BIOMETHANE AS AN OPTION FOR ON-FARM ENERGY PRODUCTION

Norma McDonald

Organic Waste Systems

OWS COMPANY PROFILE

- DRANCO TECHNOLOGY DEVELOPED IN 1983
- OWS CREATED IN 1988
- SALES: $25-35 MILLION PER YEAR
- 80 PEOPLE

SUBSIDIARIES
- DRANCO NV (BELGIUM): operating and investment company (owns 52% of Nüstedt plant)
- OWS INC (Dayton, Ohio, USA since 1992; integrated Phase 3 Renewables 9/2009)
- BES GMBH (GERMANY, since 2008)

ACTIVITIES
- DESIGN & CONSTRUCTION OF ANAEROBIC DIGESTION PLANTS FOR SOLID AND SEMISOLID ORGANICS
- BIOGAS CONSULTANCY & SUPPORT
- BIODEGRADATION TESTING AND WASTE MANAGEMENT CONSULTANCY

DESIGN AND CONSTRUCTION OF AD PLANTS

27 FULL-SCALE PLANTS ON:
- FOOD/BIOWASTE: 14 DRANCO PLANTS
- RESIDUAL/MIXED WASTE: 9 DRANCO PLANTS
- ENERGY CROPS: 1 DRANCO-FARM PLANT (S/U 2006)
- ENERGY CROPS/FOOD WASTE: 3 WET AD PLANTS (S/U 2008)
- MANURE & CO-FEEDS: 3 WET AD PLANTS (S/U 2005-6)

OWS RECENTLY SELECTED FOR NEW SITES:
- YORK (UK)
- NETHERLANDS
- LA AREA (US)
- IOWA (US)
- HONG KONG
- ST PAUL (US)
- BOSTON (US)
- INDIANA (US)

OPTIONS FOR USE OF BIOGAS

- BIOGAS
- ELECTRICITY FOR FARM USE & GRID
- WHEELING POWER TO LOCAL BUSINESSES
- TIE INTO GAS LINES
- CBM/LBM
- FLARE

WHAT VALUE CAN YOU GET FOR THE ENERGY?

- $20.00
- $30.00
- $40.00
- $50.00
- $60.00
- $70.00
- $80.00
- $90.00
- $100.00

NYMEX Natural Gas Futures Core (front month)

www.americanbiogascouncil.org
Raw Biogas Characteristics

- Pressure (less than 1 psig)
  - Common: 2 – 8 inches of water column
  - Municipal applications: up to 15 inches of water column

- Makeup by Major Constituents (assuming manure & cofeeds):
  
<table>
<thead>
<tr>
<th>Constituent</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td>55 to 65 %</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>35 to 45 %</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>0.4 to 1.2 %</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>0.0 to 0.4%</td>
</tr>
<tr>
<td>Hydrogen Sulfide (H₂S)</td>
<td>0.02 to 0.4%</td>
</tr>
</tbody>
</table>

- Saturated with water

Moisture removal

- Virtually all biogas needs free moisture removal, pipeline requires maximum removal
- Systems may use more than one step in combination
- The sequence of steps are often chosen depending on what steps are used to process the biogas. It may be ideal for the gas to be hot or cold.

Activated Carbon

- Removes both sulfides (and siloxanes if present) by adsorption
  - process is non-selective
- Activated carbon is often used for its high surface area and catalytic properties
- Can be made from wood, coconut shells, charcoal
- Performance affected by gas temp. and moisture (better on dry, cool/warm gas)

Sulfatreat

- Removes sulfides
  - Uses unique combination of iron oxides react with sulfides (H₂S) to produce iron pyrite.
  - Can be enhanced with water spray and low air injection if some oxygen is not an issue (vehicles)
  - Can be single vessel or lead/lag with 2 vessels in series, single use or regenerated
Iron Sponge
- Removes sulfides
- Iron sponge normally wood chips impregnated with iron oxide
- Upflow/Downflow of gas through packed bed of iron sponge
- Iron oxide (Fe₂O₃) reacts with sulfides (H₂S) to produce iron sulfide (Fe₂S₃) and water (H₂O)
- Must drain excess water occasionally so as not to flood the bed
- Bed can be regenerated several times before needing replacement

