BOOSTING ENERGY PRODUCTION THROUGH CO-DIGESTION

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ABSTRACT

Many wastewater treatment plants (WWTPs) are seizing the opportunity to become an energy production facility as well as a treatment facility. Glenelg WWTP in Adelaide (South Australia) is an example of this and has been working towards becoming energy neutral. Three combustion engines are located at Glenelg WWTP which utilise either biogas (from the anaerobic digesters) or natural gas for electricity production. Historically the digesters were only fed with primary sludge and thickened secondary sludge drawn from the wastewater treatment process, and produced enough biogas to provide approximately 55% of the power used onsite.

Ways to boost the biogas production were investigated including adding liquid waste with a high organic load from industry to the anaerobic digesters (referred to as co-digestion). This has the advantages of not only generating more energy, but it also avoids overloading the sewer and secondary treatment systems with trade waste, preventing sewer corrosion and reducing the energy required to treat wastewater.

Following the success of a co-digestion research program, the construction of a fully automated co-digestion plant was undertaken at Glenelg WWTP. A customer base of appropriate trade wastes (or substrates) was established and rigorous testing methodologies of the substrates established. The amount of energy generated with biogas has remained above 65% of onsite electricity usage, reaching as high as 85%, since the co-digestion plant was commissioned, and the stability of the digesters has not been impacted.

Optimisation of the co-digestion process is an ongoing process to continue to increase the biogas production as more knowledge of the biogas dynamics is obtained. This paper provides an overview of the co-digestion journey and the technical and operational lessons learnt from going through this process, in addition to the innovative tools that can be utilised to boost biogas production.

KEYWORDS

Energy production, biogas, co-digestion

PRESENTER PROFILE

Jennifer Dreyfus is the Process Optimisation Engineer in wastewater at Allwater. She has been working in the water industry for the last 9 years and has spent the last 4 years at the Glenelg WWTP. Her focus there was to optimise plant operations and performances and onsite energy production.

1 INTRODUCTION

Glenelg Wastewater Treatment Plant (WWTP), located in Adelaide (South Australia), is one of six WWTPs operated and maintained by Allwater (a Joint Venture between Suez and Broadspectrum) on behalf of SA Water. The WWTP treats 50 ML/day of primarily domestic wastewater and has five anaerobic digesters, two of which have floating covers, allowing for biogas storage.

The anaerobic digestion process at Glenelg WWTP produces biogas converted onsite by three combustion engines for electricity generation. Historically the digesters were only fed with primary sludge and thickened secondary sludge drawn from the wastewater treatment process, and produced enough biogas to provide approximately 55% of the power used onsite.

The success of a number of bench scale and full scale research projects on co-digestion of industrial high strength organics to boost biogas production in anaerobic digesters driven by SA Water from 2009 (Krampe et al, 2010a, 2010b.), led to the construction in 2012-13 of a fully automated co-digestion plant at the Glenelg WWTP. Another advantage of the implementation of this plant is that it avoids overloading the sewer and secondary treatment systems with trade waste. In fact, many industries in South Australia produce liquid waste streams of high organic content but in volumes that are in most cases too small to allow an economical implementation of in-house treatment. The wastes would otherwise be disposed of to sewer, land based applications or land fill. However, each of these disposal methods has associated environmental impacts. For example, delivering the waste to compost or landfill takes up valuable land space and the process releases greenhouse gases to the atmosphere. In addition, discharging high content organic waste to the sewer network can damage infrastructure due to the highly organic and corrosive nature of the waste. The high level of organics is also difficult to treat at WWTPs, as it may overload the process due to high Biochemical Oxygen Demand (BOD) resulting in more energy required to treat the waste.

This plant is the first of its kind in Australia and this paper provides an overview of the co-digestion journey and the technical and operational lessons learnt from going through this process, in addition to the innovative tools that can be utilised to boost biogas production.

2 PROCESS

2.1 ANAEROBIC DIGESTION

The anaerobic digestion process is used to stabilise sludges generated from primary and secondary treatment and involves the decomposition of organic waste into methane and carbon dioxide (see Figure 1).

