INNOVATIVE PLASMA BASED TRANSFORMATION
OF FOOD WASTE INTO HIGH VALUE GRAPHITIC
CARBON AND RENEWABLE HYDROGEN

D2.1 BIOGAS GENERATION

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Project deliverable

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Instrument:	Thematic Priority
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Title
D2.1 Biogas Generation

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PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group defined by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

Abstract :

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1. OBJECTIVES

To generate representative biogas from an AD process any seasonal CH_4:CO_2 variations , noting the C:N Ratio and impurity levels versus seasonal input variations over a 12 month period and to assess and incorporate any economically viable process to remove trace impurities from biogas as may be required.

2. FEEDSTOCK

2.1. SOURCE

The feedstock is the result of collections from food manufacturers, restaurants and households (separated collections) within 35 miles of the plant.

Water is added to the feedstock to create the right level of moisture for the cultures to break down the material. This ratio is often as high 1:1 Dry matter: water.

	%Dry Matter	Organic Dry Matter (t)	Organic Loading Rate (kg/m^3)	pH	Density (kg l^{-1})	T (°C)
DECEMBER	20.89	8.55	5.70	4.14	0.96	21.56
JANUARY	22.03	7.40	4.93	4.55	0.97	20.02
FEBRUARY	20.14	6.49	4.33	4.25	0.96	19.36
MARCH	18.16	6.38	4.25	3.57	0.97	19.69
APRIL	19.65	6.75	4.50	3.86	0.96	21.80
MAY	18.51	6.81	4.54	3.80	0.99	24.33
JUNE	20.69	7.52	5.01	4.03	0.97	28.27
JULY	20.04	7.24	4.83	4.01	0.97	33.09
AUGUST	20.63	5.34	3.56	4.00	0.98	35.23
SEPTEMBER	18.80	7.57	5.05	3.76	0.99	30.90
OCTOBER	21.06	8.75	5.83	3.93	0.98	26.41
NOVEMBER	21.15	7.57	5.05	3.76	0.99	30.90

2.2. VARIATIONS

The feedstock comes from a relatively small geographic area however the composition does slightly vary due to a changing diet with the seasons.

The waste volume and gas potential remains constant as the calorific output remains constant as the essential material (Proteins, Carbohydrates and Fats) remains unchanged.

The biggest factor effecting the gas is the varying sulphur content present in the material as a result of where plant based products have been grown and the naturally occurring sulphur content taken up into the plant. The same factor can be seen in the meat produce, due to the diet it has been allowed to be fed on and the production of that same feed. In order to ensure the best gas yields this is managed carefully as discussed in section 5.0

2.3. CALORIFIC VALUES

Our technology provider has been able to provide the expected biogas yield and calorific values using the mix of material being received in the following mix:

Bread	55 %
Pastry	10 %
Cheese & Diary Products	5 %
Cooked Meat	20 %
Uncooked Meat	5 %
Cooked Vegetables	5 %

The Biogas being created per tonne is 247.75NM^3 on average with an electricity potential of 547.53kWh per tonne.

