

HORSE, AD 25 Narrative for Seattle Public Utilities – June 15, 2016

HORSE (High-solids Organic-waste Recycling System with Electrical output), AD 25 microdigester operations at Fremont Brewing Co. began on May 11, 2016. The following is a courtesy narrative with graphical representations of real performance data. Our official deliverable is the *Quarterly Report Form* where the reporting period is May 11, 2016 through May 31, 2016.

The digester was initially seeded with healthy digestate from Rainier Biogas in Enumclaw (their feedstock is approximately 70% manure and 30% food waste). The digester was measured for baseline gas production without any feedstock (substrate) addition. Then, a small amount of spent sugar from a local donut producer was added to test resilience and substrate-biogas response, and to grow the population of anaerobic microbes. Following this, we began a feedstock regimen of spent yeast, a liquid substrate from the brewery. This involved gradually increasing the feedstock input volume of spent yeast after starting with a mixture diluted with water. In general the feeding design was to double the input mass every 3 days (from 4 gallons to 8 to 16, over 9 successive days).

The HORSE continued to out-perform as the feeding regime advanced. Note the tracking of mass input and energy output rising together in *Figure 1 – Cumulative Mass Input & Energy Output*.

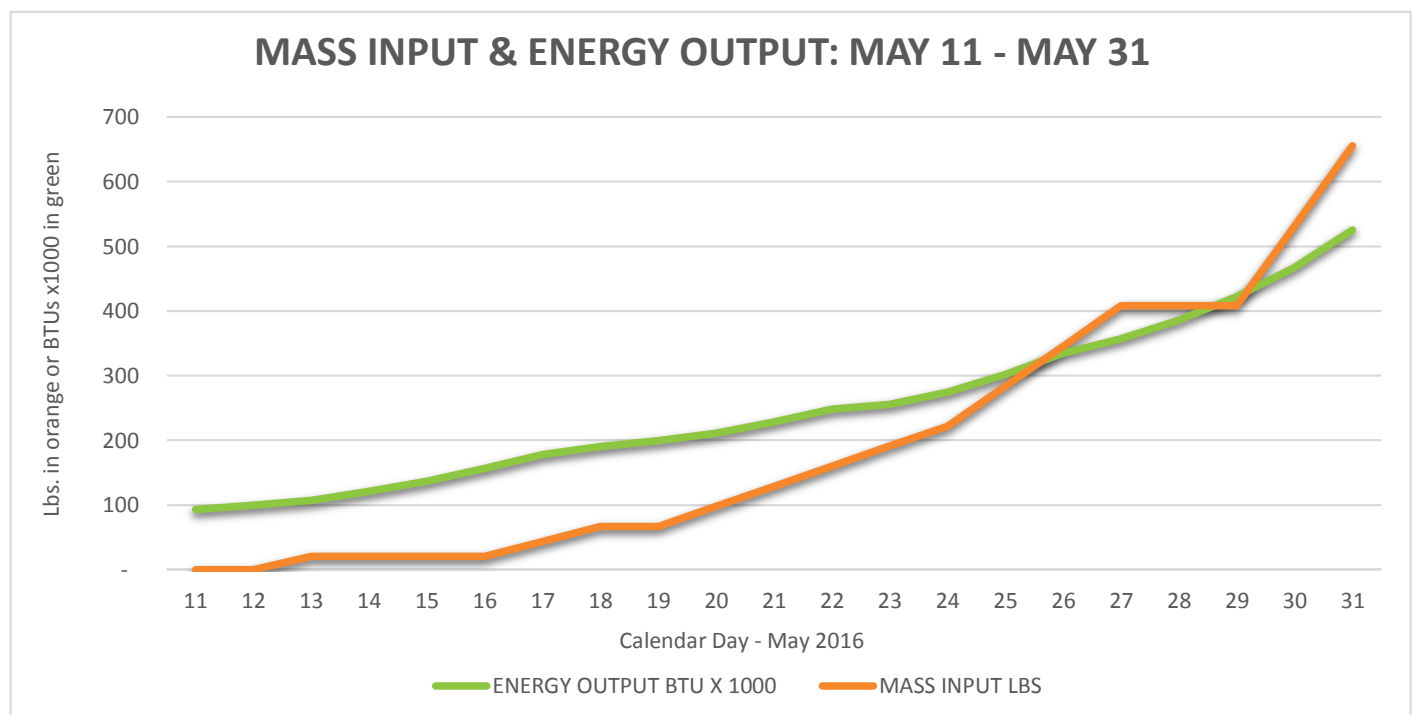


Figure 1 – Cumulative Mass Input & Energy Output