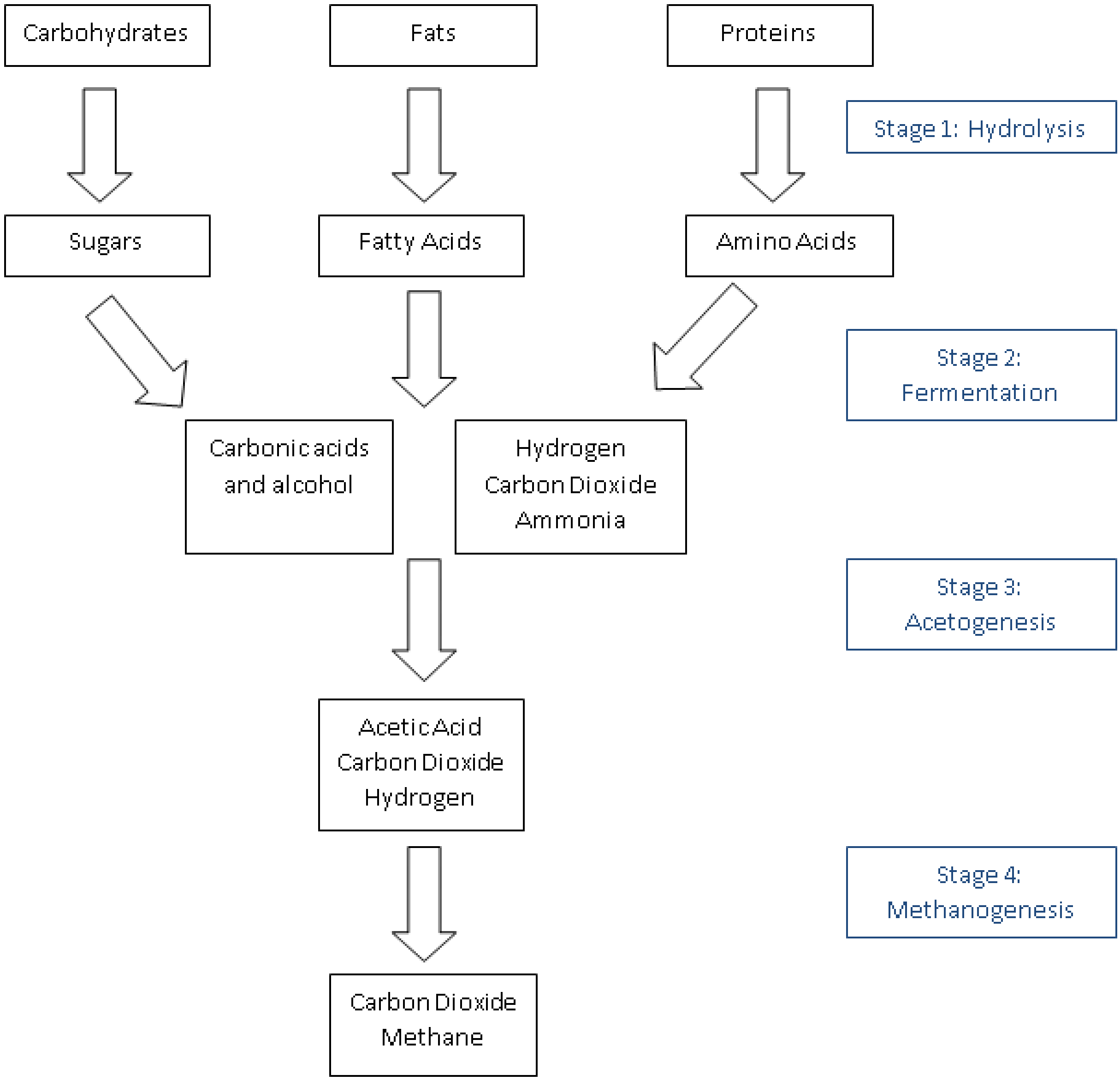


Figure 1: Anaerobic digestion process

The sludge retention time (SRT) in the digesters is critical to ensure a good degradation of the sludge. At Glenelg WWTP the average SRT is 18 days. This decomposition occurs in a number of stages involving facultative and anaerobic bacteria. The most sensitive bacteria are the obligate anaerobes, methanogens in Stage 4 of the process (see Figure 1). The bacteria are very sensitive to pH and temperature change so in order to achieve the optimum biogas production it is important to maintain a pH between 6.8 and 7.2 in the digesters and a temperature of 35 degrees Celsius. The longest stage of the process is Stage 1 during which the complex organic materials are converted into soluble organic material by bacterial extra-cellular enzymes. The soluble organic material can then enter the bacterial cells and be utilised as a food source. The time required for that stage is limiting for the anaerobic digestion process and biogas production.

Having five anaerobic digesters of 3.2ML volume each, Glenelg WWTP has excess capacity to take more load to the digesters, and with floating covers on two of the anaerobic digesters, more biogas storage is also available.

2.2 CO-DIGESTION

Adding high strength trade waste to the anaerobic digester has two main advantages: (i) it can boost biogas production to produce more energy and (ii) it also avoids overloading the sewer and secondary treatment systems with trade waste.

Many industries in South Australia produce liquid waste streams of high organic content but in volumes that are in most cases too small to allow an economical implementation of in-house treatment. The wastes would therefore be disposed of to sewer, land based applications or land fill. However, each of these disposal methods has associated environmental impacts. For example, delivering the waste to compost or landfill takes up valuable land space and the process releases greenhouse gases to the atmosphere. In addition, discharging high content organic waste to the sewer network can damage infrastructure due to the highly organic and corrosive nature of the waste. The high level of organics is also difficult to treat at WWTPs, as it may overload the process due to high Biochemical Oxygen Demand (BOD) resulting in more energy required to treat the waste.