Biofiltration
- Removes sulfides
- Uses microbes living on a support matrix
- Microbes (and normally low level oxygen addition) consume H₂S and precipitate as elemental sulfur
- Supplied as:
  - Above grade packed towers
  - Below grade systems filled with natural media like wood chips or peat moss.
- Three major types:
  - bioscrubber
  - biofilter
  - biotrickling filter

Water Wash
- Carbon dioxide and other polar molecules have a higher solubility in water than methane. Therefore water can be used to remove contaminants from biogas.
- If the contaminants are removed or ‘scrubbed’ at high pressure (~130 psig), the water can be continuously regenerated or ‘stripped’ in a separate low pressure vessel (~3 psig).
- Produces high quality biogas (renewable natural gas)

Amine Scrubber
- Raw biogas enters and is pressurized up to 100 psig
- Biogas then flows upward through a packed column where the carbon dioxide (CO₂) and sulfides are absorbed within the counter flowing amine
- Once saturated amine leaves the scrubber and carbon dioxide is driven off to the atmosphere, the amine may be regenerated by heating it
- Produces high quality biogas (renewable natural gas)

Membrane Separation
- Membrane separates methane by retaining it ("retentate"). Undesirable molecules like carbon dioxide (CO₂), water (H₂O), sulfides (H₂S), and ammonia (NH₃) pass through the membrane ("permeate"). Produces high quality biogas (renewable natural gas).
- Polymer membranes for gas separation are typically formed into very thin, hollow fibers, clustered into modules consisting of thousands of fibers. A high pressure pump forces the gas through the fiber centers where it is collected with permeate from other fibers.
- To improve separation, multiple stages may be used. Two-stage systems are common (shown below) which increases the longevity of the membrane modules. Most installations include a desulfurization and drying step before raw biogas is sent through the membrane.

Pressure Swing Adsorption (PSA)
- An adsorbing material, either particulate (carbon molecular sieve or zeolite) or structured, preferentially adsorbs carbon dioxide and other highly adsorbed compounds at pressure (~100 psig) allowing methane to pass through.
- Conventional systems have multiple tanks for separation, with only one in service at a time. Newer technology uses rotary valves, structured beds, smaller footprints, faster cycle times.
- Produces high quality biogas (renewable natural gas)
ON-FARM BIOGAS UPGRADING BACKGROUND

• Michigan Dairy
  – 2000 milking herd @ 8-12% TS, biofiber bedding
  – 1450 heifers @ 12-20% TS, straw/stover bedding
  – 350 calves @ 20-30% TS, straw bedding

• Biogas Plant
  – Original two digesters installed in 2006 with two 350kW gensets;
  – 50% expansion in 2007 to three digestion tanks
  – Increased biogas through co-feeding of ethanol and food processing waste

• Biogas Upgrading System (BUS) to Pipeline Quality – On-farm, small-scale!
  – H2S removal, chilling, moisture knockout
  – Primary Compression, moisture knockout
  – PSA gas separation
  – Revenue and energy delivery optimization approach – electric or pipeline gas

WASTE HEAT USAGE?

- Digester heating
- Biofiber drying

PROCESS OVERVIEW – NATURAL GAS

- Compression
- Upgrading (PSA, water scrubbed, amine, membrane)
- Odorization & insertion

WASTE HEAT AVAILABILITY

- Biogas to boiler
- Compressor heat exchanger
- PSA exhaust gas

Pipeline Insertion Cost & Feasibility Determination

- Proximity to site
- Pressure: Maximum, minimum, operational fluctuation
- Gas Specifications: BTU value, H2S, CO2, O, H2O
- Odorization
- Monitoring and Metering Requirements

PROCESS OVERVIEW – NATURAL GAS

- Feedstock source
- Piping & pumping
- Digestion tanks and gas storage
- Greater moisture removal requirements for compression
- Greater H2S removal requirements to meet specs

Pipe Insertion
Cost & Feasibility Determination

- Proximity to site
- Pressure: Maximum, minimum, operational fluctuation
- Gas Specifications: BTU value, H2S, CO2, O, H2O
- Odorization
- Monitoring and Metering Requirements
**FIRST COMBINATION ON-FARM RENEWABLE ENERGY PRODUCTION FACILITY**

