Small-scale Farm AD

Roald Sørheim, Norway and Clare Lukehurst, UK

Presented at a joint meeting between
CIBiogas and IEA Bioenergy Task 37
at Itaipu Technology Park on Friday April 4th, 2014




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 m^3 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

Example – The prison

- Manure from dairy farm with 100 cows at Åna prison in Rogaland county, Norway
- Co-substrate: Fish silage
- Digester: STR, 320 m^3 Lundsby, Denmark w/gas tight membrane, 37 deg C
- Heated with water circulating in pipes cast in the bottom
- Digestate concrete storage tank: 3000 m^3
- 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)

Contact: john.morken@nmbu.no
and tormod.briseid@bioforsk.no

Energy production vs consumption

Period	Cow slurry, 7.8 % fish silage Summer Low OLR	Cow slurry, 7.5% fish silage Winter	Cow slurry, 0 fish silage Winter
Biogas $m^3 \cdot week^{-1}$	1916 (±297)	2295 (±338)	923 (±76)
Average outdoor temperature, deg C	13.0 (±0.6)	0.5 (±3.9)	-1.0 (±3.1)
Total energy production, $kWh \cdot week^{-1}$	11877 (±1843)	14800 (±2183)	5560 (±457)
Thermal energy consumption, $kWh \cdot week^{-1}$	2095 (±455.5)	5350 (±476.7)	3892 (±499.1)
Electric energy consumption, $kWh \cdot week^{-1}$	1010 (±181.0)	1226 (±13.2)	1000 (±21.3)
Total energy consumption, $kWh \cdot week^{-1}$	3105 (±325.2)	6576 (±480.9)	4891 (±487.8)
Relative total energy consumption of energy in CH_4, %	26.9 (±6.8)	45.4(±9.2)	88.2 (±8.7)

Organic farm AD

Bioforsk, Tingvoll farm, Norway

Source: anne-kristin.loes@bioforsk.no

Organic Farm AD
Bioforsk, Tingvoll farm, Norway

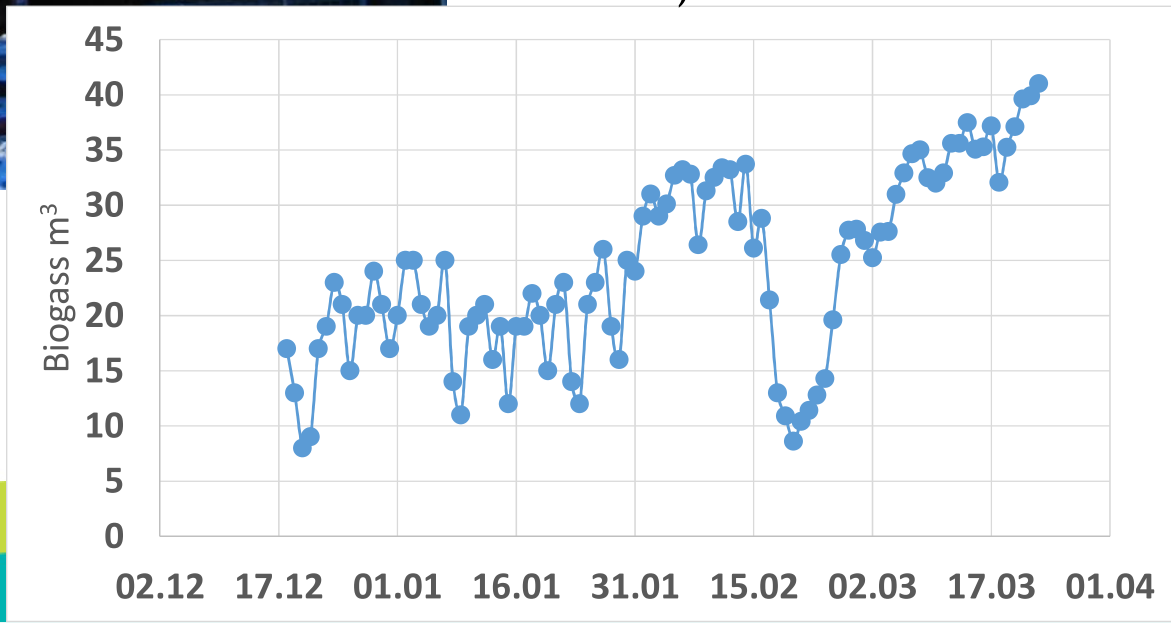
- 25 cows, 500 tonnes manure per year
- Two digesters, fibreglass, each 30m^3
- 20 cm thick glasswool insulation
- Co-substrate: Soap from purification of fish oils (5-10% added)
- Heating by passing substrate through heat exchanger,
- Mixing in digesters by pumping
- Pipes, fittings, pumps etc. – all 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