With projections of increasing energy demands, and associated costs at WWTPs, SA Water identified a need to reduce the utilisation of external energy resources and maximise onsite energy generation. Therefore in 2009, SA Water commenced their own research program on the co-digestion of readily available industrial high strength organic waste (or trade waste) with the sludge from Glenelg WWTP to maximise the efficiency of biogas production from the anaerobic digesters. A number of bench scale and full scale trials were conducted over a four year period focusing on the addition of different trade waste substrates (such as whey, beer, coke, wine, grease traps…) to the thickened sludge, at different rates, and the impact they were having on biogas production and quality (Krampe, 2010a; Krampe, 2010b).

SA Water approached companies known to produce high organic loadings located in the sewer catchments within the vicinity of Glenelg WWTP to offer an alternative and cost effective disposal option. Due to the small volumes from different suppliers and the opportunity to collate a database on the suitability of different substrates, a wide range of substrate types were initially analysed. As those trials were successful, a full scale plant was built and started to be operational in July 2013.

The substrates that are currently received by Glenelg WWTP for co-digestion are summarised in Table 1. The substrates received can have extreme pH and high BOD, therefore the addition of the substrate to the thickened waste activated sludge (TWAS) has to be carefully controlled in order to maintain stable operation of the digesters and not upset the methanogen bacteria which are very sensitive to pH and loading changes. Overloading of digesters with very high strength waste can cause excess production of gas which could result in methane being expelled to the atmosphere.

The Glenelg WWTP SCADA system has been developed to allow different substrate addition rates depending on the substrate received, as well as transferring substrates at night or early in the morning to ensure the biogas production is boosted when the onsite power demand is highest.

The pH is also monitored when the substrate is transferred to the thickened sludge in order to avoid any contamination or shock load. Often different substrates are mixed in the storage tank, which allows the pH to be balanced before transfer to the thickened sludge.