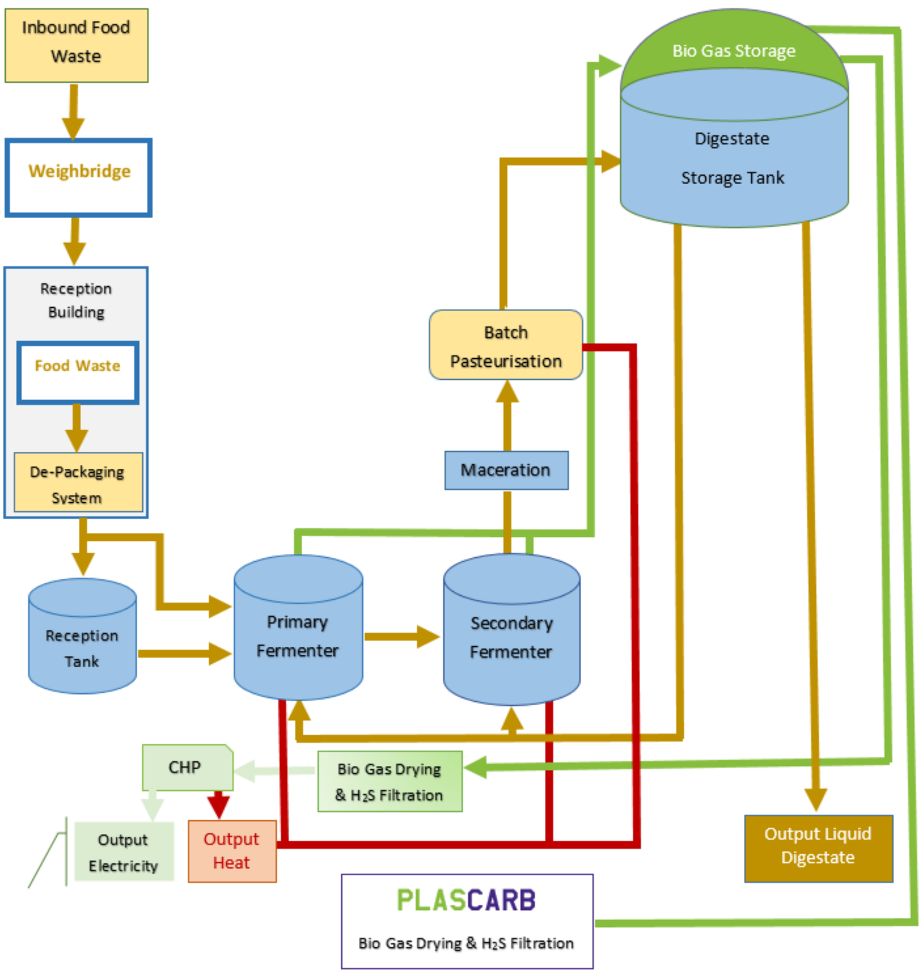
3. GENERATION OF THE BIO GAS

Food waste potentially containing packaging is received in the reception hall and checked for contaminants before being fed via a screw augur into a de-packaging plant. The augur has the effect of starting the de-packaging process by splitting packaging open allowing the organic matter to flow quickly through the de-packager.

The resultant packaging is then prepared for further treatment off site for potential recovery or conversion into Refuse Derived Fuel (RDF).

The organic matter (feedstock Soup) then flows to a holding tank where it is stored and then fed along with water into the first fermenter/digester.

Biogas has been generated as a result of 2 stage fermentation process. Due to a delay in construction the gas data has come from a sister plant that utilises the same technology, methodology, feed stock and is of the same construction as the GAP plant.



GAP PLANT GAS GENERATION & WASTE FLOWS

4. BIO GAS

The plant is constantly being monitored to provide the best CH_4 stream and environment (pH) for the cultures that because of the variations in feedstock and as discussed in 2.2 the swings and variations that might be expected in the bio gas are muted.

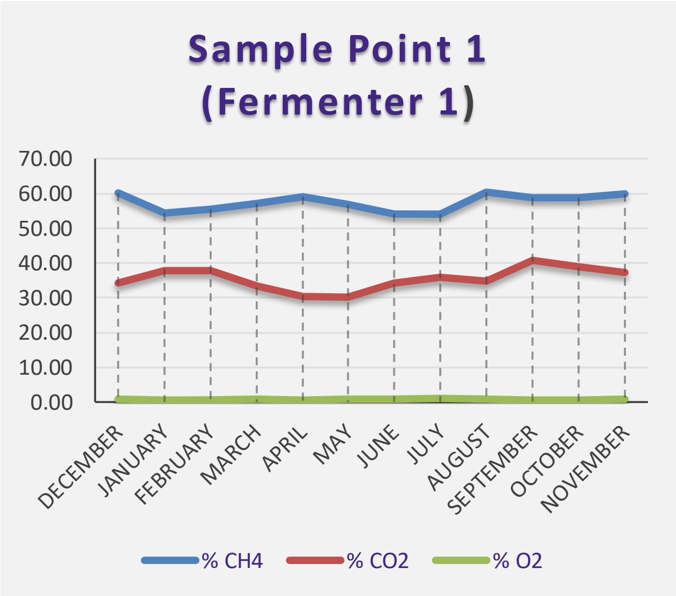
The gas is tested at 4 main points on its process through the system as follows:

