POTENTIAL of Co-DIGESTION

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Biogas Plants in Austria - Dec. 2003

Source	Number of Plants	Mio m³ Biogas per Year	% of Total Biogas
Landfills	62 Grey Waste - Landfill Gas Rec. Pl.	45-100	32
Sewage sludge	134 Sewage sludge digesters	75 - 100	38
Agriculture	119 Biogas- u. Co-Fermentation Plants	43-65	23
Industry	25 Anaerobic Waste-water Treatment Pl.	9 - 14	5
Municipalities	4 Biowaste Digestion Plants	5 - 6	2
TOTAL		177 - 285	100

Energy Policy affecting Biogas Dissemination

Elektrizitätswirtschafts- und Organisationsgesetz (ElWOG) BGBl. I Nr. 1998/143

Ökostromgesetz BGBl. I Nr. 2002/149

Austrian Eco Electricity Act (2002):

POWER (kW)	FIXED RATE (€ / kWh)*
< 100	0.165
100 - 500	0.145
500 - 1,000	0.125
> 1,000	0.123

*) 25 % reduction in case of co-digestion of defined co-substrates; consent must be achieved by end of 2004

Estimation of Biogas Trends

673 Mio m^3 /a Biogas from manure **2.844 GWh /a** (Electricity and Heat) from manure and Co-substrates **13.618-46.096** Biogas plants to be built	Amon (1998)
11.600 GWh /a (Electricity and heat) from 25 Mio t manure and 15 Mio t Plants **3.000-6.000** Biogas plants to be built	Amon (2001)
175 Biogas Plants each with 300 $kW_{el.}$ until 2009 (~**60 Mio m^3 /a** Biogas)	Agricultural Chamber Austria (2003)
111-173,5 Mio m^3 /a Biogas can be recovered additionally from landfills, Co-Fermentation, Industrial Wastes, Municipal Biowastes and Renewable Biomass (current Biogas Production in Austria is ~177 – 285 Mio m^3 /a)	Braun (2004)

Share of various Non Hydropower Renewable Energy Sources in Austria (%)

Firewood	*60.3*
Municipal waste, sludge, slops	*20*
Straw, sewage digestion and landfill gas	*13.8*
Heat pump (air)	*3.7*
Solar energy	*1*
Biogas	***0.8***
Rape oil	*0.3*
Geothermal heat	*0.1*

100 % = 143 PJ
(=12 % of total PED)

Biogenic Wastes investigated at IFA Tulln

	Biogas yield (batch tests) [$m^3 . kg^{-1} VS_{add.}$]	Minimum residence time (continuous cultivation) [days]
Animal fat	1.00	33
Flotation sludge	0.69	12
Stomach- and gut contents	0.68	62
Blood	0.65	34
Food leftovers	0.47 –1.1	33
Food leftovers (Fast Food)	0.693	35
Rumen contents	0.35	62
Primary industrial sewage sludge	0.30	20
Secondary sludge (municipal)	0.2 - 0.35	20
Egg residues (pharmceutical)	0.97	45
Blood plasma	1.36	45
Fermentation slops	0.85	35
Molasses distillery slops	0.42	14
Maize distillery slops	0.4	21
Potato distillery slops	0.47	10

Table cont.

Biogenic waste	**Biogas yield (batch tests) [m^3 . kg^{-1} $VS_{add.}$]**	**Minimum residence time (continuous cultivation) [days]**
Market waste	0.90	30
Municipal biowaste (source sep. collection)	0.40	27
Biowaste (31 %) + Sewage sludge (69%)	0.54	30
Maize (whole corn)	0.648	20
Potato waste (Chips res.)	0.692	45
Potato waste (peelings)	0.898	40
Waste edible oil	1.104	30
Chipboard manufacturing wastewater	0.893	14

Survey of co-digestion experiments performed with different co-substrates in Austrian full scale sewage sludge digesters and in pilot plants at the Institute for Agrobiotechnology (IFA) Tulln, Austria

(P_G – Biogas productivity related to the reactor volume)

Reactor type	Digester Volume	P_G - Sewage sludge ($m^3.m^{-3}.d^{-1}$)	Co-substrate addition (% v/v)	P_G - Total ($m^3.m^{-3}.d^{-1}$)	P_G – Increase (%)
Sewage sludge digester, Schwechat	2 x 4,500 m^3	0.5	15 % Fat scraper contents, leather fleshings	1 – 1.3	100 - 160
Sewage sludge digester, Tulln	620 m^3	0.5	4 % Plasma protein residues	0.9	80
Sewage sludge pilot plant, Graz	4.4 m^3	0.47	5- 20 % Poultry slaughter-house flotation sludge	0.9-1.5	90 - 220
Cattle manure pilot plant, IFA Tulln	6.2 m^3 and 100 m^3	0.17	10 % Plasma protein residues	0.68	400
Sewage sludge pilot plant, IFA-Tulln,	6.6 m^3	0.49	11 % Biowaste, 4 % Food leftovers	1	100
Laboratory experi-ments, IFA Tulln	2 L	0.6	30 % Source separated biowaste (Press water)	1.6	160

