Biomass products: biogas

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Biological Research Center, Hungarian Academy of Sciences

http://biogas.hu
http://www.szbk.hu
http://biotech.szbk.u-szeged.hu
Renewable energy
Gas bubbles in ice
By far the most terrifying film you will ever see.

*an inconvenient truth*
Loosing ice so what?
Fluid Fossil Fuel Production/Demand (petroleum and natural gas)

Renewable energy sources

- Create high-quality jobs
- Rural development
- Clean the air
- Reduce dependence on foreign oil and NG
- Prevent global warming
Energy structure of Hungary

- Natural gas: 38%
- Oil: 27%
- Coal: 16%
- Nuclear: 15%
- Renewable: 4%
Bioenergy distribution in Hungary

[Map showing distribution of bioenergy sources in Hungary, with icons for forestry, agriculture, animals, food/feed, and communal areas.]
# Biomass energy sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Unit</th>
<th>Hungary</th>
</tr>
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<tbody>
<tr>
<td><strong>Theoretical potential</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy potential</td>
<td>PJ</td>
<td>942</td>
</tr>
<tr>
<td>Forest</td>
<td>%</td>
<td>12</td>
</tr>
<tr>
<td>Agriculture - plants</td>
<td>%</td>
<td>15</td>
</tr>
<tr>
<td>Agriculture - waste</td>
<td>%</td>
<td>22</td>
</tr>
<tr>
<td>Animal waste</td>
<td>%</td>
<td>4</td>
</tr>
<tr>
<td>Food/Feed waste</td>
<td>%</td>
<td>10</td>
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<tr>
<td>Household waste</td>
<td>%</td>
<td>37</td>
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</table>

| Energy                  | PJ   | 297     |
| Direct burning          | %    | 70      |
| Biogas                  | %    | 26      |
| Biodiesel               | %    | 2       |
| Bioethanol              | %    | 2       |

| Current utilization     |      |         |
| Direct burning          | %    | 98      |
| Biogas                  | %    | 1       |
| Biodiesel               | %    | 0       |
| Bioethanol              | %    | 1       |
Biogas production of 1000 inhabitants (toe)
Biomass – biogas: HU

- Total energy need in 2010: 1200-1300 PJ/yr
- Theoretical potential: 1000 PJ/yr
- Biogas potential: 150 - 300 PJ/yr
- Renewable Strategy 2010: 2.06
- Renewable Strategy 2020: 6.75
Hungary’s position will not change
Swamp gas – St Elmo’s fire - Volta

Discovery Pages
Methane

Natural gas

Fossil Fuel

Less GHG Emissions

Both Good for Air Quality!

Biogas

Renewable Fuel

Net zero or negative GHG Emissions
Biogas is the best RES

<table>
<thead>
<tr>
<th></th>
<th>NOx</th>
<th>PM</th>
<th>Global Warming</th>
<th>Foreign Policy</th>
<th>Supply</th>
<th>Purchase Cost</th>
<th>Operating Expense</th>
<th>Total</th>
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<tbody>
<tr>
<td>Natural Gas</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>-2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Biogas</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>-2</td>
<td>1</td>
<td>12</td>
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<tr>
<td>Propane</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>4</td>
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<tr>
<td>Biodiesel -- 20%</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Biodiesel -- 100%</td>
<td>-3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>-1</td>
<td>-3</td>
<td>2</td>
</tr>
<tr>
<td>Ethanol - 10%</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>Ethanol - &gt;85%</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<td>0</td>
<td>-1</td>
<td>9</td>
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<td>Low sulphur diesel</td>
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<td>1</td>
<td>1</td>
<td>-2</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
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<tr>
<td>Petro Hybrid Electric</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>2</td>
<td>7</td>
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<tr>
<td>Hydrogen ICE</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-2</td>
<td>-1</td>
<td>7</td>
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<tr>
<td>Hydrogen Fuel Cells</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>-3</td>
<td>-1</td>
<td>8</td>
</tr>
</tbody>
</table>
Biogas is the best RES

Biofuels in comparison

Range of a car with biofuels from 1 hectare arable land

- Biomethane: 67,600 km
- BtL (Biomass-to-Liquid): 64,600 km
- Rapeseed oil: 23,300 km + 17,600 km
- Biodiesel: 23,300 km + 17,600 km
- Bioethanol: 22,400 km + 14,400 km
Basic technology

Typically Single Source Feedstock e.g. Dairy, Swine or Cattle Manure

Non-Optimal Anaerobic Digestion

Manure -> Digester Gas -> Gen Set

Heat -> Boiler

Electricity

Compost
Advanced technology

Misc. Organic Waste
Optimized Anaerobic Co-Digestion
Bio-Fertilizer

Digester Gas

CHP Unit
Gas Upgrading
Small-Scale Liquefier

Biogas

Electricity & Heat
Biogas Station
NG Pipeline
LNG Tanker

Multiple Sources of Feedstock, e.g. Slaughterhouse Waste, Manure, Food Processing Waste, Organic MSW, Sewage Sludge, Crops, etc.
Gas upgrading

- Raw digester gas approx. 65% methane (CH₄) and 35% CO₂
  - Can be used to create electricity but not as a transportation fuel