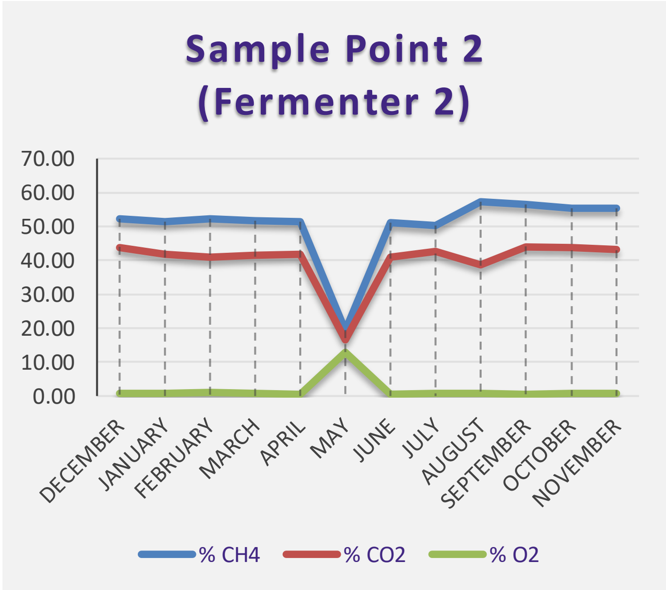
Sample Point 1 (SP1)	Fermenter 1
Sample Point 2 (SP2)	Fermenter 2
Sample Point 3 (SP3)	Gas Store
Sample Point 4 (SP4)	After Cleaning Just Prior to CHP Intake

At each Sampling point the Gas is analysed for levels of CH_4, CO_2, O_2 and H_2S. The process is being continually monitored and managed by a SCADA system to maximise CH_4 production and keep the 'feedstock soup' in the best condition for the digestion process at each stage. This data can be seen in full in Appendix A

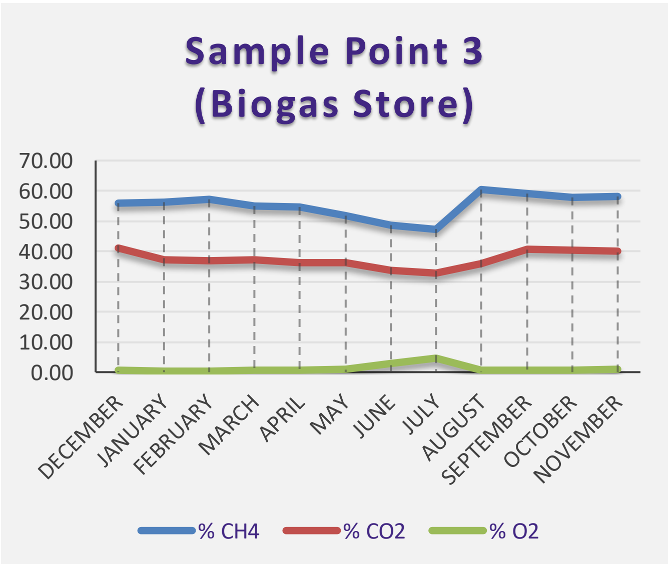
The main gases remain relatively consistent in each sample point throughout the recording period with fluctuations between 1 and 4%. During May a big dip of CH_4 and CO_2 together with a rise in O_2 as a result of damage to the CHP engine causing fermenter 2 to be slowed down while the repairs were carried out over a period of 10 days.

