Biogas from Animal Waste and Organic Industrial Waste

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Denmark
Biogas Plants in Denmark 1973 – 2008

Under changing motivations

1973-1985
Oil crisis - domestic energy supply
Less dependency on imported fuels – especially oil

1985-1995
Reduce nutrient losses from agriculture
Renewable energy

1995-2008
Tool for green house gas reduction
Sustainability in livestock production
Biogas rests on three legs

Energy  Agriculture  Environment
Development of plants

1973-1985
Pilot and farm scale plants – not successful

From 1984 -
Centralised co digestion plants, increasingly successful

2000-2001
Many, now relatively successful, farm scale plants

Future
Centralised Co digestion plants – separation, removal or distribution of surplus manure.
Structure and Activities of the
Biogas Demonstration and Development Programmes

<table>
<thead>
<tr>
<th>PROGRAM ACTIVITIES</th>
<th>Investment grants</th>
<th>Monitoring Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>New plants received up to 40% of investment costs as a government investment grant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production data and results were registered, collected and analysed. Economic results were collected and analysed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Results were communicated to plant operators in working papers, reports and in seminars</td>
<td></td>
<td></td>
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<tr>
<td>RD&amp;D</td>
<td></td>
<td></td>
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<tr>
<td>General problem fields and special development tasks were pointed out for closer investigation</td>
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</tr>
</tbody>
</table>
Actual situation i Denmark

20 centralised plants in operation

60 farm scale plants in operation

Technically well operating

Economically viable

-but co-digestion so far very important.
Production data from centralised co-digestion plants

Animal waste treatment 1.3 mil tonnes per year
Organic industrial waste 0.3 mil tonnes per year
Energy production (2007) 1.7 PJ
Potential based on manure 20-30 PJ
Centralised Co-digestion Plant Concept

Farms

Manure

Food processing industry

Organic waste

Electricity and heat
Energy application – Danish plants

Electricity – sold to the public power grid

Heat sold to district heating systems
Biomass resources

Liquid manure – could be different

Organic waste – 0-20 %, depending on the quality

-From food processing industries.

Why is waste important?

1 tonne liquid manure 5% DM = 20 m³ biogas
1 tonne organic waste = 0 – 1000 m³ biogas

And treatment fees
Biomass used in Danish biogas plants:

- Fat/flottation sludge
- Food waste
- Fish waste
- Fruit waste
- Brewery waste
- Dairy
- Sucker industry
- Garverier
- Mucosa
- Medicin industry
- Energy crops
- Plant oil waste
- Slaughter waste
- Other manure
- Cattle manure
- Pig manure
- Pig manure
Manure application

(In Denmark)

Spread in the fields and used as a fertiliser nowadays, normally by using trailing hoses.
What's in it for the farmers?

In general, it makes it easier to comply with environmental restrictions

- 9 months storage capacity
- Maximum amounts of manure to be spread per hectare

The AD plant company provides

- The needed storage capacity
- Redistribution or disposal of surplus manure

Farmers gain cost savings in

- Manure storage
- Manure transport
- Manure spreading
- Fertiliser purchase

-In Denmark, 0,7 € per tonne manure treated
# Fertilizer plan for nitrogen for 1 ha grass

<table>
<thead>
<tr>
<th>Per hectare</th>
<th>Case 1: Cattle slurry</th>
<th>Case 2: Digested slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-requirement, kg</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>N in slurry, kg total</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>N-utilization, %</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>N in slurry, utilized, kg</td>
<td>68</td>
<td>102</td>
</tr>
<tr>
<td>Mineral fertilizer</td>
<td>182</td>
<td>148</td>
</tr>
<tr>
<td>Saved, kg</td>
<td>-</td>
<td>34</td>
</tr>
<tr>
<td>Saved, €</td>
<td>-</td>
<td>20</td>
</tr>
</tbody>
</table>
Digestion reduces odour

Principles for spreading of odour:

- Wind-direction
- Untreated slurry
- Digested slurry

- 5 minutes
- 12 hours
What's in it for food processing industries

- Easy compliance with requirements on waste recycling
- Cheap and easy way to dispose waste
- Improved image
- Environmental friendliness can be used as argument for marketing purposes
- In Denmark, approx. 17 € per tonne waste
What's in it for energy consumers

- Energy from renewable source at competitive prices
- The satisfaction of environmental energy consumption
What's in it for the businessman

- Market options for green electricity trade
- Market options for heat from renewable sources
- Construction and operation of extensive technical facilities
- Market for financing and insurance of extensive technical facilities.
What's in it for local society

-New business, new local activity

-New jobs, 1-10 directly associated to the plant

-Related business – who knows ???