Table 1: Examples of substrates currently received at Glenelg WWTP

Substrate	BOD_5 (mg/l)	pH	Suspended Solids (mg/l)	Total Nitrogen (mg/kg)	Total Phosphorus (mg/kg)
Brewery Fermentation Waste	3,020	8.6	49	49.4	41
Brew house Waste	9,450	5.2	778	274	63.1
Wine Bottling Waste	2,920	5.6	78	13.8	4.62
Cola drink spoiled product	62,000	2.6	38	67.3	152
Salty Whey	20,100	3.8	5,790	1,180	609
Grease trap	11,000	6.9	13,000	26.9	45.3
Waste from food court	29,500	6.1	42,300	2,040	135
Waste from confectionery factory	27,900	7.0	13,800	140	13.1

3 RESULTS

3.1 BIOGAS PRODUCTION

The amount of energy generated from the biogas at Glenelg WWTP has enabled the plant to achieve 65 to 90% of power self-sufficiency since the co-digestion plant was commissioned (Figure 2 and 3), with yearly averages of up to 80% self-sufficiency. This change in the process has also resulted in a decrease in the amount of natural gas used by the engines, which represents significant operational savings.

The volume of biogas produced is highly dependent on the volume of substrate received every month; but this positive relationship between substrate volume and biogas production was not consistent, which suggests that other parameters impact on the biogas production. One of the parameters currently under consideration is the substrate mixing. Most of the time at Glenelg WWTP the substrates will be trickle fed to the digester pure, but on a number of occasions they will be mixed in the storage tank with other substrates, potentially impacting the characteristics of the substrates and their potential to produce biogas. Research is currently underway to mimic the blending occurring in the storage tanks to understand their impact on biogas production. This will shed light on which substrates should or shouldn’t be blended in terms of benefits and/or detriments to biogas quality and production.