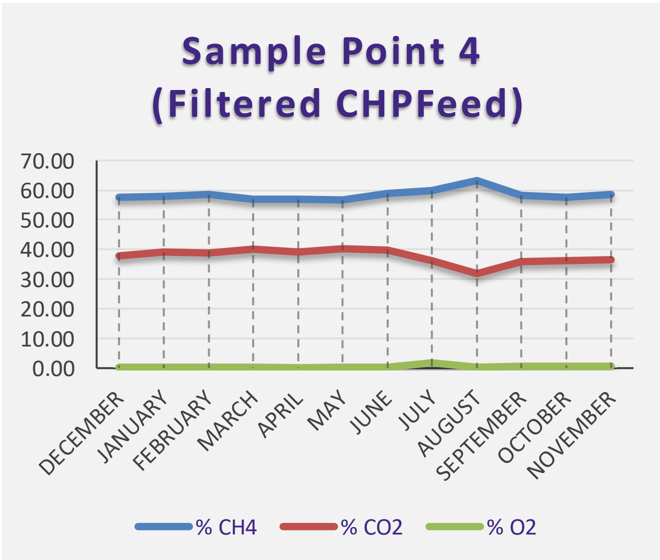
The slowing of fermenter 2 was achieved with addition of 0_2



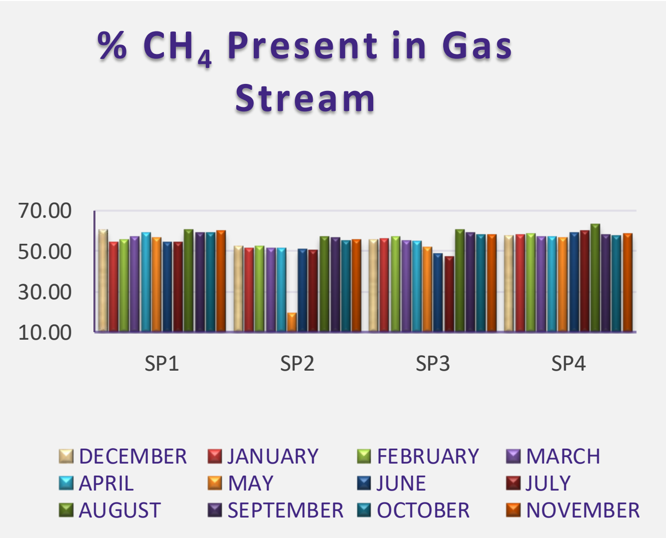


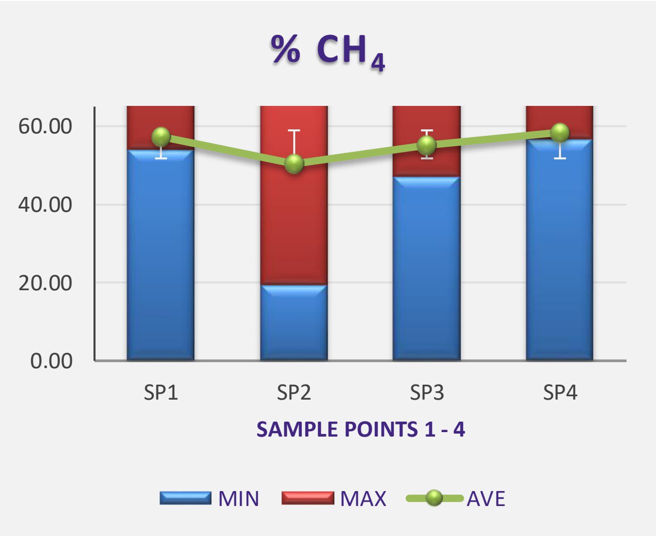
The biggest seasonal variation is seen during August after a period of 5 months of an overall reducing CH_4 content in the Biogas as seen in the biogas store. The subsequent filtered feed to CHP Engines remains largely unaffected.