(Photo: Ingvar Kvande, Bioforsk)

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)




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

The Kalimari Success Story

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

1998:

- Replace expensive electricty
- 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^3 + 20 m^3 gas storage, 35 deg C, Co-substrate: sweet factory residues from 2001
- Gas boiler, CHP, Activated C to reduce H_2S
- Components - € 9 000,- ?

* LSU = Livestock units

Benefits Achieved 1998 -2002

Self-sufficiency in heat and electricity, even during the coldest winters	Replaced wood chips and logs cut from the farm estate
Reduced cost of fuel bills: a) Labour b) Heat c) Electricity	Labour cost wood fuel to meet demand for 300 kWh of heat @ average price 50 -60 Euro/MWh 15,000 – 18,000 Euros/year 7,000 Euros/year
Reduction in fertiliser bills	5,000- 6000 Euros
Reduced veterinary bills	Not available

The Kalmari Success Story

Second stage, 2002 additions:

Digester and CHP

- 90 m^3 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 m^3
- Confectionary residues 200 m^3
- Agri-industrial residues 300 m^3
- Silage and grass 50 m^3

New 1 000 m^3 digester

- Retrofitted into existing slurry lagoon
- Covered tank for biogas and digestate 1500 m^3
- 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.ngvglobal.com/...for-biomethane-fuelled...tractors-0316) ; [www.fwi.co.uk/.../biogas-the-**tractor**-fuel-of-the-future.htm](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

Financial benefits, €/yr	Stage 1 1998-2001	Stage 2 2002-2007	Stage 3 2008-2011
Reduced expenses			
Electricity	7,000	10,000	13,000
Heat	15,000- 18,000	18,000-20,000	18,000-20,000
Car fuel	2,000	2,000	6,000
Tractor fuel	0	0	1,000
Increased income			
Electricity export	0	0	0
Vehicle fuel	0	12,000	90,000
Gate fees	0	0	5,000

