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Potential and applicability of renewable residual materials and organic waste for fermentation in biogas plants

Beside the use of purposely cultivated renewable primary products in biogas plants in order to obtain energy, under various circumstances accumulating organic wastes and residual materials of plant and animal origin can be used to produce biogas, too. Quantities and potentials for the production of electric energy are estimated. Typical substrates representing the discussed product groups are evaluated. It can be clearly shown that the use of well suitable input-materials for biogas plants is partly inhibited by inappropriate legal regulations.

Keywords

Energy production, Renewable Energy Source Act, biomass, renewable primary products, renewable residual materials, organic waste, production potential for electric energy

Abstract

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In the Renewable Energy Source Act [1; 2], the law-makers have established bonuses that allocate particular significance to renewable primary products and slurry. This has led to a growing share of agriculturally usable land being used to crop renewable primary products. Alongside this, with regard to sustainable management, the use of renewable residual materials and organic wastes for energy production is also to be increased. This article characterises residual materials from various segments suitable for biogas production with their volumes, electricity production potentials, material properties and their market potential taking the legal rules and regulations into account.

Material groups and funding

The Renewable Energy Source Act defines the material groups that lead to differing funding levels for the amounts of electricity produced from them and fed into the grid:

- renewable primary products (Annex 2 Para III, positive list)
- manure of animal origin (Annex 2 Para III, positive list)
- purely plant products, by-products and organic wastes in accordance with BioAbfV [3] (Annex 2 Para V, positive list purely plant by-products)
- products, by-products and organic wastes in accordance with BioAbfV (Annex 2 Para IV, negative list)
- sewage treatment sludges in accordance with AbfKlärV [4] (non-stabilised)

The following can also be used in biogas plants to produce energy:

- Animal by-products in accordance with Regulation (EC) No. 1774/2002 [5] in conjunction with § 3 Renewable Energy Source Act (substances not recognised as biomass). This Regulation has been superseded by Regulation (EC) No. 1069/2009 [6]. The German legal regulations referring to this, e.g. the Animal By-product Elimination Regulation (TierNebV) [7] have not yet been adapted accordingly (as at the end of November 2009).

Electricity produced from biomass is remunerated in accordance with § 27 „Biomass“ of the Renewable Energy Source Act that is staggered according to the plant capacity. If other substances in addition to those approved in accordance with the Biomass Regulation are used in biogas plants, the payment is limited to the material group specified under the Biomass Regulation. Further substrates are to be documented by keeping a material use log. The bonus for Renewable Raw Materials (**table 1**)

- is granted for those plants that satisfy the definition of renewable primary products and for animal manure, including horse manure (Annex 2 Para III, positive list).
- is not lost provided that in addition to the purely

Table 1

Funding according to Renewable-Energy-Law depending on the use of various groups of substrates in biogas plants

Boni basic tariff/boni	energy crops including by-products of plant production	manure[1]	plants or parts of plants accumulating during landscape management [2]	positive list of purely plantbased by-products	material of plant origin according to Biowaste Ordinance	sewage sludge	animal by-products
basic tariff	X[3]	X[3]	X[3]	X[3]	X[3]	X[4]	(X)[5]
technology-bonus	X	X	X	X	X	X	
bonus for electricity from energy crops	X	X	X				
manure-bonus		X					
landscape management-bonus			X				
CHP-bonus	X	X	X	X			
minimising emissions-bonus	X	X	X	X			

[1] faeces and urine, including litter used for livestock and horses, as well as food waste which accumulates in agricultural operations. [2] in the context of nature protection and landscape conservation [3] biomass-tariff according to Renewble Energy Source Act (EEG). [4] sewage treatment-tariff according to EEG. [5] not legally fixed; tariff is subject to negotiations with the energy provider.

- plant substances from the positive list, purely plant by-products (Annex 2 Para V, positive list pure plant by-products) are used in the biogas plant. The electricity produced from these substrates must be subtracted from the total electricity yield of the plant by means of „standard biogas yields".
- is lost completely if substances from the negative list are used to produce energy (Annex 2 Para IV, negative list).

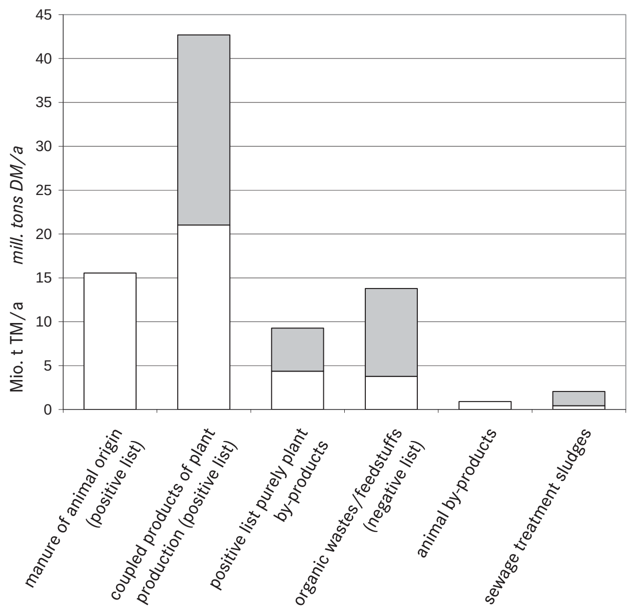
In addition to „biomass remuneration" as basic remuneration, depending on the substrates used, various bonuses can be claimed for feeding electricity made from renewable energy sources to the grid (**table 1**). The „slurry bonus" is granted provided that the share of slurry in accordance with Regulation (EC) No. 1774/2002 makes up at least 30 percent by weight, to be documented by an environmental expert opinion. For electricity produced from sewage treatment gas, the remuneration is in line with § 25 „Sewage treatment gas" of the Renewable Energy Source Act, staggered according to the plant capacity.

