Deliverable D16 B3

Report on the use of slurry derived fraction in biogas plants

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Definition

Slurry: livestock faeces. Cattle slurry has average total solids around 9%.

Manure: mix of livestock faeces and straw, average total solids around 18-20%

Shredded manure: Manure subjected to cleaning (removal of stone and metals) and shredding to shorten straw length, in order to be suitable for biogas plant.

Slurry-manure derived fractions: fractions derived from slurry and manure thanks to a specific treatment. Slurry-manure derived fractions are: **Shredded manure**, **Separated Solid fraction of slurry, Cavitated slurry -manure mix.**

Separated solid fraction of slurry: fraction of slurry separated from liquid to be suitable for transport and delivery to biogas plant. An average total solid of this fraction is 16-18%.

Cavitated slurry-manure mix: mix of slurry and manure, which undergo treatment in the prototype device to be realized in the project. The objective of the treatment is to make the materials more suitable for biogas plant , i.e. produce a material with high total solids content, high homogeneity, high digestibility, and pumpability up to 16% of total solids. Foreseen average content of total solids 13-16%.

Introduction

The B3 action within LIFE DOP project has the aim to highlight if the use of slurry and manure-derived material in biogas plants is possible, effective and if has any counter effects.

The main features to monitor are the quality of feeding mix, the quality of digestate (especially TS and Nitrogen) and of course the general functioning of the plant in relation to the feeding mix.

The main questions for answers are:

- Is the substitution of silage maize with slurry and manure-derived products affecting the general functioning of the biogas plant?
- Is the plant consuming more energy for mixing, and if yes is it a cost-effective action?
- Is the increase of nitrogen and ammonia proper for the plant?
- Is the plant working in stable and balanced condition?

- Is the cost-benefit balance positive for the biogas plant?

Materials and methods

Two different anaerobic digestion plants were monitored during the substitution of silage maize with slurry and manure-derived fractions for the production of biogas.

Biogas plant 1: the plant is situated has an installed capacity to generate energy of 999kw, is composed by 4 digesters, 2 primary fermenters (2500 m^3 volume each), 1 secondary digester and 1 post fermenter (2500 m^3 volume) for a total volume of 10.000m^3.

The base of the feeding mix is composed of silage maize. The input of the slurry-manure derived fraction in the plant has reached 75% of the total feeding mix during the monitoring activity. The average temperature of material in the digesters is set at 42°C.

The biogas is used in a CHP (Combined Heat and Power) unit to produce electric energy that is fed in the grid. The biogas is cooled up to 6 °C and the H_2S is removed thanks to air flowing in the digesters.

Biogas plant 2: the plant has an installed capacity to generate energy of 999kw, is composed by 3 digesters, 2 primary fermenters (4000 m^3 volume each), 1 secondary digester (4000 m^3 volume) for a total volume of 12.000m^3.

The base of the feeding mix is composed of silage maize. The input of the slurry-manure derived fraction in the plant has reached 80% of the total feeding mix during the monitoring. The average temperature of material in the digesters is set at 45°C.

The biogas is used in a CHP (Combined Heat and Power) unit to produce electric energy that is fed in the grid. The biogas is cooled up to 4-8 °C and the H_2S is removed thanks to air flowing in the primary digesters.

The data were monitored on site (amount of input materials, energy production, digestate production, quality of produced biogas, energy consumption for funning the plant, i.e. mixing and feed loading) and on collected samples analysed in lab.

Samples were analysed according to the standard methods indicated in table 1

Table 1: methods used in the monitoring

Parameter	Method
pH	CNR IRSA n 64 1985
Total Solids (%)	CNR IRSA n 64 1985
Volatile Solids(%ST)	ANPA 2001
Total Kieldal Nitrogen (%ST)	G.U. 180 5 Aug. 1986
Ammonia Nitrogen (mg/l)	CNR IRSA n 64 1985
Total Phosphorus	EPA 1996.
ABP	Schievano et al. 2008

Results

Biogas plant 1

Feeding mix of the plant and characterisation of input materials

The mass inputs of the plant 1 are reported in table 2.