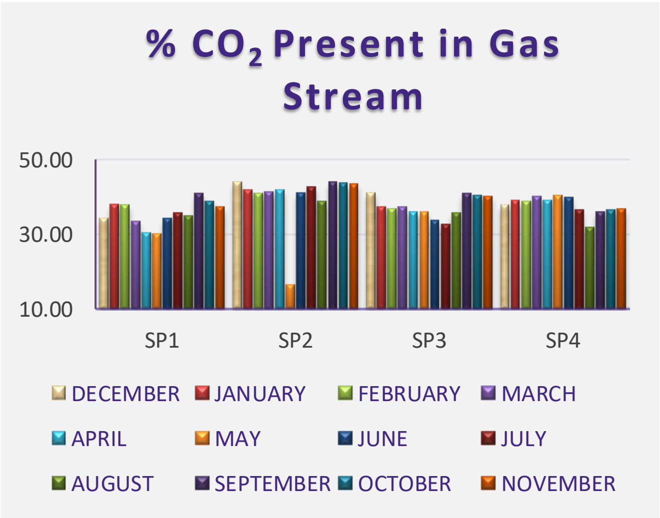


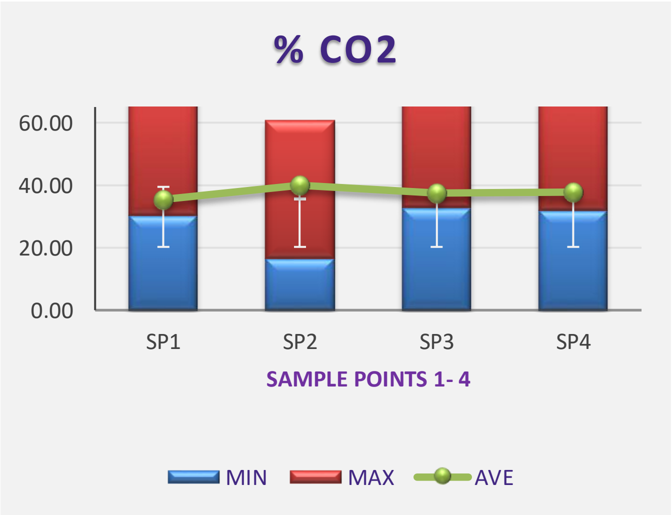
Levels of Main Constituent Gases across the 12 month period and as seen at each monitoring point.