Volumes and potential for biogas production

The „coupled products of plant production" such as grain and oilseed rape straw as well as animal manure (slurry, solid manure, liquid manure) account for by far the largest volume share of the substances considered here. Both substance groups are allocated to the renewable primary products according to the Renewable Energy Source Act (**figure 1**). Crushed oilseed rape meal, oilseed rape cakes and glycerine from the production of vegetable oils form the largest share of the substance group from the positive list of purely plant by-products according to the Renewable Energy Source Act. As regards the materials from the negative list, wastes from „organic waste" dustbins and green materials as well as distiller's solubles from bio-ethanol production contribute to the high volumes generated. Altogether, however, it should be taken into account that a portion of the individual substances accumulating is not available for biogas production because it is used for other purposes (feedstuffs, fertilisers, litter, energy production, humus reproduction, raw materials for chemical production).

The biogas formation potential – expressed as production potential for electric energy (assumption: 36 % electric efficiency of the co-generation plant) – is calculated at about 10 billion kWh_{el}/a for all manures. However, the cost effectiveness of their use depends on the volumes generated and transport di-

Fig. 1



Amount (mill. tons DM/a) of destined substrate groups (whole length of bar) and subset available for biogas production respectively (white bar)

Table 2

Characterisation and evaluation of destined residual materials resp. wastes

	Rape seed cake	Rape oil meal	Glycerine from plant oil processing	Straw (wheat)	Spent grains (pressed)	Vinasse (wet, wheat, alcohol production)	Vinasse from bioethanol production (dried)	Sugar beet leafs (silage)	Small parts of beets	Biowaste	Food waste	Fats of animal origin, category 3
Legal categorization												
bonus for electricity from energy crops, annex 2, section III EEG				X				X				
positive list of purely plant-based by-products, annex 2, section V EEG	X	X	X		X	X						
negative list (biowaste/feeding stuff), annex 2, section IV EEG							X		X	X		
Regulation (EU) No. 1774/2002 resp. Ordinance on animal by-products (2006)											X	X
Draft Biowaste Ordinance (2008)	X	X	X		X	X	X		X	X		
power output												
– electric kWh/kg DM	1474	n.d.	1557	642	1111	1313	1313	1016	1376	683	1352	1998
– electric kWh/kg FM	1341	n.d.	1557	552	267	79	1227	183	268	273	216	1998
fertilizer value												
quotient N/power output	28	n.d.	n.d.	9	26	32	43	18	13	6	12	1
quotient P_2O_5/power output	19	n.d.	n.d.	5	14	9	n.d.	6	2	3	15	0.2
costs: storage												
availability	k	k	k	s	k	k	k, s	s	s	k	k	k
storage	S, T	S, T	F	T	F, S	F, S	T	S	S, T	F-T	F	F
gas-tight storage							(yes)	(yes)	(yes)	yes	yes	yes
costs: treatment unit												
sanitizing due to phytohygienic risiks (Draft Biowaste Ordinance 2008)	yes	(P)	P		P	P	P	recom-mended	yes	yes		
sanitizing due to epidemic risks (Regulation (EU) No. 1774/2002, Draft Biowaste Ordinance 2008)										yes	yes	yes
treatment before or after	(S)	(S)		(Auf)						Stö		
costs: product												
alternatives for utilization	F	F	F, A	E, H, V	F	F	F	H, F, D	F		F	A
increasing market significance due to increasing amounts		yes	yes				yes	yes	yes	yes		
labour costs:												
recovery, supply	L, A	L, A	L, A	B	L, A	L, A	L, A	B	L, A	L	L, A	L
control of biogas plant	medium	medium	high	medium	small	small	small	medium	medium	high	high	high
product characteristics												
DM (%)	91	n.b.	100	86	24	6	93.4	18	19.5	40	16	100
oDM (% DM)	93	n.b.	99	92	96	94	94	88	96	50	90	90
biogas yield (KW/tons oDM)	680	n.b.	850	370	530	640	640	600	775	615	700	1000
methane yield (%)	63	n.b.	50	51	59	59	59	52	50	60	58	60
N (kg/tons DM)	41.4	n.b.	n.b.	6	29.2	41.7	57.1	17.8	17.6	4.3	15.6	1.6
P_2O_5 (kg/tons DM)	27.3	n.b.	n.b.	3	15.4	11.7	n.b.	5.6	2.6	2.3	20	0.4
K_2O (kg/tons DM)	18.0	n.b.	n.b.	16	1.3	10.0	n.b.	42.8	n.b.	2.8	36.3	0.1