Table 2: input materials of biogas plant 1

Date	Silage maize	Cattle slurry	Separated Solid fraction of cattle slurry	Total input	Slurry-manure derived fraction on total input
	Tons/month	Tons/month	Tons/month	Tons/month	%
Baseline only corn silage used	**1500**	**0**	**0**	**0**	**0**
9/16	1313	600	0	1913	31%
10/16	1236	780	389	2405	49%
11/16	1044	750	600	2394	56%
12/16	1077	690	580	2347	54%
1/17	1089	649	567	2304	53%

2/17	1016	612	520	2149	53%
3/17	1174	831	483	2488	53%
4/17	1087	888	586	2561	58%
5/17	1065	954	652	2671	60%
6/17	1096	959	469	2524	57%
7/17	1150	758	491	2399	52%
8/17	1267	616	137	2021	37%
9/17	1187	649	295	2131	44%

The materials fed in the digesters where maize, cattle slurry produced nearby the farm and solid fraction of cattle slurry, coming from a longer distance.

The baseline to compare results is the plant when only corn silage is used, i.e. a supply of maize of 18.000 tons/year.

The total amount of slurry and manure-derived fraction was equal to 60% of the total feeding mix at the higher level of substitution tested in the first year of the trial.

The addition of slurry derived fractions allowed to save almost 435 tons of silage maize/month (max replacement) i.e. a maize substitution of 32% respect to baseline

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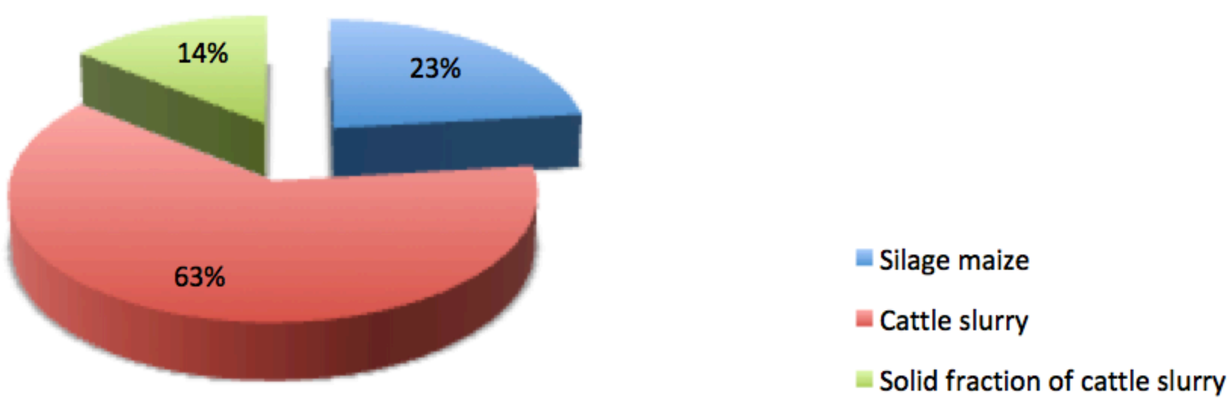

Figure 1: average composition of feeding mix during the trial period

Characterisation of input materials

In table 3 and 4 are reported the biochemical data of the feeding materials

Table 3: average value of chemical characterisation of the biomass fed in the digesters (data from 13 samples)

	pH			TS (%)			VS (%TS)		
Silage maize	3.8	±	0.11	34	±	7.9	95.6	±	0.4
cattle slurry	8.5	±	1.03	7.4	±	1.2	87.7	±	2.6
Solid fraction of cattle slurry	8.3	±	0.66	21.7	±	9.4	81.8	±	1.9

Table 4: average value of chemical characterisation of the biomass fed in the digesters (data from 13 samples)

