Anaerobic Digestion & Biogas Technology within UK Agriculture

Greenfinch Ltd
GREENFINCH LTD

- Based in Ludlow, south Shropshire.
- Specialise in anaerobic digestion.
- 8 years of R&D into the AD of food waste.
- Constructed 7 on-farm AD plants in Scotland.
- Constructed the UK’s first biowaste digester in south Shropshire.
Anaerobic Digestion is a natural biological process.

Biomass flows into a reactor maintained at 37°C, producing biogas. The biogas is then converted into biofertiliser.
AD is a 3-Product Process

Most renewable energy & bioenergy technologies do only one thing – produce energy.

Anaerobic digestion is a 3-product process:

• AD is a waste management process;
• AD is a nutrient recycling process; and
• AD is a renewable energy process.

As such it has tended to get lost in policy making.
Anaerobic Digestion Feedstock

NON-ABP

• Energy crops
• Animal slurry
• Sewage sludge

ABP

• Food processing and abattoir waste
• Source-separated biowaste
• Commercial catering waste
• Mixtures of the above
# Gas Yields

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>$m^3_{\text{CH}_4}.\text{t fresh matter}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Waste</td>
<td>66</td>
</tr>
<tr>
<td>Sewage Sludge</td>
<td>13</td>
</tr>
<tr>
<td>Cow Slurry</td>
<td>11</td>
</tr>
<tr>
<td>Pig Slurry</td>
<td>12</td>
</tr>
<tr>
<td>Wholecrop Cereal</td>
<td>126</td>
</tr>
</tbody>
</table>
## Biofuel Comparison

<table>
<thead>
<tr>
<th>Crop</th>
<th>Biofuel</th>
<th>Energy Balance GJ.ha⁻¹.y⁻¹</th>
<th>Energy Ratio (input:output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Bioethanol</td>
<td>34.67</td>
<td>1:2.3</td>
</tr>
<tr>
<td>Wheat</td>
<td>Biogas</td>
<td>68.48</td>
<td>1:3</td>
</tr>
<tr>
<td>Oilseed Rape</td>
<td>Biodiesel</td>
<td>18.25</td>
<td>1:1.8</td>
</tr>
</tbody>
</table>
Biowaste (C, N, P, K) → AD → Biofertiliser (C, N, P, K)

Biogas

$\text{CH}_4$

$\text{CO}_2$
Digestate Nutrient Values

- Nitrogen - 2.3 - 4.2 kg/tonne
- Phosphorus - 0.2 - 1.5 kg/tonne
- Potassium - 1.3 - 5.2 kg/tonne
On-Farm AD
Plants in UK
Pig Farm Digester (1970s)
Cattle Farm Digester (1980s)
Cow Slurry Digester (2004)
Pig Farm + Food Waste (2006)
Slurry is scraped into tanks under slats
Slurry is pumped from the slats by a tractor-pump.
Above-ground reception tank
Completed 80 m³ Biogas Plant
Auger Feed Systems
Anaerobic Digestion of Energy Crops
• A pan-European consortium investigating the production of biogas from agri-waste & energy crops.
Crop Digestion Trials
## Energy Crop Parameters

<table>
<thead>
<tr>
<th>Crop Variety</th>
<th>Maize</th>
<th>Ryegrass</th>
<th>WC Winter Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Yield ( t_{\text{WET}.\text{ha}^{-1}.\text{y}^{-1}} )</td>
<td>45</td>
<td>56</td>
<td>36.5</td>
</tr>
<tr>
<td>Dry Matter ( %\text{DM} )</td>
<td>30</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Organic Dry Matter ( %\text{ODM} )</td>
<td>95</td>
<td>88</td>
<td>90</td>
</tr>
<tr>
<td>ODM Yield ( t_{\text{ODM}.\text{ha}^{-1}.\text{y}^{-1}} )</td>
<td>12.8</td>
<td>9.8</td>
<td>13.1</td>
</tr>
<tr>
<td>Methane Yield ( m^3_{\text{CH}_4.\text{t}^{-1}.\text{ODM}} )</td>
<td>400</td>
<td>340</td>
<td>350</td>
</tr>
<tr>
<td>Gross Energy Yield ( \text{GJ.ha}^{-1}.\text{y}^{-1} )</td>
<td>182</td>
<td>120</td>
<td>163</td>
</tr>
<tr>
<td>Gross Energy Yield ( \text{kWf.ha}^{-1} )</td>
<td>5.8</td>
<td>3.8</td>
<td>5.2</td>
</tr>
<tr>
<td>Energy for Crop Production ( \text{GJ.ha}^{-1}.\text{y}^{-1} )</td>
<td>10</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Energy for Crop Production ( \text{kWf.ha}^{-1} )</td>
<td>0.3</td>
<td>0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Net Energy Output ( \text{GJ.ha}^{-1}.\text{y}^{-1} )</td>
<td>172</td>
<td>96</td>
<td>153</td>
</tr>
<tr>
<td>Net Energy Output ( \text{kWf.ha}^{-1} )</td>
<td>5.5</td>
<td>3.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Crop Production Cost ( \text{\text{£}.ha}^{-1}.\text{y}^{-1} )</td>
<td>£720</td>
<td>£450</td>
<td>£625</td>
</tr>
</tbody>
</table>
Energy Balance: Maize Silage

- Maize Silage: 9000 t.y⁻¹, 30% DM: 95% ODM
- 200 hectare

- Digester: 1800 m³
- Biogas: 36,600 GJ.y⁻¹, 2800 m³ CH₄.d⁻¹

- CHP: 400 kWₑ, 2000 GJ.y⁻¹, 34,600 GJ.y⁻¹
- Heat: 16,600 GJ.y⁻¹
- Electricity: 12,100 GJ.y⁻¹
- Electricity: 11,700 GJ.y⁻¹
- Heat: 1300 GJ.y⁻¹
- Heat: 15,300 GJ.y⁻¹

