Small-scale Farm AD

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Drivers and challenges

EU - More than 1500 million tonnes of manure, 65% slurry
EBA* believes that by 2030 the potential will be at least 50 million m³ biogas

**Drivers**
- Energy
- Environment
- Fertilizer
- Waste management

**Challenges**
- Incentives: lack of and/or variable
- Laws & regulations
- Capital costs
- Lack of benefit
- Competition

* European Biogas Association

www.bioforsk.no
Example - The prison

- Manure from dairy farm with 100 cows at Åna prison in Rogaland county, Norway
- Co-substrate: Fish silage
- Digester: STR, 320 m³ Lundsby, Denmark w/gas tight membrane, 37 deg C
- Heated with water circulating in pipes cast in the bottom
- Digestate concrete storage tank: 3000 m³
- Gas pressurized to 50 mbar before entering steam boiler (250kW)
- Boiler can switch between biogas and petroleum
- Hot water used for heating AD process and prison
- Digestate used as fertilizer on the farm (April - August)

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### Energy production vs consumption

<table>
<thead>
<tr>
<th>Period</th>
<th>Cow slurry, 7.8 % fish silage</th>
<th>Cow slurry, 7.5% fish silage</th>
<th>Cow slurry, 0 fish silage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer Low OLR</td>
<td>Winter</td>
<td>Winter</td>
</tr>
<tr>
<td>Biogas $\text{m}^3\cdot\text{week}^{-1}$</td>
<td>1916 ($\pm$297)</td>
<td>2295 ($\pm$338)</td>
<td>923 ($\pm$76)</td>
</tr>
<tr>
<td>Average outdoor temperature, deg C</td>
<td>13.0 ($\pm$0.6)</td>
<td>0.5 ($\pm$3.9)</td>
<td>-1.0 ($\pm$3.1)</td>
</tr>
<tr>
<td>Total energy production, $\text{kWh} \cdot \text{week}^{-1}$</td>
<td>11877 ($\pm$1843)</td>
<td>14800 ($\pm$2183)</td>
<td>5560 ($\pm$457)</td>
</tr>
<tr>
<td>Thermal energy consumption, $\text{kWh} \cdot \text{week}^{-1}$</td>
<td>2095 ($\pm$455.5)</td>
<td>5350 ($\pm$476.7)</td>
<td>3892 ($\pm$499.1)</td>
</tr>
<tr>
<td>Electric energy consumption, $\text{kWh} \cdot \text{week}^{-1}$</td>
<td>1010 ($\pm$181.0)</td>
<td>1226 ($\pm$13.2)</td>
<td>1000 ($\pm$21.3)</td>
</tr>
<tr>
<td>Total energy consumption, $\text{kWh} \cdot \text{week}^{-1}$</td>
<td>3105 ($\pm$325.2)</td>
<td>6576 ($\pm$480.9)</td>
<td>4891 ($\pm$487.8)</td>
</tr>
<tr>
<td>Relative total energy consumption of energy in $\text{CH}_4$, %</td>
<td>26.9 ($\pm$6.8)</td>
<td>45.4 ($\pm$9.2)</td>
<td>88.2 ($\pm$8.7)</td>
</tr>
</tbody>
</table>
Organic farm AD
Bioforsk, Tingvoll farm, Norway

Source: anne-kristin.loes@bioforsk.no
Organic Farm AD
Bioforsk, Tingvoll farm, Norway

- 25 cows, 500 tonnes manure per year
- Two digesters, fibreglass, each 30m³
- 20 cm thick glasswool insulation
- Co-substrate: Soap from purification of fish oils (5-10% added)
- Heating by passing substrate through heat exchanger,
- Mixing in digesters by pumping
- Pipes, fittings, pumps etc. - all industrial standard
- Combined cooling tower and static gas storage
- CHP. Heat and Electricity used on the farm
- Digestate via cooling tower to storage tank

Contacts: anne-kristin.loes@bioforsk.no and ingvar.kvande@bioforsk.no
Introduction of barrier in AD reactor

Due to loss of culture the plant experienced low biogas yield. A barrier was introduced (January) to improve retention (see left). => increased biogas yield (below) (Low production in mid Feb caused by unitentional blocking by ball of straw)

(Photo: Ingvar Kvande, Bioforsk)
The Kalmari Success Story

The Kalmari Farm Digester: Note the domed gas store over the digestate storage tank which is sunk below the ground to avoid heat loss in winter when temperatures range between -10°C to -30°C for 3-4 months.

Photo: Metener Oy

(Photo: Metener Oy - www.metener.fi)
The Kalimari Success Story

Erkki Kalmari, 11\textsuperscript{th} generation farmer working land in Finland
Dairy farm with 100 LSU\textsuperscript{*} and 70 ha fodder and other crops

1998:
• Replace expensive electricity
• Avoid labour required to harvest and chip wood for boiler
  supplying heat and hot water
• Improve hygiene standards of manure management

• 6 tonnes slurry per day; Epoxy coated steel digester 120 m\textsuperscript{3} +
  20 m\textsuperscript{3} gas storage, 35 deg C, Co-substrate: sweet factory
  residues from 2001
• Gas boiler, CHP, Activated C to reduce H\textsubscript{2}S
• Components - € 9 000,- ?