	TKN (% w.w.)			NH3 (mgL^{-1})			P (%w.w)			ABP ($NlkgTS^{-1}$)			ABP ($Nlkg^{-1}$)
Silage maize	0.42	±	0.05	369	±	69	0.06	±	0.01	690	±	63	235
cattle slurry	0.41	±	0.05	1791	±	116	0.06	±	0.01	337	±	28	25
Solid fraction of cattle slurry	0.44	±	0.03	1142	±	470	0.07	±	0.01	368	±	17	80

ABP: Anaerobic Biogas Potential

Silage maize was characterised by high variability in the content of total solids (from 38% to some samples of 23%) this of course influence the biogas production and may cause different maize consumption in different months of functioning.

Stability of the process and data from digesters

In table 5 are reported the data measured from samples collected from the primary digesters. The data are useful to evaluate the state of the biological process.

Table 5: data from the materials collected inside the digesters. Process parameter

	pH	TS%	VS (%TS)	VFA (mg.acetic ac L^{-1})	Total alkalinity CaCO3 (mgL^{-1})	VFA/alk	TKN (% w.w.)	NH3 (mg/l)	N-NH_3/TKN
Digester1									
9/16	8.10	6.01	71.15	934	11945	0.08	0.33	1330	40%
10/16	8.16	7.23	74.6	1173	10868	0.11	0.36	1454	40%
11/16	8.05	6.83	74.1	1017	9477	0.11	0.38	1593	42%
12/16	7.84	6.92	75.3	1034	14384	0.07	0.39	1784	46%
1/17	8.9	6.95	76.14	2056	15725	0.13	0.38	1762	46%
2/17	8.12	7.46	72.81	1360	13480	0.10	0.35	1706	49%
3/17	8.14	7.47	73.18	1528	14279	0.11	0.38	1759	46%
4/17	8.06	8.14	72.13	1264	13456	0.09	0.4	1627	41%
5/17	8.16	7.88	70.82	1129	13015	0.09	0.42	1937	46%
6/17	8.14	6.65	70.03	1249	16058	0.08	0.42	1897	45%
7/17	7.86	7.73	71.18	1380	13308	0.10	0.39	1735	44%
8/17	8.06	7.04	70.85	1350	14038	0.10	0.38	1700	45%
9/17	7.98	7.21	69.88	1038	13458	0.08	0.38	1695	45%
Digester 2									
9/16	8.51	6.13	66.88	915	11945	0.08	0.34	1482	44%
10/16	8.16	6.87	77.58	1173	10759	0.11	0.36	1632	45%
11/16	7.89	7.03	69.65	1056	9287	0.11	0.39	1648	42%
12/16	8.31	7.20	74.55	972	14384	0.07	0.37	1885	51%
1/17	8.72	6.60	73.09	2035	14782	0.14	0.36	1682	47%
2/17	8.44	7.31	70.63	1319	12671	0.10	0.35	1677	48%
3/17	8.47	7.77	74.64	1559	14136	0.11	0.36	1673	46%
4/17	7.98	7.90	75.02	1289	13052	0.10	0.4	1712	43%
5/17	8.00	7.64	71.53	1152	12234	0.09	0.4	1884	47%
6/17	8.63	6.45	69.33	1274	15255	0.08	0.43	1823	42%
7/17	8.17	7.88	68.33	1366	13042	0.10	0.37	1871	51%
8/17	8.46	7.04	71.56	1350	14600	0.09	0.38	1756	46%
9/17	8.14	7.35	69.18	1586	12651	0.13	0.38	1726	45%

Data from the monitoring of samples from the primary digesters outline that there is no perturbation in the biological system due to the addition of slurry-derived fractions. Even if the total HRT decreased due to the use of slurry derived fraction (up to 15% in some months) the process proved to be stable and effective. Is to note that even if the increase of total nitrogen was significant (see table 8) the concentration of ammonia was never able to affect the biological process of bio-methanation negatively.