-Environmental improvements

  -Fresh water systems
  -Improved hygienic standards due to sanitation of manure
  -Less odour nuisances.
What's in it for society in general

- Contribution to meet national environmental targets
- Implementation of green heat and electricity
- Green House Gas reduction
  - CO2
  - CH4
  - N2O
- Increased waste recycling
- Improved standards in fresh water systems
- Improved hygienic standards
- Rural development
  - New business, new activity in rural areas
  - New jobs
Green House Gas emission, with and without biogas production

Emission of GreenHouse Gas

CH$_4$ emission, CO$_2$ eqv. per Livestock unit

0
500
1000
1500
2000

Biogas

Reference

Pig
Cattle

Biogas

Housing

Biogas

Store

Biogas

Housing
### Economic situation in Danish centralised biogas plants end 2001

<table>
<thead>
<tr>
<th>Name</th>
<th>Year of construction</th>
<th>Acceptable</th>
<th>Balance</th>
<th>Under pressure</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Hjermitslev</td>
<td>1984</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegger</td>
<td>1985</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revninge</td>
<td>1989</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Ribe</td>
<td>1990</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Lintrup</td>
<td>1990</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lemvig</td>
<td>1992</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hashøj</td>
<td>1994</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorsø</td>
<td>1994</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Århus Nord</td>
<td>1995</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filskov</td>
<td>1995</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Blåbjerg</td>
<td>1996</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Snertinge</td>
<td>1996</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Blåhøj</td>
<td>1997</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaarst-Fjellerad</td>
<td>1997</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Nysted</td>
<td>1998</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
**Investment and treatment costs, 2000 prices.**

<table>
<thead>
<tr>
<th></th>
<th>Per day treatment capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment costs:</strong></td>
<td>300 m$^3$</td>
</tr>
<tr>
<td>- Biogas Plant</td>
<td>5,5 mil €</td>
</tr>
<tr>
<td>- Vehicles</td>
<td>0,4 mil €</td>
</tr>
<tr>
<td><strong>Inv. Costs per m$^3$ biomass treated per year</strong></td>
<td>55 €/m$^3$</td>
</tr>
<tr>
<td><strong>Treatment costs per m$^3$ biomass treated per year</strong></td>
<td></td>
</tr>
<tr>
<td>- Transport</td>
<td>2,2 €/m$^3$</td>
</tr>
<tr>
<td>- Biogas Plant</td>
<td>7,1 €/m$^3$</td>
</tr>
</tbody>
</table>
Break even levels of waste admixture and biogas yields

<table>
<thead>
<tr>
<th>Per day treatment capacity, m$^3$ biomass/day</th>
<th>300 m$^3$/day</th>
<th>550 m$^3$/day</th>
<th>800 m$^3$/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break even level of waste admixture</td>
<td>21 %</td>
<td>13 %</td>
<td>10 %</td>
</tr>
<tr>
<td>m$^3$ biogas/ m$^3$ biomass</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break even biogas yield</td>
<td>34</td>
<td>27</td>
<td>25</td>
</tr>
</tbody>
</table>

Key preconditions:
- Gasyield from manure 22 m$^3$ biogas/m$^3$
- Gasyield from waste 75 m$^3$ biogas/m$^3$
- Gate fee (receipt of waste) 50 DKK/m$^3$ waste
- Biogas sales price 2 DKK/m$^3$ biogas
Socio-economic effects of the CAD plant

Consequences for:

- Agriculture
- Energy-sector
- Industry
- Environment

Other aspects: Security of energy supply, ..
Monetised Externalities

**Biogas plant of treatment capacity:**

*550 ton/day  (20% waste)*

### Monetised externalities:

**Socio-economic value per ton biomass**

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Monetised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage, handling and distribution of liquid manure:</td>
<td></td>
</tr>
<tr>
<td>Storage savings for liquid manure</td>
<td>0.13 EUR/ton liquid manure</td>
</tr>
<tr>
<td>Transport savings in agriculture</td>
<td>0.07 EUR/ton liquid manure</td>
</tr>
<tr>
<td>Value of improved manurial value (NPK)</td>
<td>0.73 EUR/ton degassed</td>
</tr>
<tr>
<td>Value of reduced obnoxious smells</td>
<td>0.67 EUR/ton liquid manure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industry</th>
<th>Monetised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings related to organic waste treatment</td>
<td>16.82 EUR/ton org. waste</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environment</th>
<th>Monetised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of GHG reduction (CO$_2$, CH$_4$, N$_2$O-reduction)</td>
<td>3.01 EUR/ton degassed</td>
</tr>
<tr>
<td>Value of reduced N-eutrophication of ground water:</td>
<td></td>
</tr>
<tr>
<td>Liquid manure</td>
<td>0.39 EUR/ton degassed</td>
</tr>
<tr>
<td>Org. waste spread on farm land in reference case</td>
<td>0.37 EUR/ton liquid manure</td>
</tr>
<tr>
<td>Org. waste not spread on farm land in reference case</td>
<td>1.64 EUR/ton org. waste</td>
</tr>
<tr>
<td>Liquid manure</td>
<td>-3.03 EUR/ton org. waste</td>
</tr>
</tbody>
</table>
### Annual costs and benefits