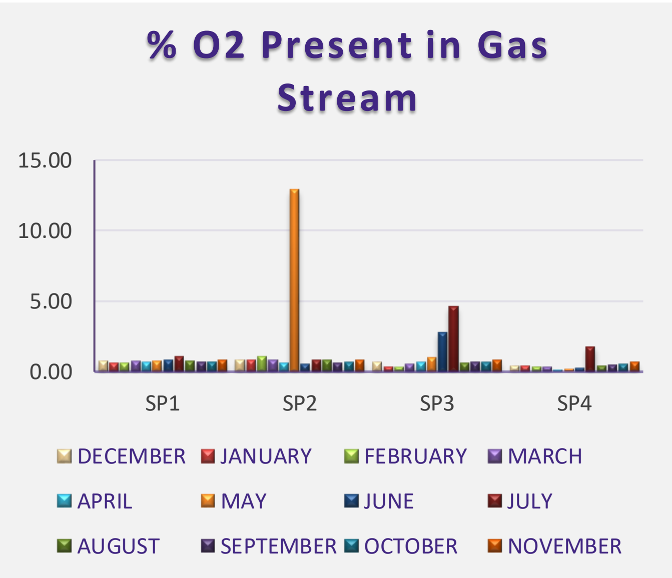


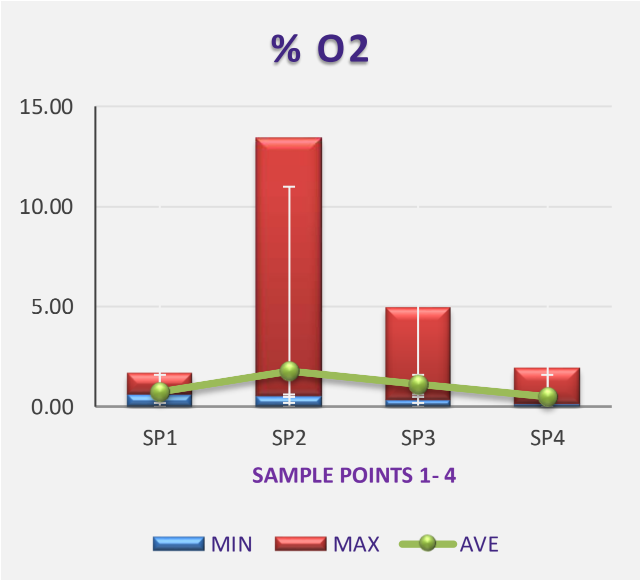


The proportion of CH_4 and CO_2 remains stable throughout both the 12 months monitoring and the AD process.









The rise in O_2 in May in SP2 (2nd Fermenter) was the result of slowing of fermenter 2 while essential repairs were carried out on the CHP engine.

Material Type Gas Sample	Result(s)	
Methane	60.7	%
Carbon Dioxide	38.3	%
Nitrogen	0.9	%
Oxygen	0.2	%
Hydrogen	131	ppm
Ethylene	<5	ppm
Ethane	<5	ppm
Acetylene	<5	ppm

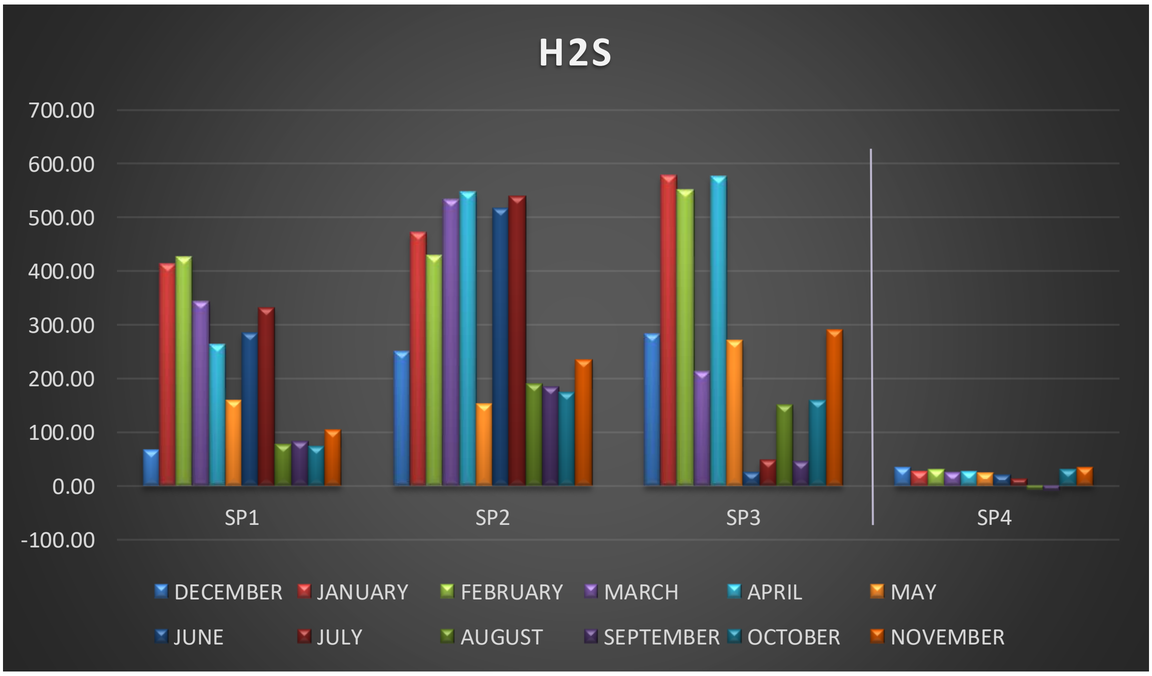
Compound	Formula	% content as carbon/nitrogen in sample
Methane	CH_4	52.03
Carbon Dioxide	$C0_2$	10.45
Nitrogen	N_2	0.9