Characterization of output materials: digestate

In table 6 are reported the chemical data of digestate

Table 6: digestate characterisation

Date	TS	TKN	N-NH3	NH3/TKN	P
	%	%	mgL^{-1}	%	%
9/16	5.4%	0.33%	1690	50.56%	0.04%
10/16	6.6%	0.37%	1823	49.89%	0.05%
11/16	6.6%	0.38%	2013	52.92%	0.05%
12/16	6.2%	0.37%	2029	54.38%	0.05%
1/17	6.2%	0.37%	2033	55.30%	0.06%
2/17	6.5%	0.37%	2112	57.55%	0.06%
3/17	6.8%	0.38%	2120	56.41%	0.06%
4/17	7.1%	0.39%	2186	56.29%	0.06%
5/17	7.0%	0.40%	2278	57.37%	0.06%
6/17	7.0%	0.39%	2385	60.59%	0.06%
7/17	6.8%	0.37%	2356	63.59%	0.06%
8/17	6.0%	0.34%	2291	67.06%	0.05%
9/17	6.0%	0.36%	2062	58.08%	0.08%

Plant functioning data

In table 7 are reported some relevant data on the plant functioning, such as the amount of energy produced, the amount of energy used for running the plant (mixing and feeding) and the Hydraulic Retention Time (HRT), i.e. the average number of days that the feeding materials stay in the digesters.

Table 7: data from plant running: energy production, energy consumption, HRT.

Date	Produced energy	Consumed energy for running	HRT	Methane in biogas	H2S in biogas
	kWh/month	kWh/month	Days	%	ppm
9/16	714,770	55,565	92	49	78

10/16	742,870	61,929	80	50	68
11/16	712,480	58,573	83	51	103
12/16	741,900	53,591	83	52	76
1/17	737,580	52,071	83	51	70
2/17	670,440	46,357	89	51	90
3/17	735,040	54,375	80	51	85
4/17	711,720	55,126	80	51	110
5/17	729,180	59,454	78	51	90
6/17	694,270	59,677	82	51	128
7/17	718,790	66,232	81	51	89
8/17	**703,720**	65,798	**89**	51	**110**
9/17	714,000	55,505	**87**	51	123

The biogas plant maintained the same average production (1Mw as target electric power capacity). About energy demand to run the plant, data outline that the primary cause for the increase of energy consumption for plant running is related to the ambient temperature and the cooling of the engine during summer time. Comparing annual average data on energy demand to run the plant no significant variation can be outlined. The average energy demand on an annual basis since 2015 is 8.2%±0.3 of the total energy production. In this plant, no significant variation was detected in energy demand due to the use of slurry derived fractions in the feeding mix of biogas plant.
The de-sulfuration system of the plant demonstrated to be able to keep H_2S level within a safe range in the biogas sent to the CHP unit. The biogas composition was in the general range (50±2) assessed for biogas plant running on energy crop such as maize.
Finally, HRT decreased of only 15%, a value that causes no concern for the stability of process and running of the plant.

Mass balance

In table 8 is reported the mass balance of the inputs and outputs of nutrients in the biogas plants.

Table 8: mass balance of nutrients and total solids load

Date	Feeding mix TS	TKN	P	S	Digestate TS
	Tons/month	Tons/month	tons/month	Tons/month	Tons/month
9/16	491	7.98	1.20	0.033	148

10/16	563	10.12	1.54	0.049	206
11/16	541	10.13	1.56	0.051	199
12/16	543	9.93	1.52	0.048	187
1/17	541	9.75	1.49	0.046	187
2/17	504	9.09	1.39	0.043	182
3/17	566	10.49	1.61	0.053	213
4/17	563	10.81	1.67	0.057	221
5/17	575	11.29	1.74	0.062	225
6/17	546	10.62	1.64	0.058	212
7/17	554	10.12	1.55	0.050	209
8/17	507	8.46	1.28	0.036	169
9/17	516	8.96	1.36	0.041	173