- Digester gas must be upgraded to biogas quality to be used as vehicle fuel for CNG/LNG vehicles
  - > 92% methane
  - Remove H₂S, H₂O and other impurities
CO$_2$ cleaning

- Methods to remove CO$_2$ from raw digester gas
  - Water scrubbing (absorption)
    - Most widely used
  - Pressure Swing Adsorption (PSA) using activated carbon
  - Membrane separation
  - Absorption by Selexol (polyglycol ether)
  - Absorption by COOAB or other amines
    - Very low methane leakage (< 0.1%)
- Multiple simple methods to remove H$_2$S and H$_2$O
- Technologies proven and affordable in various European countries
Bottlenecks

- State should support and promote
  - Farmers cannot afford initial investment
    - Green electricity price: 8-9 Eurocent/kWh
  - State motivation schemes missing
    - EU required 3.75% green electricity production is met by biomass burning
  - Inherited social support structure

- Enforcement of environmental legislation
  - Good law, week implementation
  - Need for complex waste management

- Public perception
  - Hungarian Biogas Association
Bottlenecks - example

- Natural gas support 2006-2007: 265 billion HUF
- Renewable support: 28 billion HUF
Hungarian Biogas Association

- Coordination of activities
- Training of future experts
- Education of general public
- Lobby for better legislation and financing
Biogas – Bioethanol combination
Electricity $\eta = 33 - 40\%$

Up to 90% of the energy demand the distillery could be satisfied from Biogas

Heat $\eta = 40 - 52\%$

Biogas-CHP

Electricity $\eta = 33 - 40\%$

Waste heat

Biogas

Distiller's wash

Biogas plant

Ethanol

Grain, Corn or Potatoes as raw material of the distillery

Fertilizer
Economical results

- Advantages for the bioethanol production
  - Utilization of EtOH fermentation residue (DDGS)
  - Cheap and renewable energy
  - Fertilizer for next plant biomass cultivation
- Advantages for the biogas production
  - Local energy user = economy
  - DDGS is good substrate
- Disadvantages
  - Need to build large factory = initial investment
  - Need additional biomass for biogas
Biogas biotechnology
Biotechnologie
der Fleisch-, Fett- und Milcherzeugung
im landwirtschaftlichen Großbetriebe

für
naturwissenschaftlich gebildete Landwirte

verfaßt

von

Dipl. Ing. Karl Ereky
Direktor der Viehverwertungsorganisation ungarischer Großgrundbesitzer, Budapest.

BERLIN.
VERLAGSBUCHHANDELUNG PAUL PAREY.

1919.
Biogas formation

HYDROLYSING MICROBES
Polymer degradation:
Polysaccharides (cellulose, starch), proteins, lipids

Fermentation of monomers and oligomers:
Sugars, amino acids, simple lipids

ACETOGENIC MICROBES
Volatile fatty acids + $\text{H}_2$

METHANOGENS
$\text{CH}_4 + \text{CO}_2$
Biogas production
Microbiological bottlenecks

- Natural microbial consortia
  - Biodiversity in the fermenter
  - Various metabolic interactions, “cross talk”
  - Syntrophic and inhibitory interactions

- System optimization
  - Natural = for survival and growth
  - Not optimal for biogas production

- Engineering possibility
  - Addition of selected microbes
Challenges for biotechnology

Cattle: 2-3 days

Mesophilic: 30-60 days
Thermophylic: 15-30 days
Biogas formation

HYDROLYSING MICROBES
Polymer degradation:
Polysaccharides (cellulose, starch), proteins, lipids

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ACETOGENIC MICROBES
Volatile fatty acids + $\text{H}_2$

METHANOGENS
$\text{CH}_4 + \text{CO}_2$
Batch thermophilic biogas intensification

![Graph showing gas production over days for inoculated and control conditions.]
## Mesophilic scale up

<table>
<thead>
<tr>
<th>Waste</th>
<th>Volume (m³)</th>
<th>Biogas production (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle manure</td>
<td>0.01</td>
<td>180</td>
</tr>
<tr>
<td>Pig manure</td>
<td>0.01</td>
<td>250</td>
</tr>
<tr>
<td>Pig manure</td>
<td>1</td>
<td>220</td>
</tr>
<tr>
<td>Pig manure</td>
<td>15</td>
<td>200</td>
</tr>
<tr>
<td>Pig manure</td>
<td>250</td>
<td>220</td>
</tr>
<tr>
<td>Pig manure</td>
<td>10,000</td>
<td>180</td>
</tr>
<tr>
<td>Household solid</td>
<td>300</td>
<td>140</td>
</tr>
<tr>
<td>Waste water sludge</td>
<td>0.01</td>
<td>170</td>
</tr>
<tr>
<td>Waste water sludge</td>
<td>2,500</td>
<td>160</td>
</tr>
</tbody>
</table>
Thermophilic field demonstration: pig manure
Conclusions

- Biogas has great potential among RES.
- Combination of various bioenergy production technologies is beneficial.
- There is still a lot of possibility for technology improvement through biotechnology.
Thanks for your kind attention!