**SCENIC VIEW DAIRY**
FENNVILLE, MI

FEED GAS: UP TO 170 CFM
PRODUCT GAS: ~75-85 CFM
INSERTION PRESSURE: 120-150 PSIG

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**BOTTOM LINE COMPARISON**

<table>
<thead>
<tr>
<th></th>
<th>Farm Only</th>
<th>Farm + Elec</th>
<th>Farm + Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sell Energy</td>
<td>$0</td>
<td>$90,903</td>
<td>$132,703</td>
</tr>
<tr>
<td>Sell Excess Bedding/Compost</td>
<td>$7,775</td>
<td>$7,775</td>
<td>$7,775</td>
</tr>
<tr>
<td>Sell Sulfur - Fertilizer</td>
<td>$145</td>
<td>$591</td>
<td>$642</td>
</tr>
<tr>
<td>Sell Emission Credits</td>
<td>$51,619</td>
<td>$58,028</td>
<td>$56,051</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$59,539</td>
<td>$157,296</td>
<td>$197,170</td>
</tr>
</tbody>
</table>

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**BOTTOM LINE COMPARISON**

<table>
<thead>
<tr>
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<th>Farm Only</th>
<th>Farm + Elec</th>
<th>Farm + Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating Costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gen-Set O&amp;M</td>
<td>$13,140</td>
<td>$45,990</td>
<td>$13,140</td>
</tr>
<tr>
<td>PSA &amp; Compressor</td>
<td>$90,666</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to remove Sulfur</td>
<td>$1,538</td>
<td>$6,262</td>
<td>$9,393</td>
</tr>
<tr>
<td>Other Oper Costs</td>
<td>$25,000</td>
<td>$25,000</td>
<td>$25,000</td>
</tr>
<tr>
<td><strong>Total Operating Cost</strong></td>
<td>$39,678</td>
<td>$77,252</td>
<td>$138,199</td>
</tr>
</tbody>
</table>

|                      |           |             |                 |
| **Total Cost of Goods Sold** | ($153,452) | ($115,878) | ($54,931) |
| General & Administrative Expenses | $10,000   | $10,000     | $10,000        |
| Operating Income (before depr&Int) | $202,990  | $263,173    | $242,101       |

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**BOTTOM LINE COMPARISON – LOW VOLUME HURTS ROR OF PIPELINE SYSTEM**

<table>
<thead>
<tr>
<th></th>
<th>Farm Only</th>
<th>Farm + Elec</th>
<th>Farm + Pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Purchases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas Plant</td>
<td>$502,000</td>
<td>$502,000</td>
<td>$502,000</td>
</tr>
<tr>
<td>Gen-Set(s)</td>
<td>$75,000</td>
<td>$350,000</td>
<td>$75,000</td>
</tr>
<tr>
<td>Separator &amp; Building</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Boiler</td>
<td>$10,000</td>
<td>$10,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>PSA &amp; Compressor</td>
<td>$315,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical and Interconnections</td>
<td>$100,000</td>
<td>$150,000</td>
<td>$250,000</td>
</tr>
<tr>
<td>Other Capital</td>
<td>$200,000</td>
<td>$200,000</td>
<td>$200,000</td>
</tr>
<tr>
<td><strong>Total Capital Purchases</strong></td>
<td>$987,000</td>
<td>$1,312,000</td>
<td>$1,452,000</td>
</tr>
<tr>
<td>Engineering &amp; Admin</td>
<td>$49,350</td>
<td>$65,600</td>
<td>$72,600</td>
</tr>
<tr>
<td>Contingencies</td>
<td>$74,025</td>
<td>$98,400</td>
<td>$108,900</td>
</tr>
<tr>
<td><strong>Total Other Capital Costs</strong></td>
<td>$123,375</td>
<td>$164,000</td>
<td>$181,500</td>
</tr>
<tr>
<td><strong>Total Capital Cost</strong></td>
<td>$1,110,375</td>
<td>$1,476,000</td>
<td>$1,633,500</td>
</tr>
</tbody>
</table>

**After grant ROR**

- Simple payback (yrs): 4.1, 4.2, 4.3
- 10yr MIRR: 4.2, 6.2, 3.2
- ROI (yrs): 7.1, 7.4, 9.8

