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Economical overview of small scale biogas plants and complementary technologies

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KTBL – an introduction

KTBL = Association for Technology and Structures in Agriculture

- Non-profit organisation
- Situated in Darmstadt (south of Frankfurt)
- 60 employees
- Government-financed by German Federal Ministry of Food and Agriculture
- Funding is provided annually with approx. EUR 5.8 mill. from the federal government and with EUR 1 mill. by externally funded projects

- Behalf of KTBL: Technology transfer for the agricultural sector

Main task of KTBL
→ transfer of knowledge and technology

Target groups

- politics, administration, advisory services, research, experts, farmers, industry…

Tasks

- Collect and process costing data
- Description of state of the art
- Evaluation of new technologies (economic and ecological assessment)
- Initiation and coordination of R&D projects
- Provision of scientific and technical advisory statements to policy and administration
- Contribution to national and international regulations

Approach is coordinated with a large ***network*** of 400 honorary members in KTBL-working groups

Products and services – Example biogas

Conferences and Workshops
e.g. FNR/KTBL-Congress „Biogas in agriculture – state of knowledge and prospects"

Publications
e.g. "Basic figures Biogas" (2013) or

"Understand and avoid weaknesses in biogas plants" (2009)

Products and services – Example biogas

Online tools: e.g. Biogas calculator (in German)
http://daten.ktbl.de/biogas/startseite.do#start

e.g. European Feedstock Atlas (EU-Project)
http://daten.ktbl.de/euagrobiogasbasis/

Small-scale biogas plants – an overview

Objectives and framework

- With the 2012 amendment of the German Renewable Energies Source Act (EEG), a special payment for small biogas plants (MSD) was been introduced
  [up to 75 kW electrical capacity installed till 2015: 23.46 ct/kWh$_{el}$]
- Obligation to use at least 80 % livestock manure
- The Goal was to encourage the manure digestion, because previously only about a ¼ of Germans manure potential is used for biogas production
- This should reduce the climate-related methane emissions, which will otherwise arise from manure storages

Small-scale biogas plants – an overview

Structural conditions

- Manure, especially liquid manure, has a low energy density (high water content and low specific gas yield) which makes them too expensive for certain transport distances
- Aspects such as existing livestock capacity and manure availability must be considered during planning as well as the lower energy yield
- For pure manure digestion, the heat balance of the plant may be critical in winter operation but the surplus heat mostly replaces expensive fuel for buildings, so its very important for the economy
- For economically use of manure (together with residues), small-scale biogas plants must have low investment costs and be robust to operate with little effort

Small scale AD plants – an overview

	Stirred tank (contin. operation)	Compact plant	Fixed bed fermenter	Solid-state fermentation	Other Processes
					
Process description	Often standing concrete circular tanks (possibly Ring in-Ring) with agitator	Lying stainless steel or steel fermenter in 40-foot container	Up-Down-reflow or cross-flow system, 2-step operation	Garage reactor, percolation tank	Often circulation, irrigation nozzles or injection of gas into fermenter (instead of an agitator)
Variants	Standard fermenter, high-fermenter, ring-in-Ring-system	Lying fermenter, plug-flow	Plastic pipes in internally coated steel fermenter	Garage reactor	Combination of solid-state and wet digestion, Thermo-gas-lift method
Substrates	Slurry, solid manure, energy crops, biowaste	Mainly optimized for liquid manure, low shares of energy crops	Liquid or pre-digested substrates (if crushed)	Energy crops, solid manure, biowaste; no slurry useable	Usually for difficult substrates, such as grass
Digestate storage	By co-digestion of renewable raw materials, a residence time of 150 days in a gas-tight system must be complied. This leads to digestate storage volume from 1.400-2.200 m³ for a 75 kW_{el} plant.				
Investment **40 kW_{el}** **75 kW_{el}**	 280,000 € (30kW_{el}) 350,000–600,000 €	 150,000–470,000 €	 >300,000 € 400,000–550,000 €	 240,000 € 400,000 €	 >240,000 €
Normally provided by client	Slurry store, digestate storage, foundation for container, building site preparation, permits, earthworks, grid connection, foundations, back/extra works, drainage, land development, clamp silo, flare, transformer station, crane positioning, advisory reports, assembly workers, etc. Total between 50,000 - 250,000 €				
Total investment	**550,000 – 850,000 € (75 kW_{el})**				

