RENEWABLE ENERGY DEVELOPMENT:

Anaerobic Digestion

Presentation by Mr. Chuck Martin, President, Bio-En Power Inc.

November, 2009
Bio-En Power Inc. is in the business of owning, operating or selling anaerobic digester facilities. BPI has spent the past few years locating viable anaerobic projects and partners. BPI has several projects at various stages of construction and/or permitting.
Traditional Organic Disposal Practices

- Landfilling
- Burning, Incineration, Combustion
- Aerobic composting
- Land Application
Advantages of Anaerobic Digestion

- Landfill Diversion
- Pathogen reduction
- Closed System Eliminates Odours
- Protects Groundwater and Surface Water Resources
- Captures Nutrients for Reuse & Reduces Use of Inorganic Fertilizers
- Reduces CH4 and CO2 GHG Emissions
- Promotes Carbon Sequestration
- Improving rural infrastructure and incomes
Methane gas production from different input substances

<table>
<thead>
<tr>
<th>Bio gas production:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nawaros</th>
<th>Dry substance</th>
<th>Gas yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TS</td>
<td>oTS</td>
</tr>
<tr>
<td></td>
<td>% of FM</td>
<td>% of TS</td>
</tr>
<tr>
<td>Liquid manure cattle</td>
<td>6%</td>
<td>80%</td>
</tr>
<tr>
<td>Liquid manure pig</td>
<td>4%</td>
<td>85%</td>
</tr>
<tr>
<td>Liquid manure fowl</td>
<td>10%</td>
<td>75%</td>
</tr>
<tr>
<td>Dung cattle</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Dung pig</td>
<td>20%</td>
<td>85%</td>
</tr>
<tr>
<td>Dung horse</td>
<td>28%</td>
<td>75%</td>
</tr>
<tr>
<td>Maize silage</td>
<td>35%</td>
<td>87%</td>
</tr>
<tr>
<td>Energy grass</td>
<td>30%</td>
<td>90%</td>
</tr>
<tr>
<td>Greenery</td>
<td>20%</td>
<td>90%</td>
</tr>
<tr>
<td>Pomace</td>
<td>40%</td>
<td>90%</td>
</tr>
<tr>
<td>Brewer grains</td>
<td>20%</td>
<td>90%</td>
</tr>
<tr>
<td>Potato</td>
<td>20%</td>
<td>85%</td>
</tr>
<tr>
<td>Whey</td>
<td>5%</td>
<td>92%</td>
</tr>
<tr>
<td>Vegetable waste</td>
<td>15%</td>
<td>85%</td>
</tr>
<tr>
<td>Slaughter waste - categories 2 and 3</td>
<td>15%</td>
<td>85%</td>
</tr>
<tr>
<td>Animal fats</td>
<td>40%</td>
<td>90%</td>
</tr>
<tr>
<td>Leftovers</td>
<td>18%</td>
<td>95%</td>
</tr>
<tr>
<td>Flotate sludge</td>
<td>25%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Biogas potential:
The biogas potential of plant substances is determined by its composition, especially by the levels of plant metabolites, carbohydrate, solids, proteins and, finally, the CHO levels (carbon, hydrogen, oxygen). Pre-treatment takes place at up to 10% dry matter and digestion at about 5% dry matter.
Agricultural Biogas Plant 500 kW

Biogas plant Japons

Location:
Japons, district of Horn, Lower Austria, Austria

Operator:
Bio-Energie aus Japons, comprising 42 farms and
36 real estate owners

Substrate used (14,250 t/year; 41 t/day):
corn silage, rye, manure

Output:
Electrical: 500 kW electricity
Thermal: 535 kW thermal

Annual energy output:
Electricity: 3.9 Mil. kWh/year
Heat: 4.2 Mil. kWh/year
Biogas: 1.8 Mil. Nm3/year

Energy provided:
Input of 3.7 Mil. kWh of electrical current per year into the public power grid of the EVN.
Year round heating of 8 public buildings, one industrial operation and 31 private households in the community of Japons.