C/N ratio	69.4:1

5. BIO GAS IMPURITIES

Due to the variable nature of food waste as described in section 3.1 the H_2S in the digester requires careful management to maintain the best environment and pH.

The biological removal of H_2S in the fermenters is achieved by injecting air, this is done automatically and is in operation at all times. Specialised aerobic mirco-organisms, which require a liquid-wetted surface, oxidise H_2S to mainly elementary sulphur by the following reaction: $2\ H_2S + O_2 \rightarrow 2\ S + 2\ H_2O$. There is also an addition of Ferric chloride if the H_2S levels require further control and the biological treatment is not sufficient.



Prior to use by the Combined Heat and Power engine (CHP) (SP4) the gas is dried by cooling: The biogas is cooled in heat exchangers and the condensed water is separated from the gas. Normally a chiller is used for refrigeration. The condensation is lowered to approx. 4°C due to prevent problems with freezing on the heat exchangers surface.

The final step is a carbon filter to bring that brings he H_2S levels down to an average of 20 parts per million. This is seen in the above results between SP3 (The Biogas Store) and SP4 (CHP Feed).

During the 12 month trials GASPLAS has confirmed that because of the final filter the H2S content is not causing a problem with the reactor or quality of the samples being produced in the lab trials using a reconstituted gas to the same specifications as the full analysis.

6. APPENDIX A- AVERAGE MONTHLY VALUES GAS SAMPLING

	Sample Point 1 (N1 Biogas)				Sample Point 2 (F1 Biogas)				Sample Point 3 (E1 Biogas)				Sample point 4 (CHP Biogas)			
	% CH4	% CO2	% O2	H2S (ppm)	% CH4	% CO2	% O2	H2S (ppm)	% CH4	% CO2	% O2	H2S (ppm)	% CH4	% CO2	% O2	H2S (ppm)
DECEMBER	60.27	34.19	0.74	66.93	52.27	43.84	0.82	251.90	55.83	41.06	0.64	283.30	57.49	37.77	0.40	34.70
JANUARY	54.30	37.92	0.61	414.13	51.42	41.78	0.82	472.70	56.16	37.27	0.36	577.80	57.83	39.10	0.41	27.86
FEBRUARY	55.59	37.67	0.61	427.30	52.26	40.89	1.11	429.30	57.28	36.83	0.31	551.93	58.53	38.76	0.35	30.33
MARCH	56.98	33.29	0.72	343.89	51.57	41.38	0.80	533.54	55.05	37.30	0.53	213.18	57.07	40.00	0.33	25.25
APRIL	58.94	30.24	0.66	263.41	51.49	41.79	0.63	547.48	54.74	36.09	0.64	576.21	56.98	39.17	0.13	27.48
MAY	56.82	30.16	0.75	160.32	19.32	16.57	12.91	153.13	51.62	36.08	1.00	270.77	56.73	40.26	0.17	24.32
JUNE	54.18	34.24	0.81	284.40	51.10	41.04	0.53	517.30	48.47	33.64	2.80	26.37	58.90	39.89	0.24	20.23
JULY	54.03	35.76	1.05	332.00	50.33	42.60	0.80	539.83	47.22	32.75	4.63	48.10	59.86	36.36	1.79	13.07
AUGUST	60.37	34.88	0.77	78.24	57.28	38.72	0.79	191.16	60.41	35.74	0.62	150.92	63.25	31.87	0.43	-6.34
SEPTEMBER	58.72	40.74	0.68	82.14	56.60	43.95	0.64	184.93	59.00	40.78	0.67	45.59	58.13	35.93	0.50	-8.61
OCTOBER	58.80	38.89	0.67	74.54	55.32	43.71	0.64	174.21	57.83	40.42	0.65	159.66	57.74	36.37	0.52	31.59
NOVEMBER	59.97	37.37	0.81	103.67	55.45	43.32	0.79	234.30	58.13	40.14	0.81	290.03	58.55	36.62	0.66	34.30
MIN	54.03	30.16	0.61	66.93	19.32	16.57	0.53	153.13	47.22	32.75	0.31	26.37	56.73	31.87	0.13	-8.61
MAX	60.37	40.74	1.05	427.30	57.28	43.95	12.91	547.48	60.41	41.06	4.63	577.80	63.25	40.26	1.79	34.70
AVE	57.41	35.45	0.74	219.25	50.37	39.97	1.77	352.48	55.15	37.34	1.14	266.15	58.42	37.67	0.50	21.18