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

Høgskolen i Telemark

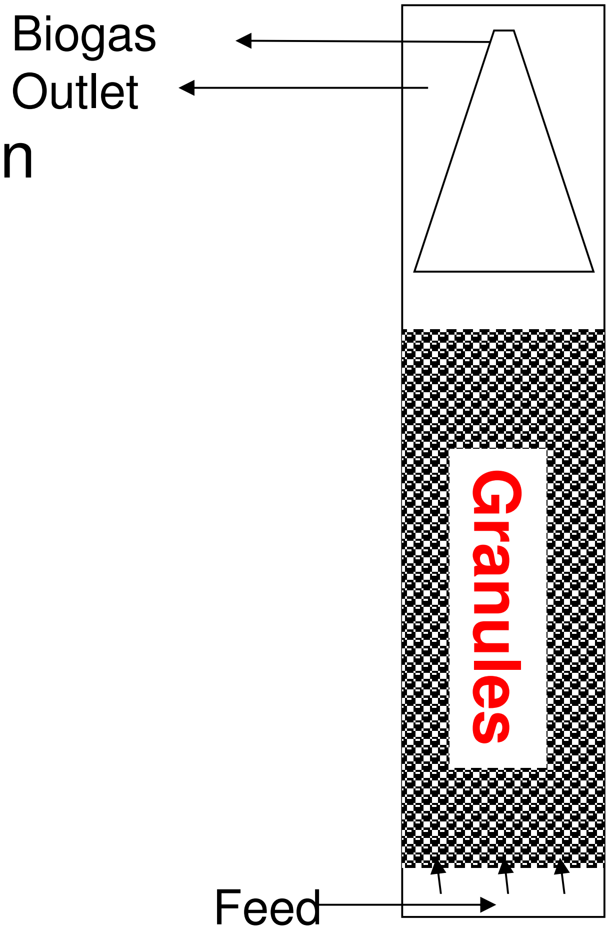
UASB

Upflow Anaerobic Sludge Blanket

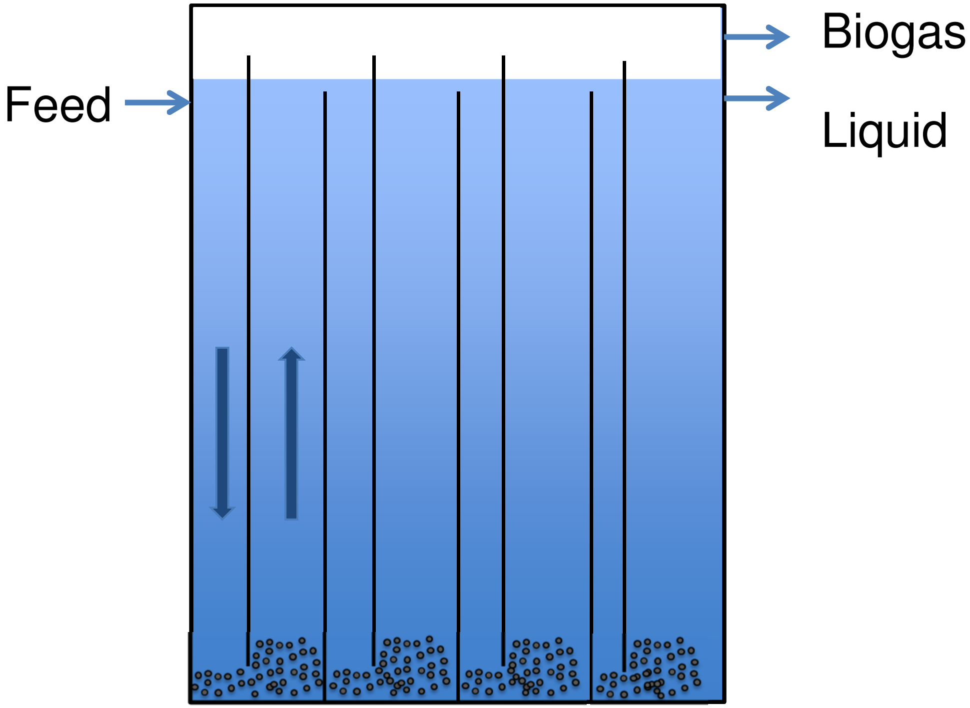
- SRT >> HRT
  => Culture retention time longer than liquid retention
- Effective; compact; inexpensive