Pics from: NovaTech GmbH, agriKomp GmbH, Bebra Biogas GmbH, minerallt GmbH, BIO4GAS EXPRESS GMBH

Economical examples of small scale biogas plants

- 3 different plant constellations (manure-based) are contemplated
  - with 20% energy crops (higher substrate costs)
  - with 45% solid manure (no substrate costs)
  - with 45% poultry dung (reduced payment)
- Assumed, plants where constructed new on "greenfield" (incl. costs for plant, building and property)
- Following methane yields were assumed
  - cattle manure 16.7 m³ CH_4/t substrate (fresh matter)
  - solid manure (cattle) 52.6 m³ CH_4/t substrate (fresh matter)
  - poultry dung 82.5 m³ CH_4/t substrate (fresh matter)
  - energy crops 112 m³ CH_4/t substrate (fresh matter)
- CHPU: injection gas-engine, efficiency: 39% elec., 38% therm.
- Labor (for plant operation, office work, maintenance and minor repairs) has been assumed with 8.4 hours/week (75 kW)
- No costs for manure or its transport assumed
- Does not account credit for digestate as a fertilizer replacement

Economical examples of small scale biogas plants (German feed-in tariff)

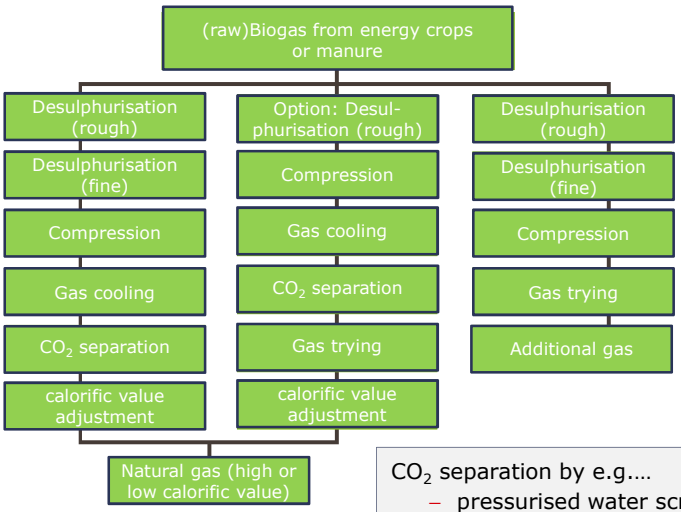
	Unit	80% manure 20% energy crops	55% manure 45 % solid manure	55% manure 45% poultry dung
Installed capacity	**kW_{el}**	**75**	**75**	**82**
Substrates				
Cattle manure	t/a	3,300	2,400	1,900
Cattle solid manure	t/a	0	2,000	0
Poultry dung	t/a	0	0	1,500
Maize silage	t/a	800	0	0
Total investment	**€**	**631,422**	**643,537**	**643,315**
Specific investment	**€/kW_{el}**	**8,420**	**8,583**	**7,833**
Revenues				
Electricity fed in	kWh/a	599,933	599,847	656,993
Feed in tariff	**ct/kWh**	**23.53**	**23.53**	**13.46**
Sale of electricity	€/a	141,164	141,144	88,431
External sold heat amount	%	20	20	20
Revenue heat (by 2 ct/kWh)	€/a	2,322	2,322	2,537
Sum revenues		**143,486**	**143,466**	**90,968**
Running costs (plant & front-end loader)				
Substrates	€/a	28,727	0	0
Operating supplies	€/a	24,720	25,404	26,136
Maintenance and repair	€/a	22,243	22,291	23,549
Others (laboratory, office etc.)	€/a	804	575	581
Sum running costs	**€/a**	**76,494**	**48,270**	**50,266**
Fixed costs (plant & front-end loader)				
Amortisation	€/a	57,487	58,933	61,143
Interest expense	€/a	13,047	13,250	13,207
Insurance	€/a	3,157	3,218	3,217
Labour expense	€/a	9,570	9,570	9,868
Others	€/a	375	375	411
Sum fixed costs	**€/a**	**83,636**	**85,345**	**87,845**
Sum totel expenses		**160,130**	**133,615**	**138,112**
Imputed profit contribution	**€/a**	**-16,644**	**9,851**	**-47,143**
Power generation costs	**ct/kWh**	**26.69**	**22.27**	**21.02**
Sensitivity analyzes				
Reduction of Invest by 5%	€/a	-12,959	13,621	-43,265
Reduction of Invest by 10%	€/a	-9,275	17,391	-39,387
Reduction of Invest by 25%	€/a	1,779	28,701	-27,752