Electricity: 16,600 GJ.y⁻¹
Energy Balance: Maize + Cow Manure

- Maize Silage: 4500 t.y\(^{-1}\), 30% DM: 95% ODM
- 100 hectare

- 600 Cows: 17,500 t.y\(^{-1}\), 8% DM: 80% ODM

- Digester: 1250 m\(^3\), 1400 m\(^3\)\(_{CH_4}\).d\(^{-1}\), 550 m\(^3\)\(_{CH_4}\).d\(^{-1}\)

- Biogas: 25,400 GJ.y\(^{-1}\)

- CHP: 280 kW\(_e\)
  - 1000 GJ.y\(^{-1}\)
  - 24,400 GJ.y\(^{-1}\)

- Energy Balance:
  - CH\(_\text{4}\) Production: 1400 m\(^3\)\(_{CH_4}\).d\(^{-1}\)
  - Digester: 1250 m\(^3\)

- Heat:
  - 11,700 GJ.y\(^{-1}\)
  - 8500 GJ.y\(^{-1}\)

- Electricity:
  - 8200 GJ.y\(^{-1}\)
  - 8800 GJ.y\(^{-1}\)

- Total Energy:
  - 24,400 GJ.y\(^{-1}\)
  - 2900 GJ.y\(^{-1}\)
Maize Silage
4,500 t.y\(^{-1}\)
30%DM : 95%ODM

Potato Waste
8000 t.y\(^{-1}\)
25%DM : 95%ODM

Energy Balance: Maize + Potato Waste

100 hectare

Maize Silage

Digester
2300m\(^3\)

1400m\(^3\)\(_{\text{CH}_4}\).d\(^{-1}\)

Biogas 45,400 GJ.y\(^{-1}\)

1000 GJ.y\(^{-1}\)

44,400 GJ.y\(^{-1}\)

CHP
500kW\(_e\)

21,300 GJ.y\(^{-1}\)
Heat

15,500 GJ.y\(^{-1}\)
Electricity

500 GJ.y\(^{-1}\)

1900 GJ.y\(^{-1}\)

19,400 GJ.y\(^{-1}\)

2100m\(^3\)\(_{\text{CH}_4}\).d\(^{-1}\)
## Commercial Analysis

<table>
<thead>
<tr>
<th></th>
<th>Maize</th>
<th>Maize + Pigs</th>
<th>Maize + Potato</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sale of Electricity</strong> (£.y⁻¹)</td>
<td>295,000</td>
<td>205,000</td>
<td>376,000</td>
</tr>
<tr>
<td><strong>Sale of Heat</strong> (£.y⁻¹)</td>
<td>17,000</td>
<td>17,000</td>
<td>17,000</td>
</tr>
<tr>
<td><strong>TOTAL INCOME</strong> (£.y⁻¹)</td>
<td>312,000</td>
<td>222,000</td>
<td>393,000</td>
</tr>
<tr>
<td><strong>Cost of Energy Crop</strong> (£.y⁻¹)</td>
<td>144,000</td>
<td>72,000</td>
<td>72,000</td>
</tr>
<tr>
<td><strong>Cost of Labour</strong> (£.y⁻¹)</td>
<td>14,000</td>
<td>14,000</td>
<td>14,000</td>
</tr>
<tr>
<td><strong>Cost of Maintenance</strong> (£.y⁻¹)</td>
<td>57,000</td>
<td>40,000</td>
<td>74,000</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong> (£.y⁻¹)</td>
<td>215,000</td>
<td>126,000</td>
<td>160,000</td>
</tr>
<tr>
<td><strong>INCOME LESS COSTS</strong> (£.y⁻¹)</td>
<td>97,000</td>
<td>96,000</td>
<td>233,000</td>
</tr>
<tr>
<td><strong>CAPITAL COST</strong> (£)</td>
<td>800,000</td>
<td>700,000</td>
<td>900,000</td>
</tr>
<tr>
<td><strong>PAY-BACK</strong> (yrs)</td>
<td>8.2</td>
<td>7.3</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Economic Viability Depends on:

- Housed Time of Stock
- On Site Heat Use
- Electricity Use
  - On site = 11p/kWhr
  - Export to grid = 8p/kWhr
- Production of waste on site
- Use of Energy Crops
- Sale/Value of Bio-fertiliser
- Gate Fees
Permitting

- **Planning Permission:** Application to local planning authority; if waste is included it must go to county planning.
- **Waste Management License:** Application to the Environment Agency.
- **Animal By-Products Approval:** Application to State Veterinary Service if ABPs are to be processed.
- **Renewable Electricity Accreditation:** Application to Ofgem.
- **Biofertiliser Land Use Exemption:** If waste is imported application to EA.
Low-Carbon Process

- Anaerobic digestion reduces greenhouse gas emissions in 4 ways:
  - by preventing the uncontrolled emissions of CH$_4$ (22 times more powerful than CO$_2$);
  - by beneficial use of the biofertiliser in agriculture, displacing mineral fertilisers;
  - by reducing the transport of waste; and
  - by the production of renewable electricity & heat.
Conclusions

• As yet there are no grants available to help with the high capital cost, which is preventing small scale digesters from emerging.

• Co-digestion of energy crops with food waste & animal manure is becoming economic in the UK.

• The economics are improved if;
  – the electricity is used on site, for example for refrigeration;
  – there is a use for the heat;
  – if there is a market for the bio-fertiliser, on or off-site.

• We expect the first UK energy crop AD plant to be built in 2007…..