Figure 2: Power used and generated at Glenelg WWTP

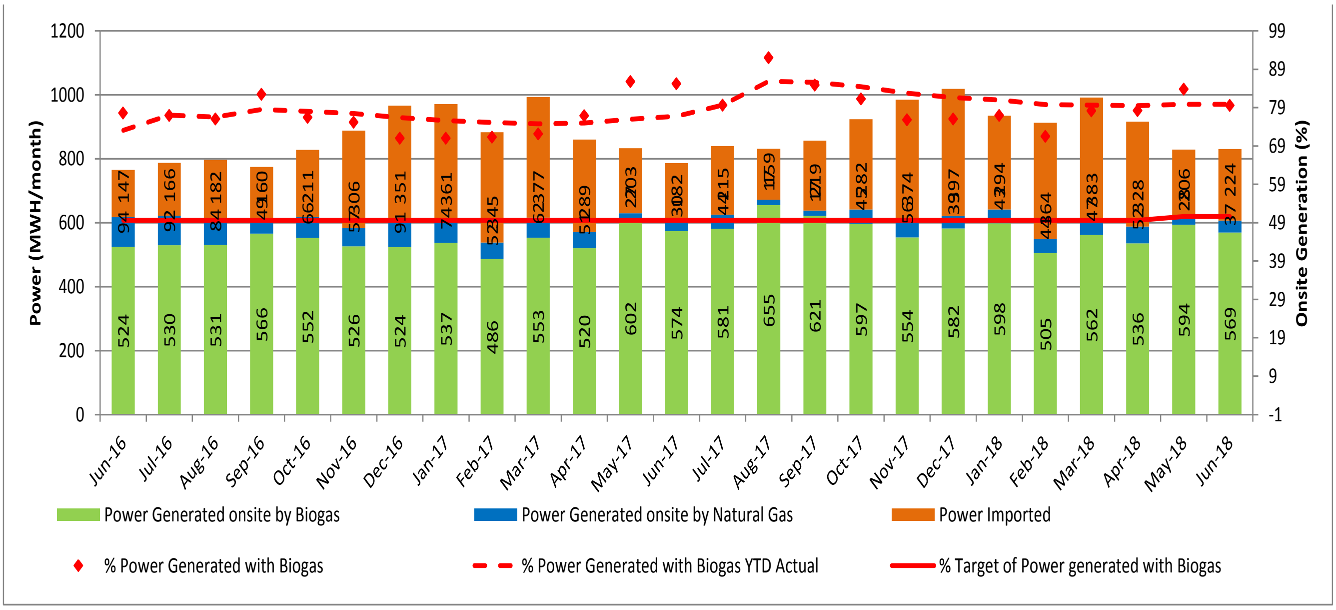
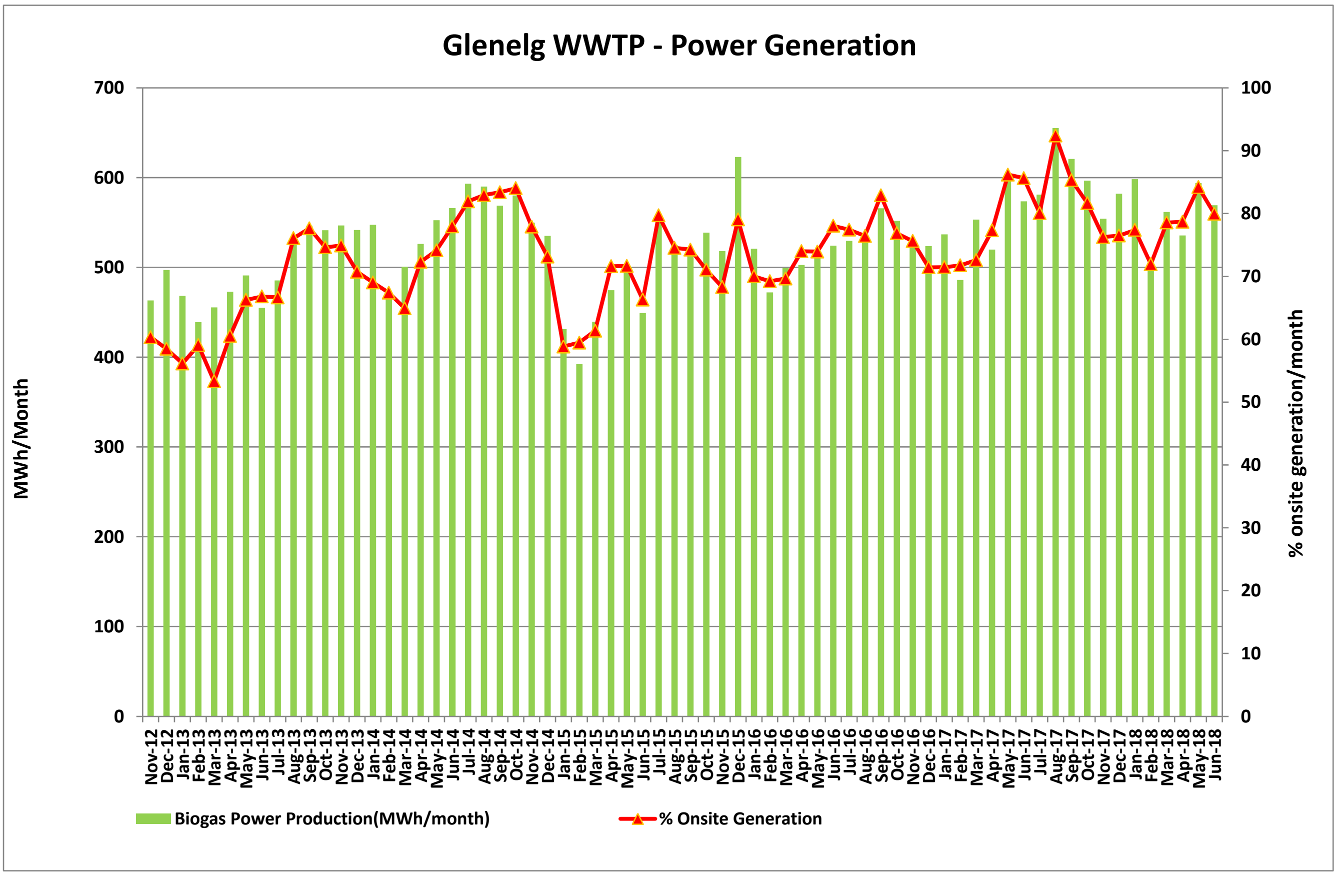


