare
Pilot Plant
Flame Trap
## How Much Electricity Can I Get?

### Effluent Flow Rate = 1000 m$^3$/d

<table>
<thead>
<tr>
<th>COD (mg/l)</th>
<th>100</th>
<th>1,000</th>
<th>5,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas (m³/d)</td>
<td>48</td>
<td>485</td>
<td>2,423</td>
</tr>
<tr>
<td>Energy (MJ/d)</td>
<td>1,071</td>
<td>10,710</td>
<td>53,550</td>
</tr>
<tr>
<td>Electricity (kWe)</td>
<td>4</td>
<td>40</td>
<td>200</td>
</tr>
</tbody>
</table>

### Annual Value £/year:

<table>
<thead>
<tr>
<th>Electricity Value</th>
<th>1,737</th>
<th>17,374</th>
<th>86,900</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Value</td>
<td>926</td>
<td>9,263</td>
<td>46,320</td>
</tr>
</tbody>
</table>

### Total Cogeneration

<table>
<thead>
<tr>
<th></th>
<th>2,663</th>
<th>26,640</th>
<th>133,220</th>
</tr>
</thead>
</table>

### Total Boiler

|                     | 1,853 | 18,530 | 92,634  |
Hall & Woodhouse Limited
Submerged Combustion

Submerged Combustion

Boiler Use

99% hot water

25-40% waste heat

60-75%
Submerged Combustion

Diagram showing air and biogas entering a digester, with exhaust and venturi indicated.
The End