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**FEEDSTOCK OPTIONS TO INCREASE BIOGAS PRODUCTION**

- SYRUP
- STILLAGE
- GLYCERINE
- WASTE SILAGE
- ALGAE
- OFFAL
- YARD WASTE
- OTHER MANURES
**Assumptions:**
- Manure Volume - Gallons: 10,950,000
- Assumed Total Solid %'s: 8%
- Co-feed - Gallons: 547,500, 50% CH4 producer

<table>
<thead>
<tr>
<th>Biogas Production per year - cft</th>
<th>Biogas Flowrate - cft / minute</th>
<th>Biogas Methane per year</th>
<th>MMBTU's per year (millions)</th>
<th>MMBTU's per hour</th>
<th>CH4 PER DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>22d</td>
<td>24d</td>
<td>26d</td>
<td>----------------------------</td>
<td>------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>83,220,000</td>
<td>156</td>
<td>167</td>
<td>56,925,000</td>
<td>5.3</td>
<td>724</td>
</tr>
<tr>
<td>87,600,000</td>
<td></td>
<td></td>
<td>58,945,000</td>
<td>6.0</td>
<td>874</td>
</tr>
<tr>
<td>89,790,000</td>
<td></td>
<td></td>
<td>61,115</td>
<td>6.4</td>
<td>877</td>
</tr>
<tr>
<td>CFT CH4 PER DAY</td>
<td></td>
<td></td>
<td></td>
<td>7,320</td>
<td></td>
</tr>
<tr>
<td><strong>Add: Just 5% Co-feed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Increase of</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>175%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Energy Sales**

<table>
<thead>
<tr>
<th>Energy Sales</th>
<th>Total volume (1000 cft) of Natural Gas available for Pipeline / year</th>
<th>Potential Natural Gas Revenue Stream / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$4,000</td>
<td>$178,704</td>
</tr>
<tr>
<td>Modeled</td>
<td>$7,000</td>
<td>$312,732</td>
</tr>
<tr>
<td>High</td>
<td>$10,000</td>
<td>$446,760</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential Electricity Production / year</th>
<th>Potential Electricity Revenue Stream / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>$0.030</td>
</tr>
<tr>
<td>Modeled</td>
<td>$0.038</td>
</tr>
<tr>
<td>High</td>
<td>$0.060</td>
</tr>
</tbody>
</table>

**CAPEX INCREASES FOR HIGHER ELECTRICITY PRODUCTION – BUT PIPELINE SYSTEM STILL ADEQUATE**

<table>
<thead>
<tr>
<th>Capital Purchases</th>
<th>Farm</th>
<th>Farm + Farm +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas Plant</td>
<td>$502,000</td>
<td>$502,000</td>
</tr>
<tr>
<td>Gen-Set(s)</td>
<td>$75,000</td>
<td>$700,000</td>
</tr>
<tr>
<td>Separator &amp; Building</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Boiler</td>
<td>$10,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>PSA &amp; Compressor</td>
<td>$315,000</td>
<td></td>
</tr>
<tr>
<td>Electrical and Interconnections</td>
<td>$100,000</td>
<td>$150,000</td>
</tr>
<tr>
<td>Other Capital</td>
<td>$200,000</td>
<td>$200,000</td>
</tr>
<tr>
<td>Total Capital Purchases</td>
<td>$987,000</td>
<td>$1,662,000</td>
</tr>
<tr>
<td>Other Capital Cost</td>
<td>$49,350</td>
<td>$83,100</td>
</tr>
<tr>
<td>Contingencies</td>
<td>$74,025</td>
<td>$124,650</td>
</tr>
<tr>
<td>Total Other Capital Costs</td>
<td>$123,375</td>
<td>$207,750</td>
</tr>
<tr>
<td><strong>Total Capital Cost</strong></td>
<td>$1,110,375</td>
<td>$1,889,750</td>
</tr>
</tbody>
</table>