As expected, following initial installation the parasitic load for heating, ventilation, safety systems and lighting was higher than normal due to startup requirements. Also as expected, energy generation started at a low point. The parasitic load was comparable in order of magnitude to energy generated during the period, which is estimated to be 154 kWh from approximately 875 cf of biogas. This assumes a conservative 600 BTUs/cf¹ and 3,412 BTUs per kWh. Methane content was confirmed to be at least 60% based on field testing during the month. Given the addition of 656 lbs. of substrate over a feeding period of 21 days, energy output reached approximately 525,000 BTUs. Below, *Figure 2 – Energy Output in BTUs per day* shows daily energy yield of the HORSE during the period.

¹ [U.S. Environmental Protection Agency Combined Heat and Power Partnership, 2011](#)

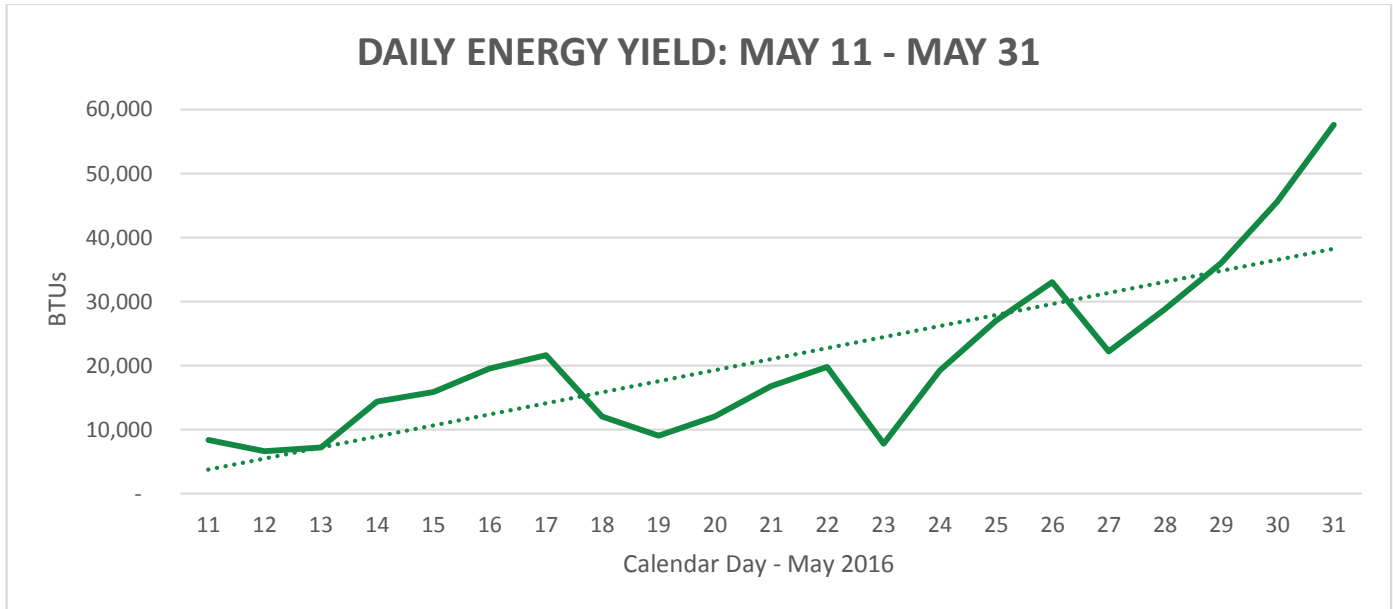


Figure 2 – Energy Output in BTU per day

Operational procedures were performed as-designed. All liquid handling was completely enclosed with the exception of the few minutes of mass transfer and input during each feeding. Odor control exceeded expectations. The digestate was discharged from the HORSE into a 330 gallon intermediate bulk container. Total input for the period was approximately 2,932 lbs. which included 273 gallons of water (approximately 2,277 lbs. at 8.34 lbs./gal), of which 16 gallons were used for biofilter irrigation. The water was not necessary for the digester to operate but was initially used for feedstock dilution, after which we gradually increased the strength of dosages to see how biogas and feedstock rate are related. No wastewater was generated.