Figure 3: Energy production at Glenelg WWTP since co-digestion was implemented



3.2 BIOGAS QUALITY

Another important parameter to monitor is the quality of the biogas produced. Individual substrates are screened at a laboratory scale using a eudiometer prior to addition to the full-scale facility. The biogas quality is monitored and results obtained suggest that the addition of substrates will not impact biogas quality. However, at the full scale, substrates are often mixed together prior to injection into the digesters. Thus, biogas monitoring has been implemented to understand the impact co-digestion has onsite, comparing the biogas quality before and after co-digestion. An online biogas analyser was recently installed, so the information presented here on pre co-digestion gas quality was based on grab samples.

Table 2 shows the biogas content before implementation of the co-digestion at Glenelg WWTP when the digesters were only fed with primary sludge and thickened secondary sludge drawn from the wastewater treatment process. The content was quite stable with an average H_2S concentration of 1816 ppmw/v. After the implementation of co-digestion onsite the methane content of the biogas has increased which means the engines are now more efficient when using biogas. However, the H_2S concentration has also increased, and concentrations were notably more variable, which may suggest that the assets may corrode at a faster rate.

Table 2: Comparison of gas and sludge quality pre and post the implementation of co-digestion, showing parameter mean (± 1SD)

	Pre co-digestion	**With co-digestion**
Biogas		
Daily biogas volume (m^3/day)	7036.9 (1048)	8596.6 (1320)
Onsite power generation (% self-sufficiency)	57.9 (11.2)	73.2 (11.4)
CH_4 (Mol %)	51.5 (4.1)	53.6 (1)
CO_2 (Mol %)	36.9 (2.1)	38.3 (1.13)
H_2S (ppm w/v)	1816 (50)	2137 (122)
Treated sludge		
pH	6.98 (0.03)	6.96 (0.03)
Alkalinity (mg/L)	2423.3 (57.5)	2450.6 (17.4)
Volatile Matter (%)	0.68 (0.15)	0.78 (0.18)

Table 2 also shows that pH and alkalinity have not been impacted by the addition of high organic substrates, the volatile matter of the digested sludge has slightly increased but the overall percentage of sludge destruction through the digesters is still above what is acceptable for an anaerobic digestion process.

4 THE FUTURE

The Anaerobic Digestion (AD) process at WWTPs is driven by microbial processes and is largely a 'black box'. To be able to develop an increased knowledge of the AD process to enable process improvements to be made to reduce risk and increase biogas production, an understanding is being developed of the microbial interaction in the digesters including selection and resilience of the microbial communities.

With the recent advances in the application of genomic tools in many fields, a move to biotech-science-driven techniques in wastewater (and in this case for the ADs) is an innovative area being investigated.

Work is currently underway to develop a baseline of microbiome in standard digesters and co-digestion digesters to determine if it is a useful tool for anaerobic digester troubleshooting and optimisation.

5 CONCLUSIONS

Co-digestion has proven to have many benefits including reducing the amount of natural gas required, increasing the energy production on site and has also provided a beneficial use for materials that would otherwise have been disposed of to sewer, land based applications or landfill. The utilisation of such a broad range of substrates is challenging and quite unique. It is important to continuously monitor for any impact on the treatment process and on the assets to develop a more accurate asset management strategy.

The installation, operation and optimisation of a co-digestion plant at Glenelg WWTP has led to a reduction in imported power and natural gas use at Glenelg WWTP. This has reduced the plant's carbon footprint by producing up to 90% of the power required onsite, without compromising the performance of the digesters.

ACKNOWLEDGEMENTS

The Glenelg WWTP operations and maintenance team is acknowledged for the great work they do daily to maintain the co-digestion facility.

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