) nutrient 1000 [kg/tons DM]/power output [electric kW/kg DM]
availability: k = continuous, s = seasonal; storage: F = material is liquid, S = material has a higher DM-content and can be silaged, T = material is offered in dry condition or is produced dry; sanitization: recommended = sanitization is recommended without legal background in order to cut infection circles, P = sanitization during production process of main product; treatment before or after: Auf = chemical-physical disintegration, Stö = removement of impurities, S = desulfurication; alternatives for utilization: D = direct use as fertilizer, E = litter, F = feed, H = humus reproduction, V = direct incineration, Ch = raw product for chemical industry; recovery, supply: L = delivery to biogas plant (tank-truck), B = recovery per loading wagon; A = collection

stances. A large part is produced on relatively small farms with partly large distances to the nearest biogas plant. More than 90 % of the coupled products of plant production with an estimated production potential for electric energy of altogether about 12 billion kWh_{el}/a consists of substances with a high lignin component or high degree of lignification. Various processes have already been developed to the implementation stage for energy use of these substances. For the substances taken into account from the positive list of purely plant by-products, including oilseed rape meal and rape cakes, a production potential for electric energy of about 4.5 billion kWh_{el}/a is calculated. The animal by-products recorded contain a series of energy-rich substrates such as stomach and rumen contents, animal fats, meat-and-bone and blood meals, as well as food wastes, and display a production potential for electric energy of about 1 billion kWh_{el}/a. Only a small portion of the sewage treatment sludges generated is available for biogas production (production potential for electric energy about 0.2 billion kWh_{el}/a), as fermentation is frequently carried out already in the course of sludge treatment in larger sewage treatment plants. This group of substances is thus of subordinate importance.

Material properties

The following assumptions are made to assess selected residual materials (**table 2**):

- Yield from feed-in funding according to Renewable Energy Source Act: depends on the substance group (**table 1**).
- Fertilising value: high nutrient contents are assessed negatively with regard to the electricity yield, as it is assumed that the recycling area for the fermenting residues is in short supply.
- Costs of storage and treatment outlay are classified as low if continuous delivery of the substrate up to the plant location can be assured. The cost of storing dry to ensilable substrates is rated lower than that of storing liquid substrates. Odour-intensive or pollutant gas emitting substrates are assessed unfavourably. The need to treat substrates/fermenting residues to comply with the legally stipulated hygiene properties has a negative effect on the costs. This also applies for treatment steps resulting from the respective material characteristic, such as degradation, desulphurisation or segregation of undesirable substances.
- Work inputs: If these are high, this is assessed negatively for the collection and provision of the substrate or for monitoring the plant operation.
- Procurement costs: if several different recycling avenues are available for substrates, this is assessed negatively due to the competition situation and the resulting price-driving effect.

Revenues from feeding electricity into the grid depend on the one hand on the legal classification of the substrates and on the other on their material properties, e.g. the dry matter content. Where this is low, a great deal of unproductive water also has to be treated, as the comparison between wet and dry distiller's solubles shows. The quotient of P_2O_5/electricity yield makes it clear that for energy production from rape cakes and brewer's grains, more land area has to be provided for recycling the fermenting residues than is the case for animal fats. Organic waste dustbins, food wastes and animal fats require optimal conditions for intermediate storage. As these wastes are generated continuously, these stores can be relatively small in volume. Hygiene-improving – generally thermal – treatment is also necessary for the use of rape cakes, while due to the production conditions no hygiene treatment measures are necessary for oilseed rape meal. Although hygiene treatment measures are cost intensive, they lead to improved degradation of the material and consequently to higher gas yields. Growing market importance is forecast for wastes from energy plant production, e.g. oilseed rape meal and glycerine from vegetable oil production, distiller's solubles (from grain and sugar beet) and further wastes from sugar beet processing. Many of the residual and waste materials considered are generated continuously or are even delivered to the plants. This reflects positively on the costs and labour input. The use of very energy-rich substrates such as animal fats and glycerine might require higher monitoring and controlling inputs for the biogas plant, which is rated negatively.

Conclusions

The residual materials offered on the market display a large bandwidth of material properties and characteristics. However, where the cost effectiveness of a biogas plant is calculated with the renewable primary products bonus, many of the residual materials listed cannot be used in biogas plants. Especially in connection with increasing energy plant production (biomethanol and biodiesel), large quantities of residual materials with good to very good production potentials for biogas and electricity yield are generated. A cost effectiveness calculation must take into account in this connection that if for example distiller's solubles from bioethanol production and beet smalls are used in biogas plants, the renewable primary products bonus will be lost in the long term. The Fertiliser Regulation (DüMV) [9] also allows recycling of various animal by-products as constituents of fertilisers, provided that these materials are subjected to appropriate hygiene treatment. Although these residual materials contain a high energy potential, they have so far not been taken into account in the Renewable Energy Source Act. From case to case using these materials in biogas plants can certainly be cost effective.

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