Table 9: comparison of critical parameters, baseline VS trial (data at higher maize replacement)

	Baseline	test	variation
	Ton/month	Ton/month	
Maize	1500	1016	-32%
Feeding Mix	1500	2671	78%
Feeding mix TS	495	575	16%
Digestate	2407	2843	18%
Digestate TS	152	225	48%
TKN	8	11	40%
P	1.21	1.81	50%
HRT	90	78	-13%

The mass balance outlines that:

the maximum replacement of maize by slurry derived fraction achieved in this year for the Biogas plant 1 was, around 32% of the baseline 1(biogas plant only fed by maize).

The total input of solids increased respectively of 16%

Digestate production increased by about 18%.

Total nitrogen and phosphorus input is almost 2 times the amount recorded in baseline. This increase in nutrient input allows to displace these nutrients where needed, i.e. outside the breeding district.

Biogas plant 2:

Feeding mix of the plant and characterisation of input materials

The mass inputs of the plant 2 are reported in table 10.

Table 10: input materials of biogas plant 2

Date	Silage maize	Cattle slurry	Solid fraction of cattle slurry	Manure	Total input	Slurry-manure derived fraction on total input
	Tons/month	Tons/month	Tons/month	Tons/month	Tons/month	%
Baseline only corn silage use	**1500**	**0**	**0**	0	1500	0%
01/09/16	1129	1450	0	0	2579	56%
01/10/16	891	1480	350	811	3532	75%
01/11/16	863	1408	380	825	3476	75%
01/12/16	880	1293	403	845	3421	74%
01/01/17	845	1607	560	935	3947	79%
01/02/17	818	1562	385	763	3528	77%
01/03/17	767	1645	666	928	4006	81%
01/04/17	724	1645	695	925	3989	82%
01/05/17	725	1695	650	903	3973	82%
01/06/17	701	1700	786	888	4075	83%
01/07/17	761	1655	656	915	3987	81%
01/08/17	637	1663	873	1170	4343	85%
01/09/17	676	1655	896	1062	4289	84%

The material fed in the digesters where silage maize, cattle slurry, solid fraction of cattle slurry and manure.

The total amount of slurry and manure-derived fraction was equal to 80% of the total feeding mix at the higher level of substitution tested in the first year of trials. The addition of slurry derived fractions allowed to save almost 863 tons of silage maize/month, i.e. a maize substitution close to 58%.

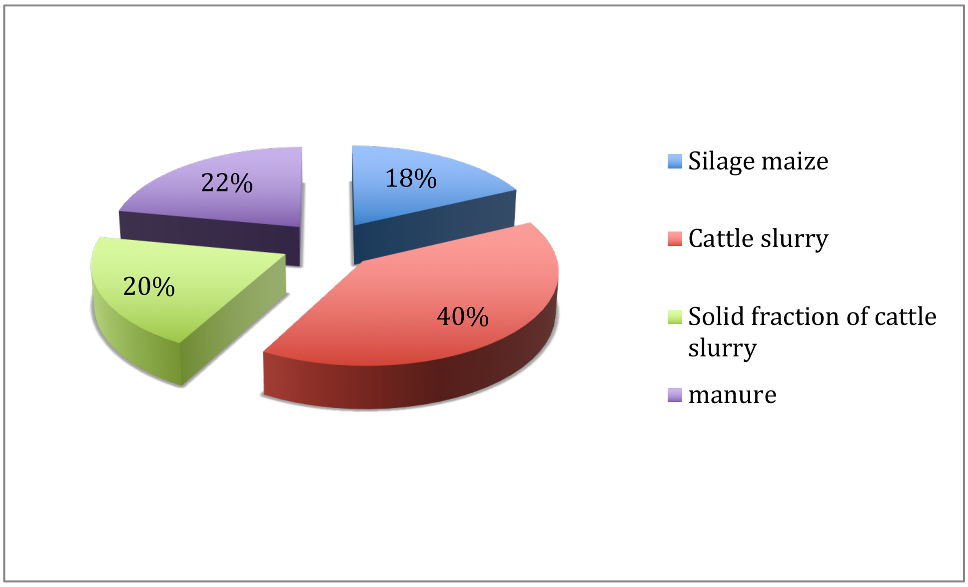

Figure 2: composition of feeding mix at the end of the trials

Characterisation of input materials

In table 11 and 12 are reported the biochemical data of the feeding materials during the testing period.