Environment:
Through the substitution of heating oil, this means a reduction of approximately 2,200 tons per year of CO₂.
Agricultural Biogas Plant 1 MW

Biogas plant Gabersdorf

Location:
Gabersdorf, district of Leibnitz, Styria, Austria

Operator:
Bioenergie Gabersdorf GesmbH

Substrate used (30,000 t/year; 86 t/day):
corn silage, Sudan grass, sun flowers, rye-greenery

Output:
Electrical: 1,000 kW electricity
Thermal: 1,060 kW thermal

Annual energy output:
Electricity: 7.8 Mil. kWh/year
Heat: 8.4 Mil. kWh/year
Biogas: 3.5 Mil. Nm3/year

Energy provided:
Input of 7.4 Mil. kWh electrical current into the public power grid of EW Ebner. Heating of the neighbouring factory for window production.

Environment:
Through the substitution of heating oil, this means a reduction of approximately 4,400 tonnes per year of CO₂.
Industrial Biogas Plant – 2.12 MW

Biogas plant Casar, Mlajtinci

Location:
Mlajtinci, Moravske Toplice, Murska Sobota, Slovenia

Operator:
Bioplin Casar d.o.o., comprising one farm and several investors

Substrate used (86,100 t/year; 239 t/day):
corn silage, cattle manure, pig manure, slaughter waste, blood, leftovers

Output:
Electrical 2,120 kW electricity
Thermal 2,420 kW thermal

Annual energy output:
Electricity 16.9 Mil. kWh/year
Heat: 19.4 Mil. kWh/year
Biogas: 8.2 Mil. Nm3/year

Energy provided:
Input of 16.3 Mil. kWh electrical current per year into the public power grid of the Elektro Maribor.
Year round heating of two green houses (total area 2 ha).

Environment:
Through the substitution of natural gas, this means a reduction of approximately 8,200 tonnes per year of CO₂.
Agricultural Biogas Plant – 1.6 MW

Biogas plant under construction

Location:
Leaminton, Ontario

Operator:
Seacliff Energy Inc. comprising one farm and several investors

Substrate used: 55,000t/year
Sweet corn silage, manure, vegetable waste, vegetable cake, glycerol, DAF, FOG, coffee grounds

Output:
Electrical 1,600 kW electricity
Thermal 1,760 kW thermal

Annual energy output:
Electricity 12.8 Mil. kWh/year
Heat: 14.1 Mil. kWh/year
Biogas: 6.2 Mil. Nm3/year

Energy provided:
Input of 12.3 Mil. kWh electrical current per year into the public power grid of Hydro One.
Year round heating of green houses. CO2 supply to green houses.

Environment:
Through the substitution of natural gas, this means a reduction of approximately 11,200 tonnes per year of CO2.
Conceptual Elmira Facility
Proposed Industrial Biogas Plant – 2.85 MW

Biogas plant application in process

Location:
Elmira, Ontario

Operator:
Woolwich Bio-En Inc., a group of local investors

Substrate used: 45,000 t/year
Food processing organics, kitchen waste, manure, glycerol, DAF, FOG, energy crops

Output:
Electrical 2,850 kW electricity
Thermal 3,100 kW thermal

Annual energy output:
Electricity 22.8 Mil. kWh/year
Heat: 24.1 Mil. kWh/year
Biogas: 11.2 Mil. Nm³/year

Energy provided:
Input of 21.3 Mil. kWh electrical current per year into the public power grid of Waterloo North Hydro.
Supply of steam or hot water to neighbouring industry or green houses.

Environment:
Through the substitution of natural gas, this means a reduction of approximately 19,200 tonnes per year of CO₂.
Capital Cost Range

- $3 – 12 million per MW
- Depends on:
  - size (scale, storage capacities)
  - quality of input (energy density, contraries)
  - location (odour, noise, residual management)
  - local infrastructure
  - further processing of residuals (heat, fertilizer, water recycling)
Operating Cost Range

• $10 – 15 per input tonne (no deprec., admin., interest)
• Variables are similar to those under capital cost
• Tipping fees required under current FIT program pricing($30-75 per tonne typical) in order to generate a reasonable return.
Biogas Process

• Multi-step fermentation process

• Breakdown of organic substances with high molecular weight into substances of lower molecular weight until it reaches methane

• High moisture anaerobic environment

Stages of fermentation

1. Hydrolysis
2. Formation of acid
3. Formation of acetic acid
4. Formation of methane
Pre-treatment Process

• The process creates stability, ease of operation and more predictable microbial activity. It reduces the complexity of operating anaerobic digestion; including susceptibility to digester upset and foaming.
Pre-treatment Process