The HORSE digestate was not pasteurized before being tested for fertility and for public health quality requirements per Title 40 CFR 503.13. Results of ion-exchange resin analysis to determine bioavailable nutrients are summarized in *Table 1 – UNIBEST Lab Results on Bioavailable Primary Macronutrients* and *Table 2 – UNIBEST Lab Results on Bioavailable Secondary Macronutrients & Micronutrients*. As expected, on a wet basis the macronutrients were low (28 – 265 ppm) due to very low total solids content during startup (diluted feedstock). On a dry basis the macronutrients are estimated to be 5.3-0.6-3.3 as percentage N-P-K. Lab results are in ppm, extracted with 50ml 2M HCl.

Sample Location	#	Depth	Total N	NO3-N	NH4-N	P	K
Fremont Brewing	#1		264.91	0.56	264.35	28.60	166.39
as received							
as reported							
correction to dry basis			5.3%	0.0%	5.3%	0.6%	3.3%
estimated total solids	0.005						

Table 1 – UNIBEST Lab Results on Bioavailable Primary Macronutrients

Sample Location	Al	B	Ca	Cu	Fe	Mg	Mn	Na	S	Zn
Fremont Brewing	0.25	0.05	90.59	0.05	9.09	35.93	0.35	46.89	9.26	0.04
as received										
as reported										
correction to dry basis	0.0%	0.0%	1.8%	0.0%	0.2%	0.7%	0.0%	0.9%	0.2%	0.0%
estimated total solids										

Table 2 – UNIBEST Lab Results on Bioavailable Secondary Macronutrients & Micronutrients

pH and conductivity were 7.5 and 8.6 mS/cm respectively. Total metals were very low in comparison to limits set forth in Title 40 CFR 503.13. Per Table 3 – Fremont Analytical Lab Results on Public Health Qualities and Figure 3 – Percentage Metals Allowable per Title 40 CFR 503.13, total metals were between zero and 10% of limits for unrestricted sale and use on home vegetable gardens.

The HORSE generated approximately 175 gallons of liquid digestate during the reporting period. According to the revised National Organic Program (NOP) Standard, products of anaerobic digestion processes are allowed without restriction and are classified as Crop Fertilizers and Soil Amendments that are acceptable if made from allowed, non-manure feedstock materials². Liquid fertilizer from this HORSE has been approved by Washington State Department of Agriculture for experimental use on our partner’s certified organic farm.

fecal coliform	CFU/100 ml	12,000
conductivity	mS/cm	8.6
pH		7.5
Hg	ug/l	non detect
AS	mg/l	0.00235
Cd	mg/l	0.000755
Cu	mg/l	0.378
Pb	mg/l	0.00293
Mo	mg/l	0.0128
Ni	mg/l	0.0335
Se	mg/l	0.0088
Zn	mg/l	1.46

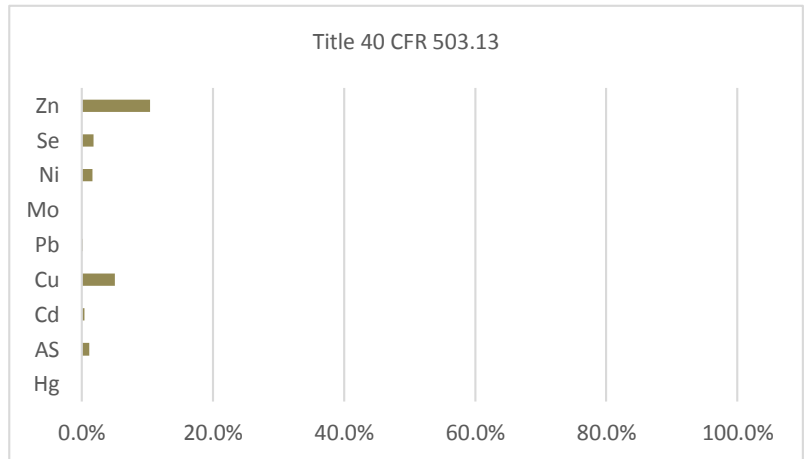


Table 3 – Fremont Analytical Lab Results on Public Health Qualities

Figure 3 – Percentage Metals Allowable per Title 40 CFR 503.13

² RULE REFERENCE: 205.105; 205.203(c) REVISION DATE:03/14/2016