Table 11: average value of chemical characterisation of the biomass fed in the digesters (data from 12 samples)

	pH			TS (%)			VS (%TS)		
Silage maize	4.2	±	0.09	31.5	±	2.12	95.6	±	0.4
cattle slurry	8.4	±	0.95	8.7	±	4.19	85.8	±	1.3
Solid fraction of cattle slurry	8.4	±	0.86	19.3	±	6.28	84.7	±	2.4
Manure	8.12	±	0.86	18.8	±	3.96	84.96	±	3.1

Table 12: average value of chemical characterisation of the biomass fed in the digesters (data from 12 samples)

	TKN (% w.w.)			NH3 (mgL^{-1})			P (%)			BMP ($NlkgTS^{-1}$)		

Silage maize	0.42	±	0.12	284	±	58	0.06	±	0.01	704	±	83
cattle slurry	0.39	±	0.09	1784	±	165	0.07	±	0.01	330	±	28
Solid fraction of cattle slurry	0.44	±	0.15	1927	±	204	0.07	±	0.01	363	±	37
Manure	0.46		0.02	1559	±	124	0.07	±	0.01	354	±	18

Stability of the process and data from digesters

In table 13 are reported the data measured from samples collected from the primary digesters. The data are useful to evaluate the state of the biological process.

Table 13: data from the materials collected inside the digesters. Process parameter

	pH	TS (%)	VS (%TS)	VFA (mg.acetic acid L^{-1})	Total alkalinity CaCO3 (mgL^{-1})	VFA/alk	TKN (% w.w.)	NH3 (mgL^{-1})	N-NH3/TKN
Digester 1									
9/16	8.23	7.15	74.00	1046	10989	0.10	0.3	1676	56%
10/16	8.25	9.18	77.58	1302	11194	0.12	0.37	1974	53%
11/16	8.12	6.90	77.81	1119	8719	0.13	0.38	2086	55%
12/16	8.2	7.68	79.82	1168	16110	0.07	0.4	2420	62%
1/17	8.04	7.51	78.42	2200	16669	0.13	0.38	2374	62%
2/17	8.24	8.43	69.90	1523	14424	0.11	0.37	2362	64%
3/17	8.12	7.84	79.77	1436	15992	0.09	0.4	2461	62%
4/17	8.08	8.47	73.57	1251	13052	0.10	0.44	2391	55%
5/17	8.31	9.38	69.40	1163	14186	0.08	0.42	2716	65%
6/17	8.16	8.38	67.23	1261	17664	0.07	0.39	2442	62%
7/17	7.08	9.59	71.89	1518	12643	0.12	0.39	2498	65%
8/17	8.28	8.80	75.10	1242	15442	0.08	0.42	2420	58%
9/17	8.27	8.08	67.78	1111	14938	0.07	0.43	2589	60%
Digester 2									
	pH	TS (%)	VS (%TS)	VFA (mg.acetic acid L^{-1})	Total alkalinity CaCO3 (mg/l)	VFA/alk	TKN (% w.w.)	NH_3 (mg/l)	N-NH3/TKN
9/16	8.39	6.87	73.48	1015	10440	0.10	0.29	1644	56%