Digestate of MSD-Models

	Model 1		Model 2		Model 3	
Substrate (input 75 kW)	3,300 t cattle manure	800 t energy crops	2,400 t cattle manure	2,000 t solid manure	1,900 t cattle manure	1,500 t poultry dung
Digestate (output)	**3,740 t/a**		**4,060 t/a**		**3,040 t/a**	
Total nitrogen value	0.88 €/t		0.92 €/t		1.55 €/t	
Phosphate (P_2O_5) value	0.36 €/t		0.47 €/t		1.16 €/t	
Potassium (K_20) value	0.91 €/t		0.98 €/t		1.31 €/t	
Total fertilizer value (before spreading)	**8,050 €/a**		**9,600 €/a**		**12,200 €/a**	

Assumed pure nutrient prices: 110 €/dt nitrogen; 60 €/dt potash; 80 €/dt phosphate

Principle of biomethane production (upgrading biogas)



CO_2 separation by e.g.…

- pressurised water scrubbing (DWW)
- pressure swing adsorption (PSA)
- physical and chemical absorption
- membrane technology

Source: Urban et al 2009

Investment and operational costs of biogas upgrading (free gas grid)

Treatment plant capacity: **400 m_n^3** raw biogas/h
Running hours/year: 8,000

	Pressure swing adsorption (PSA)	Pressurised water scrubbing (DWW)	Amine gas treating
Investment (upgrading plant)	1,544,770 €	1,537,450 €	1,270,200 €
Running costs	254,150 €/a	185,050 €/a	208,160 €/a
Fixed costs	144,340 €/a	143,670 €/a	119,170 €/a
Costs grid connection / transfer station	58,579 €/a	59,310 €/a	59,640 €/a
Total upgrading costs (free grid) without biogas production	**457,070 €/a**	**388,030 €/a**	**386,970 €/a**

[Biogas production rate of a **150 kW** MSD: about **75 m_n^3** raw biogas/h]

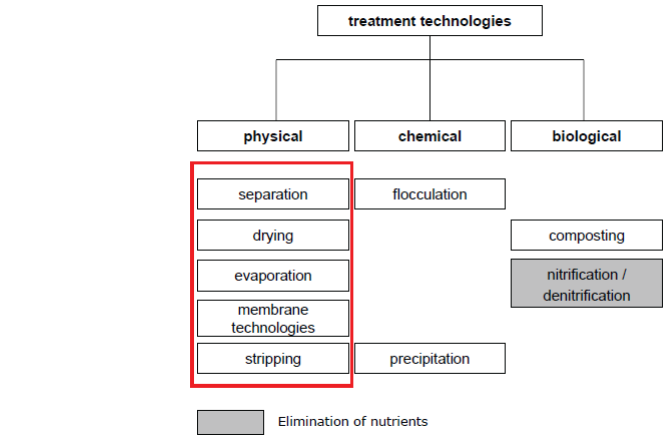
Biomethane production - an option for German MSD?