- Low temp: ok
- Stable
- Production on demand

Anaerobic Baffle Reactor, ABR

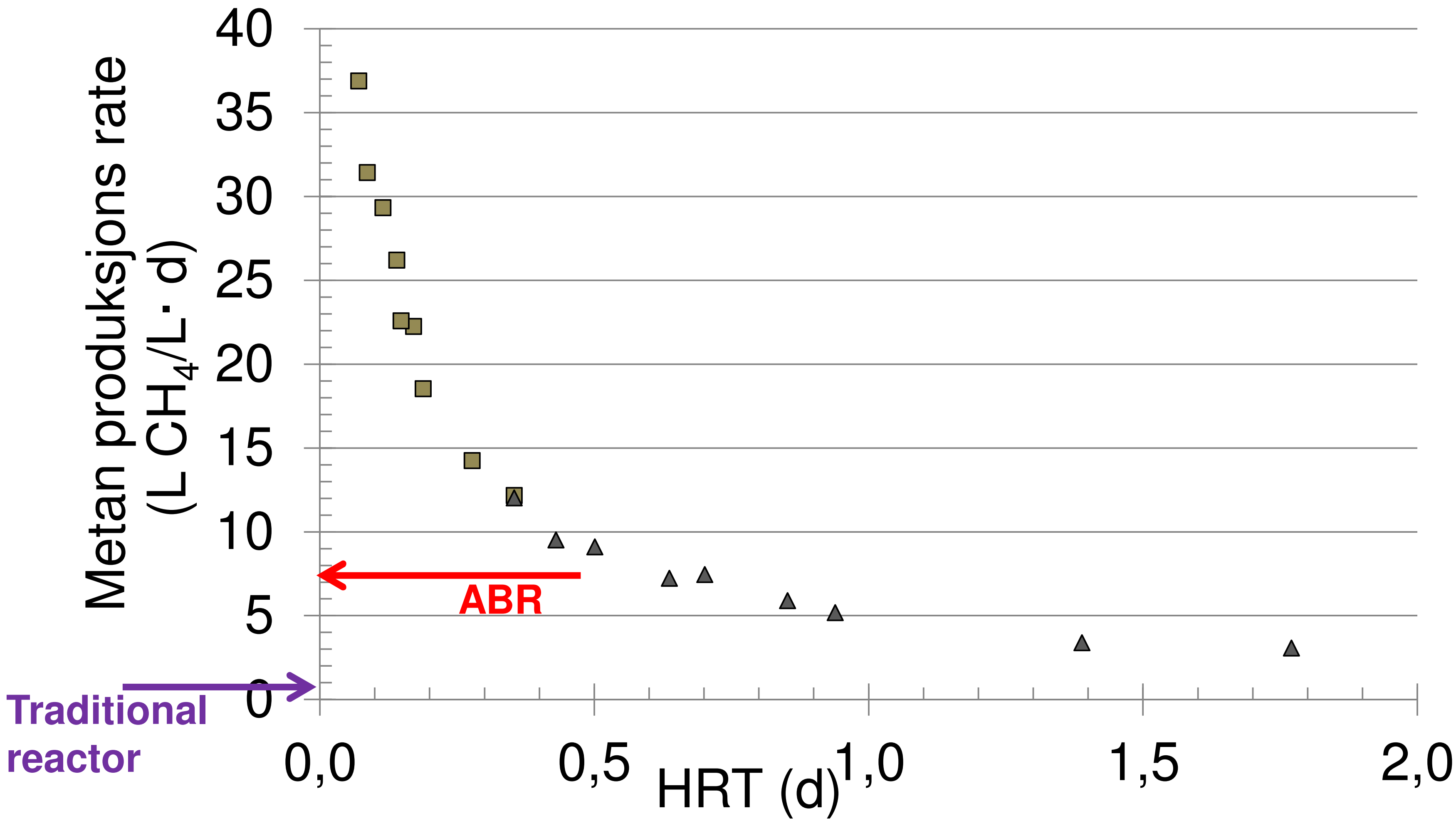


Anaerobic Baffel Reactor - ABR



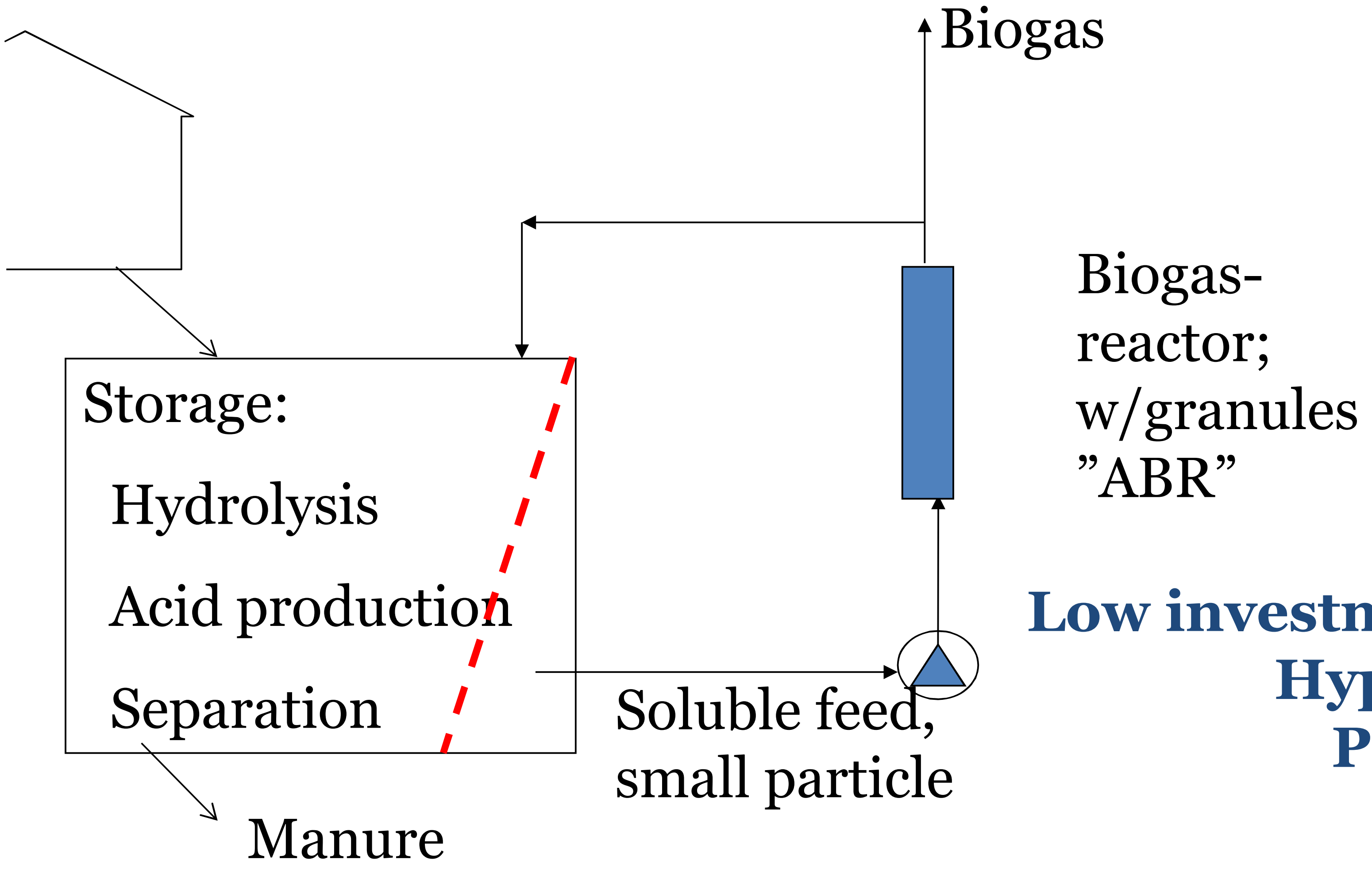
Contacts: Prof rune.bakke@hit.no and jon.hovland@tel-tek.no

Productivity in ABR compared to standard STR



Høgskolen i Telemark

Possible connection between storage and reactor



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, techology, climate, incentives, regulations – generalisation in practice impossible

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