#### Socio-economic results

**Annual costs and benefits**

#### Results based on biogas plant:

- **Biogas plant size:** 550 ton/day (20% waste)

### Costs (levelised annuity)

<table>
<thead>
<tr>
<th>Description</th>
<th>Result 0</th>
<th>Result 1</th>
<th>Result 2</th>
<th>Result 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investments, operation and maintenance:</strong></td>
<td>1.481</td>
<td>1.481</td>
<td>1.481</td>
<td>1.481</td>
</tr>
</tbody>
</table>

### Benefits (levelised annuity)

<table>
<thead>
<tr>
<th>Description</th>
<th>Result 0</th>
<th>Result 1</th>
<th>Result 2</th>
<th>Result 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy production:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas sales</td>
<td>0.526</td>
<td>0.526</td>
<td>0.526</td>
<td>0.526</td>
</tr>
<tr>
<td>Electricity sales</td>
<td>0.061</td>
<td>0.061</td>
<td>0.061</td>
<td>0.061</td>
</tr>
<tr>
<td><strong>Agriculture:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage, handling and distribution of liquid manure</td>
<td>0.032</td>
<td>0.032</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>Value of improved manurial value (NPK)</td>
<td>0.186</td>
<td>0.186</td>
<td>0.186</td>
<td></td>
</tr>
<tr>
<td>Value of reduced obnoxious smells</td>
<td></td>
<td></td>
<td></td>
<td>0.097</td>
</tr>
<tr>
<td><strong>Industry:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings related to organic waste treatment</td>
<td>0.675</td>
<td>0.675</td>
<td>0.675</td>
<td></td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of GHG reduction (CO2, CH4, N2O-reduction)</td>
<td>0.605</td>
<td>0.605</td>
<td>0.605</td>
<td></td>
</tr>
<tr>
<td>Value of reduced N-eutrophication of ground water:</td>
<td>0.079</td>
<td>0.079</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sum:</strong></td>
<td>0.588</td>
<td>1.481</td>
<td>2.165</td>
<td>2.262</td>
</tr>
</tbody>
</table>

### Surplus as annuity: Benefits - costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Result 0</th>
<th>Result 1</th>
<th>Result 2</th>
<th>Result 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surplus as annuity:</strong></td>
<td>-0.893</td>
<td>0.000</td>
<td>0.684</td>
<td>0.781</td>
</tr>
</tbody>
</table>
Estimated Environmental Benefits

under Danish Conditions

Reduced Green House Gas emissions

90 kg CO$_2$ EQ per tonne biomass treated

Reduced Nitrogen leaches to fresh water systems

0.11 kg N per tonne biomass treated
Conclusions

Economically and socio – economically feasible when:

- Organic waste is included, and

- Environmental and economic externalities are taken into account

Very cost-efficient as a tool for Green House Gas reduction

Beneficial for related farmers

Creates jobs and local activity
Why so far (almost) only in Denmark?

- District heating systems are widespread

- Waste recycling via arable land is/was encouraged

- Legislative push on farmers – regulations on manure application

- Tradition to utilise nutrients from manure in crop production

- Market access and fixed electricity prices.

- Openminded authorities and organisations.
But

Danish centralised co-digestion plants became victims of their own success.

Demand for suitable organic waste increased, and the market is vacuum-cleaned, so now good waste is hard to find, or too expensive.

Treatment fees were reduced or converted into costs.
Since 1998 the enlargement with plants was halted due to a number of barriers;

Reduced public acceptance – fear of smell

-difficult to find sites for construction of plants

Uncertainty about economic performance

-due to reduced average electricity price

-uncertainty about waste supplies

Lack of incentives for farmers

-some farmers wish to redistribute/dispose surplus manure
But now things start moving again because;

- Electricity price increased to 10 eurocents/kwh
- General increase in energy prices makes heat from CHP attractive
- Restrictions on manure handling still increasing
- Farmers wish to supply concentrated animal waste fractions
Government ambition;

3 new large plants every year until 2025

Potentially up to 75% of manure in DK
Plant concepts of the future

- Farms
- Transportsystem
- On farm separation
- Pretreatment
- Biogas plant
- Posttreatment
- Storage tanks
- Spreading and util of manure
- Chem. fertiliser
- Long distance transport
Aknowledgement

Thanks to Danish Biogas Association for letting us use the pictures in this presentation

[www.biogasbranchen.dk](http://www.biogasbranchen.dk)

Thank you for your attention