- Methane enrichment has to be conform with DVGW Work-Sheets G260 and G262 (gas quality regulation)
- Connection to natural gas grid is not always feasible; need to meet pressure level of gas grid (compressing costs)
- Purification is cost-intensive (for 400 m_n^3 1.8 – 2.2 ct/kWhHs)
- Additional expenses are profitable from about 1 MW_{el} plant size (raw biogas production)
- Membrane technology might cut the costs in future for small upgrading units (low specific investment costs)
- The very simple technical construction and virtually maintenance-free handling are advantageous

Why treating digestate?

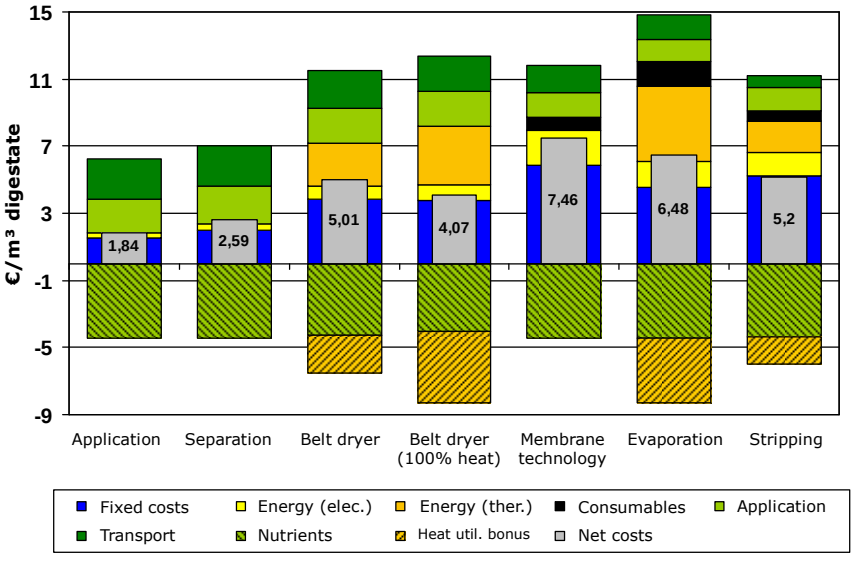
- "Export" nutrients in nutrient surplus
- Storage and application saving costs
- Reduce costs for land purchase or lease (nitrogen balance)
- Trading of treatment products (transportable and storable, liquid and spreadable fertilizer)
- Reduce environmental pollution
  - nutrient discharge to the liquid phase
  - avoiding volatile air and atmospheric pollutants
  - odour reduction
  - inactivation of pathogens and weed seeds)

Principles of digestate treatment



Source: Wulf 2010

Specific costs of digestate treatment technologies
(for 30.000 t/a (eq. a 1.2 MW_{el} AD plant))



Source: Döhler 2010

Example: digestate treatment costs for MSD-Models
(technology costs based on 30.000 t/a capacity; models from slide11)

	Model 1		Model 2		Model 3	
Substrate (input 75 kW)	3,300 t cattle manure	800 t energy crops	2,400 t cattle manure	2,000 t solid manure	1,900 t cattle manure	1,500 t poultry dung
Digestate (output)	**3,740 t/a**		**4,060 t/a**		**3,040 t/a**	
Application	6,900 €/a		5,600 €/a		5,600 €/a	
Separation	9,700 €/a		10,500 €/a		7,870 €/a	
Belt dryer	18,700 €/a		20,300 €/a		15,230 €/a	
Membrane technology	27,900 €/a		30,300 €/a		22,670 €/a	
Evaporation	24,200 €/a		26,300 €/a		19,700 €/a	
Stripping	19,400 €/a		21,100 €/a		15,800 €/a	

Conclusion digestate treatment

- For small biogas plants treatmemt costs are higher than application without treatment
- Product quality is seldom high enough to make it a treadeable good

- But treatment can be useful:
  - In areas with high nutrient surpluss
  - In areas focussing on living and recreational quality
  - If there is a (also local) market for treatment products

Thank you very much for your kind attention!

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