10/16	8.00	9.37	72.93	1302	11418	0.11	0.39	2013	52%
11/16	7.88	6.97	78.58	1108	9765	0.11	0.36	1806	51%
12/16	7.95	7.37	71.41	1087	11466	0.09	0.43	1985	46%
1/17	8.36	7.58	73.72	1486	16769	0.09	0.39	1844	47%
2/17	8.08	8.51	69.90	1478	12145	0.12	0.33	2056	63%
3/17	8.44	7.61	72.16	1465	17112	0.09	0.41	2029	50%
4/17	8.24	8.38	76.52	1139	12661	0.09	0.45	1999	45%
5/17	7.98	8.91	71.49	1128	13335	0.08	0.42	2637	63%
6/17	8.49	8.38	65.21	1261	19783	0.06	0.45	2571	57%
7/17	6.94	9.01	74.05	1609	12895	0.12	0.39	2220	57%
8/17	8.36	8.45	71.35	1317	15905	0.08	0.39	2090	54%
9/17	8.19	7.83	65.07	1200	15984	0.08	0.45	2147	55%

Data from the monitoring of the material inside the primary digesters outline that there is no perturbation in the biological system due to the higher addition of slurry-derived fractions. Even if the use of slurry derived fraction decreases the total HRT (up to 34%) the process proved to be stable and effective.

Plant Characterization of output materials: digestate

In table 14 are reported the chemical data of digestate

Table 14: digestate characterisation

Date	TS	TKN	N-NH3	NH3/TKN	P
	%	%	mgL^{-1}	%	%
9/16	7.1%	0.44%	2284	52%	0.44%
10/16	8.3%	0.47%	2782	59%	0.47%
11/16	8.3%	0.47%	2849	60%	0.47%
12/16	8.1%	0.46%	2940	63%	0.46%
1/17	8.6%	0.48%	2833	59%	0.48%
2/17	8.9%	0.48%	2806	58%	0.48%
3/17	9.0%	0.49%	2785	57%	0.49%
4/17	9.1%	0.49%	2986	60%	0.49%
5/17	8.9%	0.50%	3061	62%	0.50%
6/17	9.3%	0.50%	2950	59%	0.50%
7/17	9.2%	0.49%	2964	60%	0.49%
8/17	9.8%	0.50%	2791	56%	0.50%
9/17	7.9%	0.50%	2762	55%	0.50%

Plant functioning data

In table 12 are reported some relevant data on the plant functioning, such as the amount of energy produced, the amount of energy used for running the plant (mixing and feeding) and the Hydraulic Retention Time (HRT), i.e. the average number of days that the feeding materials stay in the digesters.

Table 15: data from plant running: energy production, energy consumption, HRT.

Date	Produced energy	Consumed energy for running	HRT	Methane in biogas	H2S in biogas
	kWh/month	kWh/month	Days	%	ppm
09/16	608,098	39,526	108	50	188
10/16	701,789	42,107	87	50	116
11/16	690,805	45,593	88	51	118
12/16	712,975	39,214	87	52	106
1/17	741,234	44,474	79	51	149
2/17	637,838	39,546	89	51	194
3/17	711,493	44,113	79	51	459
4/17	689,508	41,370	80	51	154
5/17	696,668	44,587	81	51	193
6/17	688,394	44,746	79	51	93
7/17	687,309	48,799	80	51	147
8/17	691,487	42,872	**74**	51	148
9/17	706,924	44,536	**75**	51	178

The biogas plant maintained the same average production (1Mw as target electric power capacity). About energy demand to run the plant, no variation was detected in energy demand due to the use of slurry derived fractions in the feeding mix of biogas plant. This may be due to some updates in the plant equipment that decreased the energy demand compared with previous years. This ugrade of the plant, unfortunately, does not allow to make proper data comparisons. In any case, the staff of the biogas plant reported that some setting of the digester's mixers (time on and off) may allow significant improvement even when using a high amount of slurry and manure-derived fractions in the feeding mix

The desulphurization system of the plant demonstrated to be able to keep H_2S level within a safe range in the biogas sent to the CHP unit. The biogas composition was in the general range (50±2) assessed for biogas plant running on energy crop such as maize.