• Pre-treatment technology is well suited to handle high energy recipes consisting of DAF, FOG, glycerin, food waste, slaughter house waste and SSO with low levels of manure or no manure.
Pre-treatment Process

• The pre-treatment creates improved efficiency and higher gas production per unit of input. Compared to a typical European energy crop plant, pre-treatment technology produces up to 30-35% more gas with the same inputs in a shorter period of time.
Pre-treatment Process

• Pre-treatment allows flexibility of input material and fast change of menu. Every batch can be a different recipe. Need only change feed rate to main digesters, depending on energy content. Less effect on methane stage. The use of high energy feed stock is not only possible but easy to manage and control in the digester stage.
Pre-treatment Process

• Thermophilic 1st stage produces substrate that meets Class A, bio-solid pathogen reduction specifications. Reduces pathogen in livestock manure, waste water and organic wastes by up to 99%.
Public Approval Process

- M.O.E. – renewable energy approval: part V, air, noise, financial security, construction plan, emergency response plan, decommissioning plan
- O.P.A. – security deposit, FIT contract
- Utility – security deposit, connection impact assessment, cost sharing agreement
- T.S.S.A. – gas and steam
- C.F.I.A. – inputs, outputs, fertilizer
- O.M.A.F.R.A. – nutrient management
- Municipality – 2 public meetings, building permit (official plan, zoning, site plan)
- M.N.R., Conservation Authority, Aboriginal also possible
Safety, Odor and Noise Concerns

Examples of successful implementations of biogas plants

Biogas Plant Gleisdorf

170m from next residents
Input: waste water, organic waste from food production
Safety, Odor and Noise Concerns

Biogas Plant Assinger

- 70m from next residents
- With uncovered repository and uncovered input storage!
Gas Buffer:

- Double membrane buffer
- Operation on little overpressure of ~ 8mbar
- Capacity: ~ 6,000 m³ -> Heat value 120,000 MJ
- Equal to 3,200 liter fuel oil (size of 4 family homes)
Explosion Prevention

Three material diagram for ignition of methane

Operation point of the biogas plant

Far too little oxygen to reach a flammable composition!

Only place to reach an explosive composition is the cylinder of the gas engine!
Explosion Prevention

For safety reasons a zone definition is made to locate critical areas according to regulations of the European Union:

Directive 94/9/EG concerning equipment and protective systems intended for use in potentially explosive atmospheres

Zone 0: most critical
Zone 1: less critical
Zone 2: least critical

All equipment must be certified for use in the applied zone!
Explosion Prevention

1. Preventing explosive atmospheres
   - limiting the oxygen content in biogas
   - monitoring the gas composition in every step of the process

2. Elimination of possible ignition sources
   - proved and certified equipment
   - working with standards like ATEX, VEXAT, TSSA...
Fire Prevention

Fire in the transformer station
• Situated in non-critical area to gas buffer

Fire at the gas engine
• Engine room is constructed as a fire compartment
• A deflagration arrester inhibits fire in the gas pipe

Fire in the machinery hall
• Machinery hall is constructed as a fire compartment
• Situated in non-critical area

No source of ignition for fire in the gas buffer
Prevention of Toxic Gases

Biogas contains small amounts of hydrogen sulfide (H2S) and ammonia (NH3)

Ammonia in biogas:

< 50 ppm → threshold limit value 50 ppm

Hydrogen Sulfide in biogas:

through biological desulfurization and chemical precipitation the H2S content in the biogas is limited to < 200 ppm (needed to reach emission standards and prevent damage of the Gas engine).

→ damage to health only by direct inhalation of biogas
Failure Scenario 1

**Damage of a Gas Pipe:**
- Drop in pressure leads to shut down of the engines
- Alarm via mobile phone
- Biogas is detected in every room by a gas sensor and leads to shut down of every electrical device in that room
- Seeking the leaking pipe via mobile gas analysis
- No explosion because of absence of ignition source
- Separation of leaking pipe from gas system via gas valves
- Repairs done by professionals
Failure Scenario 2

Black out in the Grid – no electricity on the site:

- shut-down of the engines
- UPS (uninterruptible power supply) operates control and safety devices
- Alarm via mobile phone
- produced biogas is stored in the gas storage (capacity ~ 2h)
- standby set is activated
- if after 2h still grid black out, excess biogas is flared
- No biogas is emitted!