Factors influencing co-digestion overall economy

Factor	Impacts
EU- and national waste management legislation	Allowable waste type and share; Quality requirements; Hygienisation requirements
EU- and national environmental legislation	Waste air treatment; Plant operational requirements; Heavy metal limits etc.
Waste collection and waste composition	Impurities ; Contaminants ; Recyclable contents
General waste treatment costs and gate fees for co–substrates	Availability and gate fees (costs) of wastes for co–digestion; Transportation costs
Waste pre-treatment and sterilization requirements	Content of impurities and contaminants; Hygienic status
Additional digester equipment requirements for co–substrate receiving digesters	Sorting; Sieving; Filtration; Homogenisation; Storage capacity; Mixing; Post treatment; Hygienisation; Dewatering equipment
Volumetric limits of co-substrate addition	Legislation; Maximum volumetric loading
Substrate degradation efficiency and biogas yield	Organic content; Degradeability; C:N:P - proportion
Degree of use and cost efficiency of using the end products biogas and digestate	Obtainable prices for biogas, electricity, heat and compost
End product upgrading costs	Biogas purification requirements; Digestate handling requirements (direct land application possible?); Composting required?
Effluent treatment costs	Wastewater; Waste gas (biofilter)

Evaluation of organic resources for a possible use in anaerobic digestion

(NPR = No Pretreatment Required)

Material	excellent	good	poor	Remarks
Biogenic materials from agriculture				
Straw and other fibrous plant residues			+	Chopping or grinding recommanded
Green plant material, crops, grain, silages		+		Chopping required, disturbing sand, stones,scum lyer formation can occur
Silage leachate	+			NPR
Harvest residues		+		Chopping required, disturbing sand, stones
Animal manure[1]				
Chicken manure		+		Inhibiting NH_3-contents can occur
Liquid piggery manure	+			NPR
Cow manure		+		Chopping of bedding straw
Animal manure from other animals		+		-"-
Industrial and trade waste				
Food industry waste				
Expired food		+		Expensive unpacking required
Dough, confectionary		+		Liquefaction (dilution) required
Whey	+			NPR
Residues from canning & frozen foods		+		Expensive unpacking required
Residues from fruit juice production		+		Chopping adviseable
Yeast and yeastlike products	+			NPR
Yeast- and coolersludge from breweries	+			NPR
Sludge from wineproduction	+			NPR
Sludge from distilleries	+			NPR
Fruit-, Corn- and Potatoslops	+			NPR

TABLE (cont.)

Material	excellent	good	poor	Remarks
Other fermentation wastes	+			
Residues from animal feed production				
Expired feed		+		Pretreatment case dependent
Animal- and slaughterhouse wastes				
Slaughterhouse waste[1]				
Animal fat	+			Scum layers can occur
Flotation sludge	+			Scum layers can occur
Stomach- and gut - contents		+		Hygienization may be required
Blood	+			NPR, High NH_3 conc. can occur
Fish - waste		+		Grinding adviseable
Chicken - waste		+		Scum layers can occur (fat, feathers)
Animal wastes[1]				
Animal parts			+	Obligatory delivered to rendering plants
Animals from confiscation			+	Obligatory delivered to rendering plants
Carcasses			+	Obligatory delivered to rendering plants
Animal homogenisate from rendering		+		Obligatory delivered to combustion
Wastes from plant and animal fat prod.				
Spoilt plant oils	+			Scum layers can occur
Oil seed residues		+		Scum layers can occur
Fat trap contents		+		Scum layers and fat hardening can occur
Fats		+		Scum layers and fat hardening can occur
Oil containing bleaching earth	+			High inert materials content

TABLE (cont.)

Material	excellent	good	poor	Remarks
Edible oil sludge	+			Scum layers can occur
Edible fat sludge	+			-"-
Pharmaceutical wastes				
Proteineous wastes	+			Inhibiting NH_3-contents can occur
Bacterial cells and fungal mycelium	+			Hygienization may be required
Wastes from other trade				
Food leftovers from restaurants, large kitchens, refectories[1]		+		Impurities separation (metals, plastics, bones) and hygienization required
Catering and airport food leftovers[1]			+	Obligatory incineration
Wastes from leather production and processing				
Leather-, tissue-, gelatine residues		+		Poor degradable contents, high salt- and heavy metal (chromium) content
Pulp- and paper industry wastes		+		High fibre (cellulose) content, bactericidal agents from pulp additives
Municipal wastes				
Wastes from source sep. collection				
Biogenic wastes		+		Extended impurities separation required
Garden- and yard wastes			+	Chopping and impurities separation
Market wastes		+		Chopping and impurities separation
Wastes from wastewater treatment				
Primary sludge	+			NPR
Surplus sludge	+			NPR

TABLE (cont.)