	CH4				CO2			
	SP1	SP2	SP3	SP4	SP1	SP2	SP3	SP4
DECEMBER	60.27	52.27	55.83	57.49	34.19	43.84	41.06	37.77
JANUARY	54.30	51.42	56.16	57.83	37.92	41.78	37.27	39.10
FEBRUARY	55.59	52.26	57.28	58.53	37.67	40.89	36.83	38.76
MARCH	56.98	51.57	55.05	57.07	33.29	41.38	37.30	40.00
APRIL	58.94	51.49	54.74	56.98	30.24	41.79	36.09	39.17
MAY	56.82	19.32	51.62	56.73	30.16	16.57	36.08	40.26
JUNE	54.18	51.10	48.47	58.90	34.24	41.04	33.64	39.89
JULY	54.03	50.33	47.22	59.86	35.76	42.60	32.75	36.36
AUGUST	60.37	57.28	60.41	63.25	34.88	38.72	35.74	31.87
SEPTEMBER	58.72	56.60	59.00	58.13	40.74	43.95	40.78	35.93
OCTOBER	58.80	55.32	57.83	57.74	38.89	43.71	40.42	36.37
NOVEMBER	59.97	55.45	58.13	58.55	37.37	43.32	40.14	36.62
MIN	54.03	19.32	47.22	56.73	30.16	16.57	32.75	31.87
MAX	60.37	57.28	60.41	63.25	40.74	43.95	41.06	40.26

	O2				H2S			
	SP1	SP2	SP3	SP4	SP1	SP2	SP3	SP4
DECEMBER	0.74	0.82	0.64	0.40	66.9	251.9	283.3	34.7
JANUARY	0.61	0.82	0.36	0.41	414.1	472.7	577.8	27.9
FEBRUARY	0.61	1.11	0.31	0.35	427.3	429.3	551.9	30.3
MARCH	0.72	0.80	0.53	0.33	343.9	533.5	213.2	25.3
APRIL	0.66	0.63	0.64	0.13	263.4	547.5	576.2	27.5
MAY	0.75	12.91	1.00	0.17	160.3	153.1	270.8	24.3
JUNE	0.81	0.53	2.80	0.24	284.4	517.3	26.4	20.2
JULY	1.05	0.80	4.63	1.79	332.0	539.8	48.1	13.1
AUGUST	0.77	0.79	0.62	0.43	78.2	191.2	150.9	-6.3
SEPTEMBER	0.68	0.64	0.67	0.50	82.1	184.9	45.6	-8.6
OCTOBER	0.67	0.64	0.65	0.52	74.5	174.2	159.7	31.6
NOVEMBER	0.81	0.79	0.81	0.66	103.7	234.3	290.0	34.3
MIN	0.61	0.53	0.31	0.13	66.93	153.13	26.37	-8.61
MAX	1.05	12.91	4.63	1.79	427.30	547.48	577.80	34.70
AVE	0.74	1.77	1.14	0.50	219.25	352.48	266.15	21.18