Finally, HRT decreased of only 34%, but no adverse effects were detected in the digesters and in the biological parameters of samples.

Mass balance

In table 13 is reported the mass balance of the inputs and outputs of nutrients in the biogas plants.

Table 16: mass balance of nutrients and total solids load

Date	Feeding mix TS	TKN	P input	S input in the digester (from biomass)	Soluble S	Digestate TS produced in 1 month
	tons/month	tons/month	tons/month	tons/month	kg/month	tons
9/16	482	10.40	1.66	0.070	190	482
10/16	623	14.80	2.35	0.078	286	623
11/16	616	14.60	2.32	0.076	285	616
12/16	620	14.42	2.28	0.071	278	620
1/17	683	16.61	2.65	0.088	327	683
2/17	606	14.75	2.36	0.082	299	606
3/17	681	16.87	2.69	0.092	339	681
4/17	672	16.80	2.69	0.093	341	672
5/17	664	16.70	2.67	0.094	330	664
6/17	681	17.15	2.75	0.097	350	681
7/17	675	16.78	2.68	0.092	345	675
8/17	725	18.43	2.94	0.097	393	725
9/17	721	18.16	2.90	0.097	317	721

Table 17: comparison of critical parameters, baseline VS trial (data at higher maize replacement)

	Baseline Ton/month	Test Ton/month	Variation
Maize	1500	637	-58%
Feeding mix TS	495	735	48%
Digestate	2416	3750	55%
Digestate TS	161	403	151%
TKN	6.30	18.43	193%
P	0.90	2.94	227%
HRT	109	73	-33%

The mass balance provides some useful information:

The replacement of maize by slurry derived fraction achieved in this first period was around 44%

The total input of solids increased of 58%

Digestate production increased of about 55%, but the total solids amount in digestate more than doubled.

Total nitrogen input is almost 3 times the amount that is introduced without any slurry fractions, the same for phosphorus. This increase in nutrient input can be an advantage if there is the possibility to displace these nutrients where needed, i.e. outside the breeding district.

Economic evaluation

The substitution of maize has generated for biogas 1 and 2 this economics:

Table 18: economic data for plant 1

Average maize demand (baseline, only corn used)	tons/month	18000
Saved maize	tons/month	484
Money saved from maize	euros/month	21762
Money spent for slurry transport, treatment and farmer reward	euros/month	11607
Total saving for biogas plant	euros/month	10156
Total money for farmers selling manure	euros/month	4352
Money for slurry treatment and transport	euros/month	7254

Table 19: economic data for plant 2

Average maize demand (baseline, only corn used)	tons/month	18000
Saved maize	tons/month	863
Money saved from maize	euros/month	38814
Money spent for slurry transport, treatment and farmer reward	euros/month	20701
Total money for farmers selling manure	euros/month	7763
Money for slurry treatment and transport	euros/month	12938

By the point of view of technical evaluation, process parameter and production, the synthesis of relevant criteria to be taken into account is reported in table 15

Table 20: technical criteria to evaluate the use of slurry derived fraction in digesters

Parameter	Criteria for positive assessment	Biogas plant 1	Biogas plant 2
Energy demand increase	<5-7% of baseline	Not detectable	Not detectable due to upgrade in plant equipment
Stability of process	Yes	yes	yes
Increase in digestate volume	<30%	17%	40%
Increase in the amount of nitrogen	To be evaluated	2 fold increase	3 fold increase
Concentration of ammonia in digesters	< 3000 mg/l	<3000	<3000
Stop of running due to maize substitution with slurry and manure-derived fraction	No	No	No
Savings compared with maize	<5-7% of baseline	Not detectable	Not detectable

The substitution of silage maize with slurry derived fractions in the two biogas plants was (According to the outlined numbers) :

Feasible by the point of view of the technical parameters in plant running (table 15)

Economically valuable for biogas plants and farmers, as the expenses for slurry treatment and transport allowed in any case significant savings for biogas plants and new income for farmers.