Material	excellent	good	poor	Remarks
Decentralized sewer wastes	+			NPR
Oil- and fattrap wastes		+		Scum layers and hardening can occur
Other Wastes				
Sludge from gelatine production	+			NPR
Sludge from starch production	+			NPR
Residues from potato starch production	+			NPR
Residues from maize starch production	+			NPR
Residues from rice starch production	+			NPR

[1)] Requirements of the Animal By-products Regulation (EC) 1774/2002 have to be followed

Economic evaluation of 3 selected farm scale Co – digestion plants

Parameter	**Plant 1**	**Plant 2**	**Plant 3**
DIGESTER VOLUME (m^3)	100	235	1,200
MAIN SUBSTRATE	Cattle manure	Piggery manure	Piggery manure
Co – SUBSTRATE	Industrial waste	Food leftovers (15%), Harvest residues (2%)	Industrial waste
INVESTMENT COSTS (Euro)	**345,202**	**145,349**	**90,900**
SUBSIDIES (Euro)	**72,674**	**36,337**	**n.a.**
NET ENERGY (kWh / a)	273,600	75,000 (Electricity)	203,178
ELECTRICITY RATES (Euro cents / kWh)	Solely thermal use	7.63-10.2	13 - 17
RUNNING COSTS (Euro / a)	**6,541**	**12,636**	**8,367**
Labour	5,305	11,125	n.a.
Maintenance	292	1,090	8,367
Various	945	421	n.a.
INCOME (Energy, Euro / a)	7,953	6,677	37,598
INCOME (Co - substrates)	29,070	13,808	n.a.
TOTAL INCOME (Euro / a)	**37,023**	**20,485**	**37,598**
NET MARGIN (Euro / a)	**30,482**	**7,849**	**29,231**

n.a. – not available

***Economic evaluation of 3 selected farm scale energy crop* Co – digestion plants**

Parameter	**Plant 4**	**Plant 5**	**Plant 6**
DIGESTER VOLUME (m^3)	400	560	700
MAIN SUBSTRATE	Grass or grass silage (40 %)	Maize silage (75%)	Corn silage
Co – SUBSTRATE	Industrial waste (60%)	Harvest residues 20%, green cut 3% , others 2%	manure
INVESTMENT COSTS (Euro)	**872,093**	**254,354**	**250,000**
SUBSIDIES (Euro)	**218,023**	**97,096**	**50,000**
NET ENERGY (kWh / a)	454,060 (Electricity)	497.940kWh/a	750,000
ELECTRICITY RATES (Euro cents / kWh)	6.18 - 9.45	8 cents	10.23
RUNNING COSTS (Euro / a)	**30,000**[1)]	**10,900**	**58,200**
Labour	n.a.	n.a.	9,000
Maintenance	n.a.	n.a.	750
Various	n.a.	n.a.	48,450
INCOME (Energy, Euro / a)	32,174	39.835	78,225
INCOME (Co - substrates)	64,000	0	0
TOTAL INCOME (Euro / a)	**96,174**	**39835**	**78,225**
NET MARGIN (Euro / a)	**66,174**	**28,935**	**20,025**

n.a. – not available; [1)] estimated

Economic evaluation of 3 selected large scale, centralized (CAD) plants

Parameter	**Plant 7**	**Plant 8**	**Plant 9**
DIGESTER VOLUME (m^3)	4650	6,600	5,500
MAIN SUBSTRATE	Manure	Piggery manure	Fat waste
Co – SUBSTRATE	Industrial waste	Industrial waste (20 %)	Food industry waste
INVESTMENT COSTS (Euro)	**5,023,000**	**5,493,300**	**1,023,000**
SUBSIDIES (Euro)	**2,000,000**	**0**	**122,710**
NET ENERGY (kWh / a)	13,939,000	23,203,000	2,000,000
ELECTRICITY RATES (Euro cents / kWh)	8 – 8.7	8 – 8,7	10,23
RUNNING COSTS (Euro / a)	**989,999**	**452,132**	**74,000**
Labour	350,000	164,666	n.a.
Maintenance	293,230	124,000	n.a.
Various	346,769	163,466	n.a.
INCOME (Energy, Euro / a)	1,163,923	905,200	204,600
INCOME (Co - substrates)	417,000	146,000	240,000
TOTAL INCOME (Euro / a)	**1,518,154**	**1,051,200**	**444,600**
NET MARGIN (Euro / a)	**528,155**	**599,068**	**370,600**

n.a. – not available

Conclusions

BENEFITS

Better nutrient balance

Improved co-substrate handling

Improved fluid dynamics

Improved biogas yield

Less residual solids to be treated

Improved process economics

REQUIREMENTS

Additional technical equipment

Contaminant removal

Homogenization, mixing

Hygienization requirements

Extended land requirement for digestate

Limited quantity of high quality wastes

Viability of „Energy Crops“ digestion

depends on high electricity tariffs