**BOTTOM LINE COMPARISON**

**Revenue**

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<thead>
<tr>
<th>Farm Only Revenue</th>
<th>Farm + Elec Revenue</th>
<th>Farm + Pipeline Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sell Energy</td>
<td>$0</td>
<td>$180,779</td>
</tr>
<tr>
<td>Sell Excess Bedding/Compost</td>
<td>$8,326</td>
<td>$8,326</td>
</tr>
<tr>
<td>Sell Sulfur - Fertilizer</td>
<td>$151</td>
<td>$1,090</td>
</tr>
<tr>
<td>Sell Emission Credits</td>
<td>$83,937</td>
<td>$96,681</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$92,414</td>
<td>$286,877</td>
</tr>
</tbody>
</table>

**After grant ROR**

| Simple payback (yrs) | 4.1 | 4.6 | 3.3 |
| 10yr MIRR            | 6.8% | 5.1% | 10.7% |
| ROI (yrs)            | 7.3 | 8.4 | 5.3 |

**HIGHER POTENTIAL ENERGY SALES**

<table>
<thead>
<tr>
<th>Total volume (kWh) of Electricity Production / year</th>
<th>Potential Electricity Revenue Stream / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
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<tr>
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<td>$0.038</td>
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<td>$0.060</td>
</tr>
</tbody>
</table>

**HILARIDES DAIRY**

- Lindsay, California
- 9,000 head jersey milking herd, UF to cheese plant, dried manure solids bedding
- 2000 calf hutches

**PRE-EXISTING SYSTEM**

*INITIAL SETTLING POND*

- Clay lined, emptied 3X/year
- Solids float, liquid gravity flows to covered lagoon

**TWO COVERED LAGOONS**

- Ambient, no agitation, clay lined

**4 ELECTRIC GENERATORS**

- each 125kW, minimal controls, rebuilt, >10yrs old
**RECENT EXPANSION**
- Covered 3rd lagoon, adding 18 million gallons
- Ambient, no agitation, ? Retention time
- Increased biogas capture by 70%

**CONNECTING TO EXISTING BIOGAS LINES**
- Tied into header, creating bypass loop
- Note use of S40 PVC (no freezing)

**H2S REMOVAL**
- Although PSA can remove H2S, preferable to remove H2S before upgrading — otherwise H2SO4 will form somewhere!
- Initially using lead-lag Sulfatreat vessels, used tanks, with “adaptations” to increase bed life and lower cost
- Researching additional options to lower cost further

**NEW SYSTEM, NEW BUILDING**
- Erected new 3-sided building to house BUS™, compression skid, and storage cylinders. (System could be outdoors in colder climate also with frost package added.)

**AN INTEGRATED SYSTEM APPROACH**
- Biogas Upgrading System – BUS™ A
  - Switched to shop fabrication vs. field erection
  - Performance check prior to shipment on entire system
  - Shipped to site for faster installation
  - Lower cost, higher reliability
HIGH SIDE COMPRESSION
3600 psig, ~775 GDE/day

30hp three stage reciprocating compressor fills cascade storage vessels, 70,000 scf capacity, 15 hours of production time at nameplate capacity. CH4 concentration in biogas and PSA setting determine actual throughput of upgraded biomethane.

MILK TRUCKS RUNNING ON CBM
(Compressed Biomethane)

Two new Peterbilt glider kits with Cummins-Westport natural gas engines. Fill time determined by pressure differential between CBM in storage and truck fuel tank. At max differential, fill time for 120 GDE is four minutes.

PICK UP TRUCKS TOO!
- Found six used CNG pickups on e-bay and purchased for farm use

WORLD AG EXPO 2009
http://wud.telefeed.com/#latestvideo

BY THE NUMBERS
- Fuel Value: 775 GDE per day, $2.325 @ $3/gal in CA
- CA Pollution tax avoidance of $0.04/mile, $186/day
- Truck O&M: Less, but TBD
- Carbon Credits: TBD, may take as SOx or NOx
- Advanced Biofuel Production Tax Credit: TBD
- Installed cost: $1.2 million, not including new lagoon cover or trucks. Interest & depreciation of $300/day, ignoring grant contribution
- Operating cost:
  - 90hp + 30 hp compression, about 90kW. At self-generated O&M of $0.03/kWh, $64.80/day
  - H2S removal, $200-400/day at projected bed life
  - Compressor oil, belts, plugs, TBD but budgeted for $20/day.
  - Labor, 30 minutes/day, $30/day
- Net – About $1500-$1700 per day benefit