\* LSU = Livestock units
## Benefits Achieved 1998 -2002

<table>
<thead>
<tr>
<th>Benefits Achieved</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>Self-sufficiency in heat and electricity, even during the coldest winters</td>
<td>Replaced wood chips and logs cut from the farm estate</td>
</tr>
<tr>
<td>Reduced cost of fuel bills:</td>
<td>Labour cost wood fuel to meet demand for 300 kWh of heat @ average price 50 -60 Euro/MWh</td>
</tr>
<tr>
<td>a) Labour</td>
<td>15,000 - 18,000 Euros/year</td>
</tr>
<tr>
<td>b) Heat</td>
<td>7,000 Euros/year</td>
</tr>
<tr>
<td>c) Electricity</td>
<td></td>
</tr>
<tr>
<td>Reduction in fertiliser bills</td>
<td>5,000- 6000 Euros</td>
</tr>
<tr>
<td>Reduced veterinary bills</td>
<td>Not available</td>
</tr>
</tbody>
</table>
The Kalmari Success Story

Second stage, 2002 additions:

Digester and CHP
  • 90 m³ Feedstock concrete slab mixing tank
  • 25 kWe self-converted diesel engine for operation with biogas

Biogas upgrading and biomethane filling station
  • High pressure water scrubber
  • Compressors, 270 bar
  • Volvo V70 bifuel car
  • Biomethane filling station, also for use by neighbours
The Kalmari Success Story

Third stage 2008:

Increased feedstock and biogas yield

- Cow manure 2000 m³
- Confectionary residues 200 m³
- Agri-industrial residues 300 m³
- Silage and grass 50 m³

New 1000 m³ digester

- Retrofitted into existing slurry lagoon
- Covered tank for biogas and digestate 1500 m³
- New biogas upgrading equipment
- Larger vehicle fueling unit
The Kalmari Success Story

2009:
Valtra biomethane/diesel tractor (Photo left below (Source: [www.ngvglobal.com/...for-biomethane-fuelled...tractors-0316 ; www.fwi.co.uk/.../biogas-the-tractor-fuel-of-the-future.htm]))
- saved 40% on tractor operation

2011:
The farm’s first public metered biomethane filling station, capacity 200 cars - 300 regular customers. (Patented Metener biogas upgrading technology (Jussi Läntelä) (below centre) and Kalmari Farm’s new fully commercial biogas filling station (Outi Pakarinen) (below right)

Sales income from vehicle fuel has overtaken that from the livestock which provided the basis for this plant!
# The Kalmari Success Story - Summary

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<tr>
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<tbody>
<tr>
<td><strong>Reduced expenses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>7,000</td>
<td>10,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Heat</td>
<td>15,000-18,000</td>
<td>18,000-20,000</td>
<td>18,000-20,000</td>
</tr>
<tr>
<td>Car fuel</td>
<td>2,000</td>
<td>2,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Tractor fuel</td>
<td>0</td>
<td>0</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Increased income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity export</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vehicle fuel</td>
<td>0</td>
<td>12,000</td>
<td>90,000</td>
</tr>
<tr>
<td>Gate fees</td>
<td>0</td>
<td>0</td>
<td>5,000</td>
</tr>
</tbody>
</table>
Norwegian farms are small

- Average 25 cows (bigger if joint operations with common cowhouse)
- Pigs licence: max 2100 per year
- Typical amounts of slurry 1500 to 2500 m$^3$/yr
  - 4 to 8 % Dry matter
- Most of feedstock has > 90 % water
  - Not financially viable to transport to centralised plant
=> Small scale farm AD
UASB
Upflow Anaerobic Sludge Blanket

- SRT >> HRT
  => Culture retention time longer than liquid retention
- Effective; compact; inexpensive
- Low temp: ok
- Stable
- Production on demand

Anaerobic Baffle Reactor, ABR
Anaerobic Baffel Reactor - ABR

Contacts: Prof rune.bakke@hit.no and jon.hovland@tel-tek.no
Productivity in ABR compared to standard STR

- Metan produksjons rate (L CH₄/L·d)
- HRT (d)

Comparison of productivity between ABR and traditional reactor.
Possible connection between storage and reactor

Storage:
- Hydrolysis
- Acid production
- Separation

Biogas-reactor; w/granules "ABR"

Soluble feed, small particle
Manure

Low investment cost
Hypothesis: Profitable

Contacts: Prof rune.bakke@hit.no and jon.hovland@tel-tek.no
**Summary**

**Drivers**
- Energy
- Environment
- Fertilizer
- Waste management

**Challenges**
- Incentives
- Laws & regulations
- Lack of benefit
- Competition

Variation in substrates, technology, climate, incentives, regulations - generalisation in practice impossible

Small scale AD is environmentally sound, but adaptation to local possibilities and obstacles is necessary